The Natural Environment Research Council

Institute of Hydrology Report for 1985/86

The Natural Environment Research Council

Report of the Council for the period 1 April 1985-31 March 1986

Report of the Institute of Hydrology for 1985-1986

Abbreviations

The more important acronyms and abbreviations used in this report are given in full below.

NERC Component and Grant-aided Research Organisations

BAS	British Antarctic Survey
BGS	British Geological Survey
FBA	Freshwater Biological Association
IH	Institute of Hydrology
IMB	Institute of Marine Biochemistry
IMER	Institute for Marine Environmental Research
IOS	Institute of Oceanographic Sciences
IOV	Institute of Virology
ITE	Institute of Terrestrial Ecology
MBA	Marine Biological Association of the UK
NCS	NERC Computer Services
NSS	NERC Scientific Services
NUTIS	NERC Unit for Thematic Information Systems
RVS	Research Vessel Services
SMBA	Scottish Marine Biological Association
SMRU	Sea Mammal Research Unit
UCPE	Unit of Comparative Plant Ecology

Others

ABRC	Advisory Board for the Research Councils
AFRC	Agricultural and Food Research Council
AERE	Atomic Energy Research Establishment
BIRPS	British Institutions Reflection Profiling Syndicate
CEC	Commission of the European Communities
DAFS	Department of Agriculture and Fisheries for Scotland
DES	Department of Education and Science
DEn	Department of Energy
DOE	Department of the Environment
DTI	Department of Trade and Industry
ESRC	Economic and Social Research Council
ESF	European Science Foundation
FC	Forestry Commission
IOC	Intergovernmental Oceanographic Commission
IPOD	International Phase of Ocean Drilling
IRCCOPR	Inter Research Council Committee on Pollution Research
MRC	Medical Research Council
MAFF	Ministry of Agriculture, Fisheries and Food
NCC	Nature Conservancy Council
ODA	Overseas Development Administration
SERC	Science and Engineering Research Council
SCAR	Scientific Committee on Antarctic Research
UKAEA	United Kingdom Atomic Energy Authority
EPA	(United States) Environmental Protection Agency
USGS	United States Geological Survey
UGC	University Grants Committee

Contents

The Natural Environment Research Council

The Natural Environment Research Council, established by Royal Charter in 1965, has responsibility for planning, encouraging and carrying out research in the physical and biological sciences which explain the natural processes of the environment. Only through such studies can an understanding of man's impact on his surroundings and their influence on his activities be achieved and sensible policies for the exploitation of natural resources be formed.

The Council carries out this research and training through its own institutes, and grant-aided associations, and by grants, fellowships, and other postgraduate awards to universities and other higher education establishments.

The Council is financed by a grant-in aid from Parliament, received through the Department of Education and Science, and by commissioned research from Government departments and other agencies. In the year under review, the Council's total expenditure was £100,149,274 of which £68,105,203 was funded from the Science Budget, £27,788,094 from commissioned research and £4,255,977 from ordinary receipts.

Report of the Natural Environment Research Council

1 April 1985 – 31 March 1986

To the Secretary of State for Education and Science

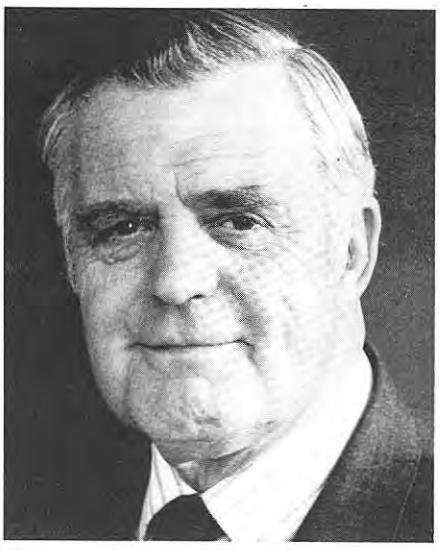
We have the honour on behalf of the Natural Environment Research Council of submitting the following report on the Council's activities for the year ending 31 March 1986

The report consists of an introductory section which includes highlights of some of the Council's work including international liaison, followed by a section which offers a selective account of scientific research supported by NERC during the year in its own institutes and in universities. A much fuller analysis of this work will be found in the annual reports or other publications produced by the various NERC institutes. A brief account of those component and grant-aided institutes, with the names of their senior staff, appears at the end of this report.

Mr H Fish CBE *Chairman*

Dr J C Bowman CBE *Secretary*

Chairman's Introduction



This year has been a somewhat better one than I expected. It started with a considerable furore of mainly criticism and condemnation from the scientific community regarding the rectitude and practicability of the major changes proposed in our first 5-year Corporate Plan. However, as the year progressed our financial position improved a little as a result of increased income from commissioned research. Also, positive benefits began to appear as the management changes proceeded to give the first practical indications that our intentions were sound. Nevertheless the uncertainty and disturbance imposed on our staff during this year of change remained substantial and regrettable, but necessary to achieve our long-term goals. At least by the year end we were substantially on target in the pursuit of the demanding objectives we had set ourselves. The details of this are set out in our second Plan published in February 1986.

I am pleased to report that at Council level, the reorganisation of our former four science-policy Preparatory Groups into three Committees of Science, dealing with Earth Science, Marine Science and Terrestrial and Freshwater Science, was effected around mid-year. A new Services and Facilities Committee was also created. Immediate benefits resulted from these changes. These Committees are now in a position to make recommendations to Council on a basis which takes proper account of priorities and financial feasibility. They are also in a position to monitor the execution of policy and performance with increasing effectiveness. A key factor in the establishment of this better management is the appointment of Directors of Science as the principal advisers to each of the three Committees of Science. The making of these appointments was completed most satisfactorily towards the end of the year.

These appointments have given an important new dimension to the management of corporate affairs at senior level. Sound line management arrangements for the whole of NERC now exist, based on the principles of good leadership rather than dictat. These arrangements are integrated with the formulation of research programmes and priorities and with the further development of communities of science between scientists in NERC, in the academic community and in industry. Perhaps most importantly, for the first time a well-defined mechanism for ensuring the reasonable amalgamation of 'bottom up' and 'top down' contributions to NERC's affairs is now in operation. These new arrangements will enable increased inter-disciplinary, cross-institute, co-operative work. They will also speed up the planning processes and decision making, giving overall greater flexibility and cost-effectiveness in the deployment of limited resources. I am wholly convinced, by observation, that these characteristics of our new organisation will powerfully assist in the attainment of our major objective – the maintenance and extension of our support and output of first-class science.

There are of course many internal problems to be managed. Over the year we have reduced our staff numbers by 190, some 6.4% of the total at the start of the year. This has been done by natural wastage and by voluntary retirement on a controlled basis. We have lost some good scientists to other organisations – an occurrence which is inevitable during a period of major change. Our need to recruit good young scientists and to achieve a better balanced staff structure must be met despite the severe constraints arising during the present period of substantial staff reduction. Steps towards effective management of these difficulties are being taken.

We have to continue to seek reductions in our overhead expenditure, particularly in reducing the number of research stations we maintain wherever this is feasible and sensible. During the year the Taunton laboratory of the NERC Institute of Oceanographic Sciences was closed. Also two other decisions were made. One was to transfer the work of the Cambridge based Culture Centre for Algae and Protozoa of the NERC Institute of Terrestrial Ecology to the Windermere laboratory of the Freshwater Biological Association and to the Oban laboratory of the Scottish Marine Biological Association. The second was to transfer the work of the

NERC Institute of Marine Biochemistry at Aberdeen to Stirling University and to Oban. There is scope for further rationalisation of sites but for very sound reasons this will be limited.

In increasing our support of the academic community, as indicated in the Corporate Plan, we are seeking to make the optimum allocations of resources in relation to needs for responsive support of research and training, for specific support of new research programmes, and for the provision of expensive central research facilities accessible to the researchers in academic institutions. In the latter category the NERC Unit for Thematic Information Systems at Reading University was established this year. Further initiatives of this kind seem likely to be taken. We plan to increase the number of university and industry researchers formally working in NERC institutes, to assist in meeting our commitment to the creation of new communities of science and encourage the transfer of our research results into commercial development.

During the year careful consideration has been given to the improvement of our mechanisms for science and technology transfer, on our own account and in collaboration with industry and consultants. In response to Sir Keith Joseph's initiative to encourage researchers to deploy commercially their individual inventions and knowledge, a scheme has been produced to encourage NERC scientists in this endeavour and it is hoped this can be approved and implemented next year. The possibility of consolidating many aspects of the research marketing activities, both of our institutes and of our Research Marketing Group, in a new NERC commercial company is being explored vigorously with the intention of creating such a company in 1987.

We also have to achieve a sensible balance between innovative basic and strategic research which will be beneficial over the longer term, and the more applied research producing early benefits. Yet as the value of the Science Vote funding we receive for basic and strategic research diminishes, we continue to pursue energetically more commissioned research and especially contract work at home and overseas. Much of this research for customers is applied work. Our staff are giving a most heartening response to this pursuit of new income notwithstanding that this, in a period of overall manpower reduction, militates against the achievement of the balance referred to above. We are taking all the steps we can internally to contain this problem while encouraging the new entrepreneurial outlook of most of our staff.

There are however external matters which give cause for concern. First the efforts NERC makes internally to maintain a reasonable balance between innovative and applied research will be nullified if the real value of the Science Vote funding allocated to NERC continues to diminish. Second, NERC fully accepts that publicly-funded research should be highly relevant to future economic and social benefit, and is itself demonstrably pursuing this objective. There is more to be done in this direction as priority selection in current research continues and as in consequence resources can be diverted into new and promising research endeavours. However if the funds allocated to NERC fall short of requirements, for whatever reason, there will not be scope for support of existing research which survives priority selection and for support of new research. In so far as most of this total of research will be of an innovative nature, the result will be that NERC's drive towards increased science and technology transfer cannot be sustained because of a diminishing output of transferable knowledge from a diminishing investment in innovative research. The NERC view is that an adequate level of Science Vote funding of the innovative research it carries out and supports provides the only way of maintaining and expanding both the application of science to the optimum solution of problems peculiar to the UK environment, and the commercial export of environmental science and associated technology to appropriate overseas markets.

Third, about a quarter of NERC's research activity is underpinned by a steady flow of commissioned research from the Departments of State. NERC is ready and willing to show whatever reasonable flexibility is demanded to meet the changing research needs of the Departments and will extend its own initiative in presenting new and worthwhile proposals for research to those Departments. Nevertheless when rapid and substantial reductions in commissioned research programmes are to be made, fair notice of this should be given to minimise the onset of serious imbalance in manpower deployment and the consequential costs of making rapid reductions in manpower.

Fourth, again in the context of Science Vote funding, if it is manifest that particular research organisations are achieving major improvements in their effectiveness and efficiency, this fact should be given appropriate credit when allocations of funds are made. This is partly a call for the provision of some incentive to the pursuit of greater cost effectiveness, and otherwise a call for equitable backing of demonstrable excellence, in terms of both quality and cost, in research of importance to the national well being. NERC would be content with the outcome of judgements made on that basis.

In conclusion I wish to record my appreciation of the excellent service rendered by the Council members, particularly the Chairmen of Committees, and by the Secretary to Council and his senior colleagues. I congratulate the most important people in NERC, our staff generally, on their splendid response to the challenges put to them.

Hugh Fish CBE
31 March 1986

Highlights

NERC Joins British National Space Centre

National participation in space activities received a boost in 1985 with the decision to establish the British National Space Centre (BNSC) with a mandate to improve the development of space technology and to co-ordinate policy. NERC participation in the BNSC has been approved by Council, and contributions to the work of the Space Centre will include the provision of staff for a Remote Sensing Applications Development Unit and the operation of the satellite receiving station at the University of Dundee.

NERC participation in the BNSC should result in achieving a better balance between space technology and utilisation and concentrate efforts on areas of greatest benefit to the environmental sciences. An early task for NERC as a member of the BNSC has been to contribute to the preparation of a national space plan for publication in 1986.

Application Centres of Expertise

One of the recommendations in the House of Lords Select Committee on Remote Sensing and Digital Mapping concerned the establishment of centres of expertise in key remote sensing application areas. The requirements for application centres resulted from the need for the users of space systems to influence developments, and at the same time to strengthen the use of satellite data for Earth observation science. In response to the House of Lords' recommendations, NERC has established three centres of expertise in the following areas:

- Geology and mineral exploration at the British Geological Survey
- Ecology, rural land use and freshwater sciences at the Institute of Terrestrial Ecology
- Marine Sciences at the Institute of Oceanographic Sciences

In addition to strengthening practical use of remotely sensed data the centres of expertise would serve as windows into NERC to illustrate the Council's expertise and capabilities in the application of remote sensing methods in environmental sciences

Computer Capability Increased

The Honeywell computer at Wallingford has been replaced with an IBM system and linked to a new DEC VAX at Keyworth. These changes represent an increase in computing power of approximately five times the capabilities of the old system and will obviously have a profound affect on NSS services.

New Unit at Reading University

A new NERC Unit for Thematic Information Systems was established in October 1985, at Reading University under the Directorship of Dr J R G Townshend. This is a specialist research group concerned with developing techniques for the management, analysis and display of remotely sensed and digital map data.

The work of the unit involves collaboration with, as well as the provision of advice and consultancy to NERC Institutes, universities and other bodies. Their main equipment includes a DEC VAX computer, an image analysis system, a mapping system and a colour graphics workstation.

Ocean Topography and Tides

A 15-year ocean tide programme conducted by the Institute of Oceanographic Sciences (IOS) reached its conclusion in 1985. Over the period of study, pressure recording equipment developed by IOS has been used from the UK continental shelf to the abyssal depths to provide more than 90 tidal records, or about 46% of those in existence. The records provide a unique data set for the calibration of computer models and have revealed several local tidal characteristics not previously known.

In preparation for the coming World Ocean Circulation Experiment (WOCE) IOS has been monitoring long-term changes in wave activity. Useful data have been gathered to assist in the processing of satellite altitude measurements. The removal of tidal signals is also crucial to the interpretation of satellite data. work on measurements from the Seasat satellite promises useful application to the European ERS-1 and USA/France Topex-Poseidon satellites, due to be launched in the 1990s.

Hydrothermal Activity along the Mid-Atlantic Ridge

Until recently the existence of hot springs and other high temperature hydrothermal phenomena had only been established in connection with intermediate or fast-spreading oceanic ridges. However, in a series of exciting discoveries an international team which includes a NERC sponsored scientist has recorded these phenomena around the Mid-Atlantic Ridge. Such slow-spreading ridges are now believed to play an important role in the hydrothermal exchange processes which affect ocean chemistry, mineralogy and biology.

Sensitive Tracer Techniques

The world's oceans are increasingly used for the purpose of disposal. Monitoring the dispersal of such substances is important for the future health of marine and terrestrial life. A technique has been developed by the Marine Biological Association (MBA) which uses perfluorocarbons as tracers for the investigation of physical marine processes and the dispersion of dissolved components.

In September 1985, this technique was used off Southern California to trace vertical mixing over a period of eight weeks. This was the first time such mixing has been measured for more than a few days: the ability to monitor marine processes over such a long period presents a wide range of interesting possible applications in the future.

Agriculture and the Environment

There is considerable impetus for research on the impact of agriculture on the natural environment in the UK. This comes partly from reports of the Royal Commission on Environmental Pollution and the House of Lords Select Committee on Science and Technology, and partly from signs that the structure of British agriculture may have to change significantly, with important consequences for the environment.

NERC has formed with AFRC and ESRC a Joint Policy Working Group, chaired by Sir Hans Kornberg FRS. The Working Group will aim to increase collaboration between the activities of the Research Councils and to advise them on the development of a co-ordinated R & D programme on the

environmental consequences of agricultural policies and practices, and interactions with other land uses.

In another initiative in this area, the TFS Directorate has set up a new Special Topic which is co-funded by NCC. The aim of the programme is to stimulate research into present and likely future interactions between agriculture and the natural environment including on-farm habitats. The research may concentrate on effects of individual agricultural practices or agricultural systems, or analyse the consequences of change in agricultural land-use and its interactions with other land uses.

Biotechnology

Increasing attention is being paid to the environmental effects of the release of genetically engineered organisms, arising from their potential use in agriculture, forestry or waste management. Apart from many conventional studies related to population genetics, two specific areas of current work are of direct relevance in this area.

Two years ago, Institute of Virology initiated a programme of research and development aimed at genetically altering naturally occurring baculoviruses to improve their use as insecticides. Work has proceeded on three systems with a view to initiating the first controlled experimental release of a genetically modified organism to be carried out in the UK with the agreement of the various regulatory agencies.

Work at FBA is investigating the mechanisms of, and controls upon, gene transfer and how these affect the bacterial ecology of rivers, lakes and other water bodies. The research, which has focused on heavy metal tolerance and antibiotic resistance, has so far been done in microcosms or other forms of laboratory containment and there are no plans for early release experiments.

At the end of the year the TFS Directorate announced a new Special Topic on Biotechnology. This programme is designed to stimulate research in (i) the management of tree root-microflora associations to alleviate stress factors such as drought, metal toxicity and nutrient deficiency), and (ii) the prediction of the ecological consequences of the accidental or deliberate release of genetically manipulated or altered organisms into the natural environment.

Pollution Studies

Considerable amount of research effort in the TFS Directorate is concerned with the transfer and impact of a wide range of pollutants within the terrestrial and freshwater environments. Expertise and experience is also applied to the abatement of, and recovery from, pollution damage and an example of this received national recognition during the year when FBA was given a commendation under the 1985 Pollution Abatement Technology Award Scheme, jointly with British Industrial Sand Limited. The award, which was for the reclamation of acid sand quarries, is a practical example of an industrial application arising from basic research, through collaboration with industry.

Although many of the problems arising in the field of animal ecotoxicology are probably the responsibility of industry, NERC has a role to play in supporting fundamental research, method development and the identification of potential problem areas. There is a need to bring together marine, freshwater and terrestrial expertise in carrying out this basic research. TFS Directorate has therefore established a new Special Topic in Animal Ecotoxicology which aims to address these issues.

Remote Sensing of Rainfall and Vegetation

Widespread famine in Africa has emphasised the need for advance warning of drought in order to minimise its effects on local populations. For the last three years the CEC has been funding an international programme to study the dynamics of desertification in West Africa using satellite data.

During 1985/86 personnel from ITE and IH were involved in this programme, measuring rainfall and the amount and type of vegetation in the Sahel region of West Africa. These measurements were related to data derived from the Landsat and Meteosat satellites.

On the ground, results from a dense network of gauges revealed that amounts of rainfall could vary dramatically over a distance as small as 10km. Only satellite remote sensing could hope to give accurate estimates of average local rainfall.

Surface temperature data obtained by Meteosat during the wet season were used to define the extent and height of precipitating clouds. Landsat provided images of perennial vegetation which were compared with field measurements of vegetation biomass. Independent checks of the satellite information were very encouraging. It is hoped that the project will be further supported by the EEC, enabling the development of an operational system.

150th Anniversary Celebrations of BGS

The BGS opened its doors to over 800 guests on 9 October 1985 in order to celebrate its 150th anniversary. On the previous day the new Keyworth headquarters were officially opened by the Honourable Peter Brooke MP, Parlimentary Under Secretary of State for Education and Science. On Open Days which followed these ceremonies, staff at Keyworth were overwhelmed by the public interest in the BGS. Apart from representatives from Government, past Survey staff, universities, overseas surveys, museums and the Press, over 5,000 members of the public toured the

On show during the open days was an Astronomical Quadrant said to have belonged to the Survey's first Director, Sir Henry De la Beche (1796-1865). The Quadrant was on loan from the National Museum of Wales, Cardiff.

exhibits demonstrating the range of BGS activities.

A full report on the anniversary celebrations and the official opening of Keyworth can be found on page 16.

Mapping in the Southern Uplands

Our understanding of Southern Uplands geology is advancing rapidly as a result of a detailed analysis of the composition of the individual grains forming the dominant sandstones and the deduction of the direction of flow of the depositing oceanic currents. Contrasting zones within an otherwise apparently uniform succession have been established. When these are compared to the distribution of major geological structures a pattern is revealed which is difficult to reconcile with the currently popular interpretation of the region. This envisages that during the late Ordovician and early Silurian (about 460 to 420 million years ago), over the region now comprising the Southern Uplands, a series of oceanic sediment strips regularly accreted as a destructive continental margin. Instead a picture is now emerging of small, ocean basins between active volcanic island chains being closed and amalgamated by major Earth movements on a global scale. On a regional scale, interpretation is aided by an experimental use of satellite imagery; on a detailed scale the use of small, hand-held apparatus to measure the magnetic susceptibility of the rocks promises an alternative method of recognising the various sandstone types.

Ocean Drilling Programme

After a year of uncertainty, the UK rejoined the International Ocean Drilling Programme (ODP) with NERC as UK Co-ordinator and principle subscriber (contributing approximately £1m of the £1.8m UK total). The other UK contributors are six major UK oil producers, the Department of Energy, Department of the Environment and the Department of Trade and Industry. Other members of the Programme are the USA (which leads it), Canada, France, the European Science Foundation, the Federal Republic of Germany and Japan. At the time of writing the USSR is expecting to join with effect from 1 January 1987.

This extremely important research programme has implications in many areas of Earth sciences and also in oceanography. Membership of ODP gives UK scientists a chance to participate in every cruise, to have access to samples for immediate post-cruise study, and to have immediate access to the important scientific results, and to influence the future direction of the programme.

Twelve scientific topics have been selected as priority objectives be addressed by scientific ocean drilling and related programmes. Many of the topics are relevant to industrial hydrocarbon exploration and production. The topics in non-preferential order are:

1. processes of magma generation and crustal construction at mid ocean ridges;
2. configuration, chemistry and dynamics of hydrothermal systems (relevant to diagenesis and geochemical problems);
3. early rifting history of passive continental margins (locus of many oil and gas fields);
4. dynamics of fore arc evolution;
5. structure and volcanic history of Ireland arcs;
6. response of marine sedimentation to changes in sea-level;
7. sedimentation in oxygen-deficient seas and oceans (refers to source rock problems);
8. global mass balancing of sediments (relevant to basin development);
9. ocean circulation history (relevant to hydrocarbon generation);
10. response of the atmosphere and oceans to variations of the planetary orbits;
11. process and mechanism of evolution in marine organisms (applies to the biostratigraphical dating of strata);
12. history of the Earth's magnetic field.

Deep Geology of the UK

The British Institutions Reflection Profiling Syndicate (BIRPS) have continued their research into the deep structure of the UK and its surrounding area.

After the successful shooting in 1984 of the Deep Reflections from the Upper Mantle (DRUM) line off the north coast of Scotland, BIRPS recent activities include successfully imaging the Iapetus suture in the lower crust to the east of Britain; shooting further ultradeep seismic reflection profiles including one to 60s two-way time which should penetrate through the asthenosphere; and running the Western Approaches Margins (WAM) profile to examine the deep structure of the continental margin and oceanic lithosphere.

Many of the features observed on the BIRPS lines around Britain were produced or modified by crustal extension or stretching. This stretching ultimately led to the opening of the north Atlantic. The WAM survey, which was designed to investigate this in detail, ran 600km of line from an area of moderate stretching in the Celtic Sea, across the stretched edge of the continent, over the Continental Margin and into the oceanic crust. WAM appears to show that seismic layering in the lower crust is not directly related to continental extension.

For details of the research findings along the WAM line, see page 30.

Geodesy

A 1984 Royal Society Working Party report concerning the revolution in techniques of geodetic measurements indicated that recent developments were not being adequately recognised or exploited by the UK scientific community. In response a joint NERC/SERC initiative was mounted to encourage the development of the geophysical aspects of geodesy, linking solid Earth geology and oceanography.

As a result, 16 proposals requesting funds of £600,000 were received and seven research grants and four research studentships were awarded to UK universities and polytechnics.

Topics to be addressed include investigations of discrepancies in main sea-level around the UK, examination of small-scale mantle convection and the thermal evolution of the oceanic lithosphere. Use of the satellite laser ranger to test geodynamic models particularly in the Mediterranean, and the application of radar backscatter techniques from satellites to produce accurate altimeter maps over land.

A typical GLORIA map. In this case of the Cascadia Channel off the West Coast of the US. The black meandering line running across this sound 'picture' is a river of sediment flowing down the slope 10,000 ft underwater, its path dictated by the ridges and other topographical features, until it reaches the point (off the picture) where the continental plates are spreading

Joint BGS/University Geological Mapping Programme

In recent years the systematic geological mapping of the UK has lost momentum, as much British Geological Survey (BGS) effort has been directed into shorter term programmes for specific customers. Necessary as that is, it is nevertheless important to expand and upgrade UK map coverage. To do this, not only have BGS recently redirected resources back into mapping but also, following the 1982/84 Visiting Group to BGS, have initiated and encouraged collaboration with British universities. The injection of university effort and expertise into this programme will enable publication of more modern maps and the underlying scientific information that could not otherwise be produced.

Eighteen submissions were received from universities, in response to invitations to tender, for mapping projects based on BGS priorities. After extensive evaluation, six contracts have been awarded and a seventh is under discussion. Details of the six projects can be found on page 31.

GLORIA (Geological Long Range Inclined Asdic) Seabed Survey

A highlight of the year was the signing of an agreement between NERC Institute of Oceanographic Sciences (IOS) and Marconi Underwater Systems Ltd for the transfer of GLORIA (Geological Long Range Inclined Asdic) technology for surveying the deep ocean floor. The agreement means that Marconi will now build and operate the highly successful IOS GLORIA surveying sonar system.

GLORIA is a long-range towed side-scan sonar conceived, designed and developed by the NERC IOS. Its long range (up to 30km on both sides of the survey track in deep water), adaptability, and ease of operation make it unique as a tool for swift reconnaissance survey of the ocean floor. GLORIA in effect produces a map of the seabed. A pulse of sound is emitted in a narrow beam at right angles to the towing ship's track. This is reflected from seabed irregularities at successively increasing distances from the track. The echo is recorded to produce a line segment of a map which is built up from successive pulses as the ship moves forward.

GLORIA is at the moment engaged on work for the US Geological Survey as part of a six-year agreement to survey the entire 5 million square miles of the US Exclusive Economic Zone. There is considerable world-wide interest and the demand for GLORIA operations is expected to increase as exploration for hydrocarbon and other mineral resources spreads to deep waters.

Headquarters Administration

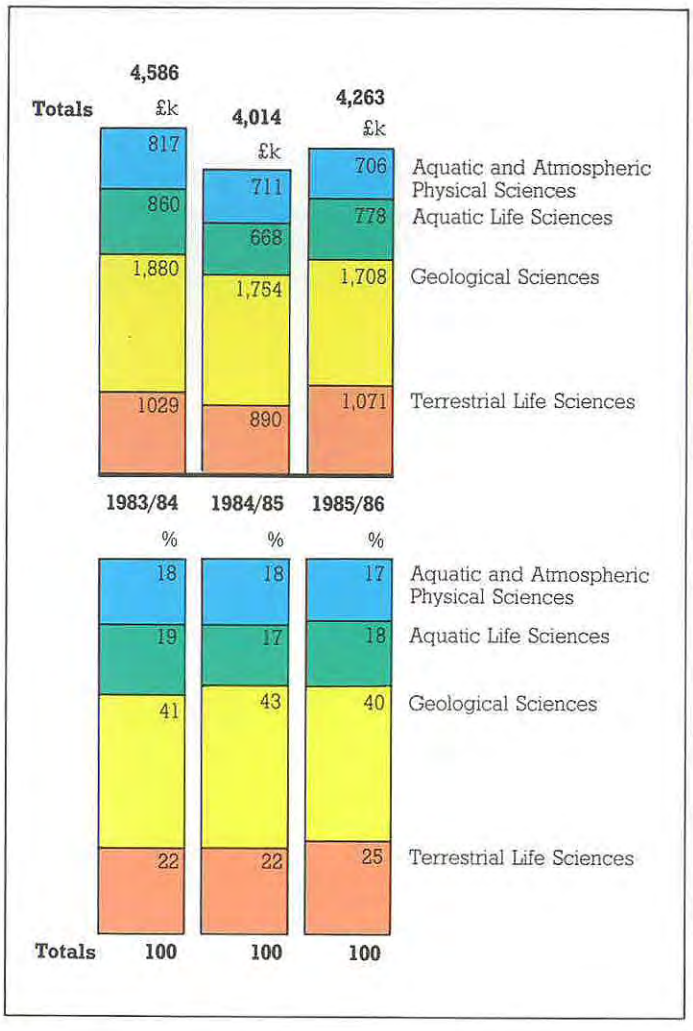
The Directorate of Policy, Planning and External Affairs was formed in September 1985 by establishing a science policy, planning and audit team and by incorporating the pre-existing University Support Section, Research Marketing Group and Public Relations Section.

An urgent task was to ensure that NERC scientific priorities and plans were reviewed by the new Committees of Council: this was achieved and, in January 1986, Council approved the 1986 NERC Corporate Plan. An early start was then made on developing the ways in which we evaluate our scientific priorities and programmes.

The Council submitted written and oral evidence to the House of Lords Select Committee enquiries on "Dumping of Waste at Sea" and "Organisation of Civil Research and Development".

The development of European scientific collaboration and initiatives is becoming increasingly important and NERC was active in developing links with and through the European Science Foundation and European Science Research Councils.

Research Grant Expenditure
1983/84 to 85/86



University Support Section

NERC responds to applications from universities and polytechnics and support is provided directly through research grants, studentships and fellowships, and indirectly through the provision of ships, equipment, and analytical facilities.

Research Grants

Demand for research grants is such that Council continues to be unable to support all the best proposals. Four hundred research grant proposals seeking £17.8m were received by NERC and, following peer review, over 300 of these (seeking £12.5m) were graded alpha. Only 115 awards could be made, with a total commitment of £3.9m over about three years. Thus, Council could support only one-third of its alpha graded proposals. The lack of sufficient resources to fund all the best proposals is of major concern to Council and, following a rigorous review of overall scientific priorities, steps are being taken to enable this to be at least partially rectified. Expenditure on research grants totalled £4.3m in 1985/86: the distribution of these resources and comparisons with earlier years are shown in the Figure above and details are given in Appendix 4. Some of the research work supported by grants is described later.

Training Awards

Research studentships are awarded following peer review of the topics proposed by university and polytechnic supervisors and the demand continues to increase. However, the number of PhD research studentships supported by Council remained at 300: details of the awards taken up in October 1985 are given in Appendix 5.

Council also awarded 200 MSc studentships for advanced courses recognised by NERC and the demand for studentships continues to be high. The advanced courses in meteorology were reviewed in 1985/86 and a new course at the University of East Anglia was recognised and supported. The distribution of advanced course studentships is shown by committee areas and institution in Appendix 6.

Council awarded nine post-doctoral research fellowships in 1985, the details of which are shown in Appendix 7.

The total expenditure on all awards in 1985/86 was £6.0m.

Other Support for Universities and Polytechnics

Council also supports research in universities and polytechnics by establishing university units, through research contracts (*) and by provision of research vessels, major equipment, analytical computing and remote sensing facilities, and the NERC aircraft. Council's contribution of £1m to the UK subscription to the Ocean Drilling Programme also adds significantly to Council's support for research in the universities and

polytechnics. Taken together, the direct and indirect support amounts to 26% of Council's Science Budget vote. There are a number of other activities undertaken by Council's staff which contribute to the overall activity: for example, lecturing, supervision of research students, provision of institute facilities and vacation employment of undergraduate students.

(*) see publication series D No. 27.

Research Marketing Group

In 1985/86, NERC continued to seek a broader base of customers for its research and income from the private sector increased. In particular, relationships with private sector consultants flourish and joint bids have been mounted during the year for work in Saudi Arabia, Africa and elsewhere. NERC, with public and the private sector partners is developing an initiative entitled Agricultural Research in Africa (ARIA) to market UK expertise and attract support from international lending agencies.

In the marine area, NERC joined with the Water Research Centre to form a marketing joint venture - Aquamarine - designed to bring to the attention of potential customers in the water sector the expertise of both bodies in a range of areas relevant to protecting the marine environment.

NERC appointed an agent (Murray Fisher Group) to represent its capabilities in South East Asia and in particular to the Asian Development Bank in Manila.

NERC has sought to improve further the commercial exploitation of its research results, in particular by UK industry. Several financial interests in the City of London have been involved in discussions on proposals for the formation of a NERC company, to undertake commercial exploitation and win more commissioned research from the private sector. Reactions to these proposals by merchant banks and venture capital companies were sufficiently encouraging for NERC to commission a feasibility study by Coopers & Lybrand Associates on establishing a NERC company. NERC also worked on a possible Small Business Scheme in which its staff might be allowed part-time conditions of employment to enable them to form small businesses to exploit specific inventions or to offer a particular service related to NERC science. Progress was made in registering service expertise and the experience and qualifications of key personnel on the BEST Database (British Expertise in Science and Technology). Working with government departments and its sister research councils, NERC has sought to develop arrangements for exploiting research in universities and polytechnics undertaken with Research Councils' support.

During the year, NERC concluded an agreement with Marconi Underwater Systems Ltd for the commercial exploitation of GLORIA ocean survey technology and its marketing on a worldwide basis. This significant agreement was announced at the Techmart Exhibition at the National Exhibition Centre in Birmingham during October where NERC had a major exhibition. The stand demonstrated important results from research in the environmental sciences and attracted considerable attention. A number of specific contracts resulted from this exhibition and it is hoped that it will become a regular event in the NERC calendar. In addition, NERC also mounted stands at the Royal Show International Pavilion, and at the Oceanology Exhibition at Brighton during the course of the year.

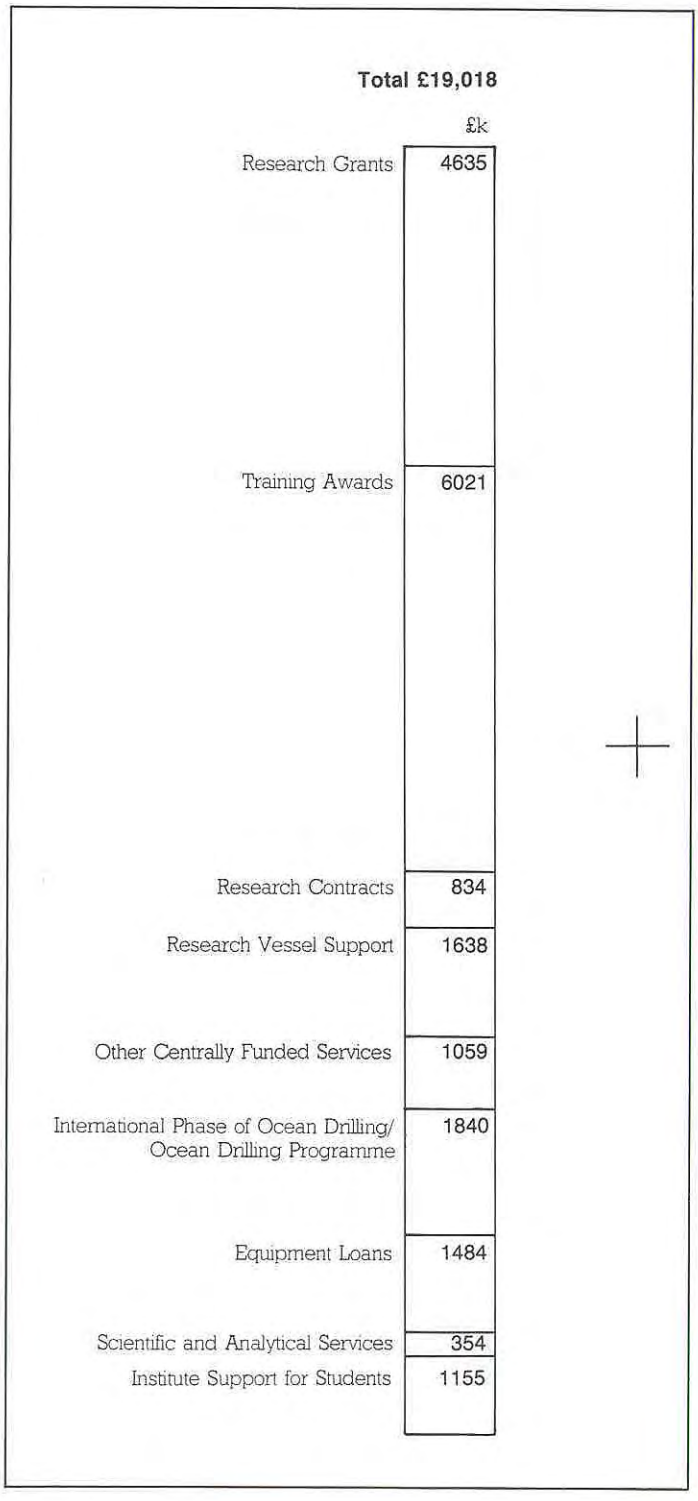
A new departure in the NERC marketing strategy has been to develop presentational seminars for specific market sectors. The first of these was held in the British Museum (Natural History) in March 1986 for the Onshore Oil Industry and further events are planned. These presentations were designed for an informed lay audience, and video films have been prepared by the Research Marketing Group to illustrate aspects of NERC science as part of the programme.

Public Relations Section

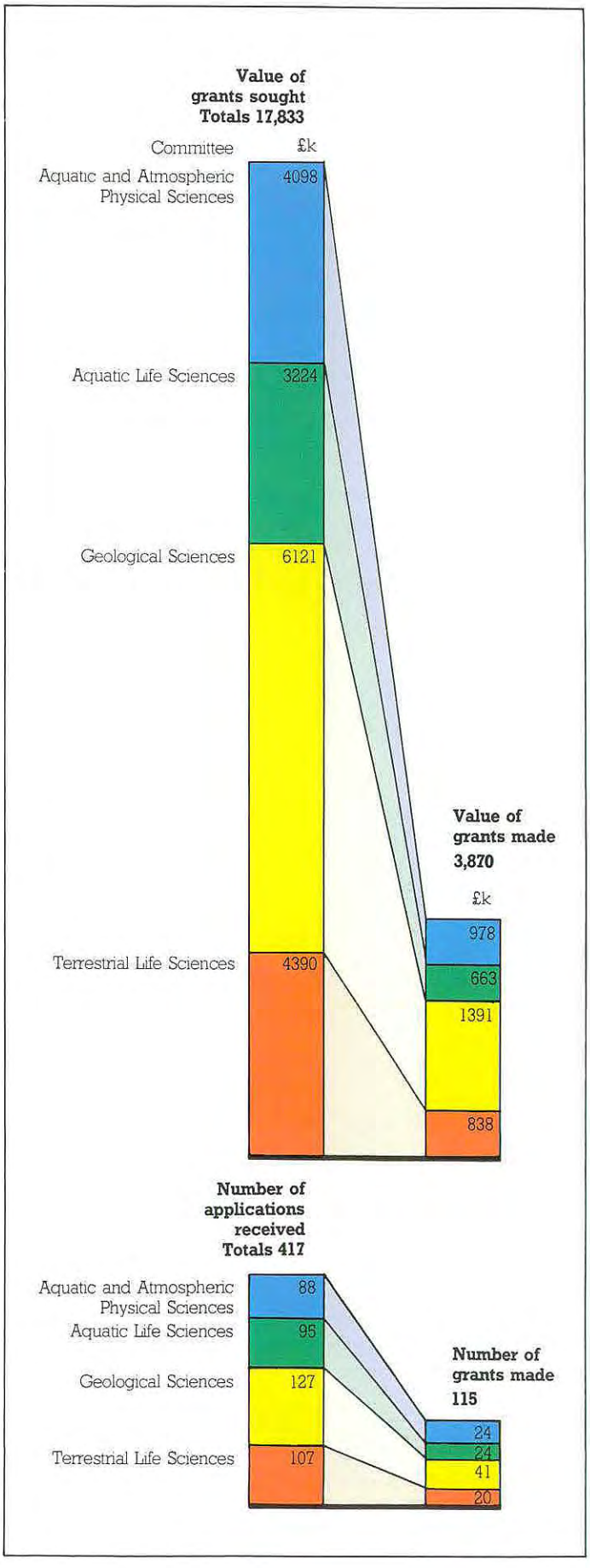
There was further development of the Council's policy of creating greater awareness of its work through increased public relations activity. Publicity has been generated around events such as the visit to the Pool of London by the Council's research ship RRS *Charles Darwin* and the signing of a licensing agreement for the GLORIA underwater surveying system with Marconi.

Professional designers started to prepare a NERC corporate design with a manual to enable all parts of the organisation to readily produce printed material with a "family" appearance.

Overall NERC Contribution to Universities and Polytechnics 1985/86



Research Grant Applications and Awards
1 July and 1 December 1985



Science Reports

The following sections describe the main features of the research carried out during the year at Council's institutes and at universities and polytechnics receiving Council support. The sequence followed is Earth Sciences, Marine Sciences, Atmospheric Sciences, and Terrestrial and Freshwater Sciences. There follows a section on NERC Scientific Services the coordinated services set up by Council to enable the research to be carried out in the most efficient way possible.

Further details of work undertaken at Council's institutes will be found in institute editions of this report. Details of research undertaken at universities and polytechnics with NERC support are available from the NERC University Support Section which is based in Swindon

Earth Sciences

The Earth sciences include geology, geophysics, geochemistry and physical geography, and draw on physics, chemistry, mathematics and biology. To further understanding of the processes that have created and are modifying the Earth it is increasingly important to bring together this range of disciplines. This is being done through multi-disciplinary teams involving national and international collaboration.

Research in the Earth sciences is carried out within three NERC institutes, the British Geological Survey (BGS), the Institute of Oceanographic Sciences (IOS) and the British Antarctic Survey (BAS). Grant support for universities and polytechnics currently comes through Special Topics in Deep Geology (including the British Institutions Reflection Profiling Syndicate), Geodesy, and a joint BGS/university geological mapping programme; and through the Geological Sciences Research Grants Committee and the Geological Sciences Training Awards Committee.

British Geological Survey

When the Geological Survey was founded in 1835, the beginning of 'modern' geology as we know it had commenced in various parts of Europe. However, the Survey was probably the first national institution of its kind in the world and 1985 was the culmination of 150 years of continual activity. To commemorate this milestone, a number of events were organised at all the Survey's offices and observatories including the BGS headquarters at Keyworth, where open days, an official opening ceremony and Anniversary Ball formed part of the proceedings.

On 9 October at Keyworth, some 800 distinguished guests arrived representing industry, government departments and funding agencies, past survey staff, local government, professional bodies and learned societies, overseas geological surveys, the universities and museums and the press. The relatively high proportions of multinational companies and government departments present clearly demonstrated the close relationships between the work of the Survey and a broad spectrum of applied geology.

Among the many distinguished visitors on that occasion were Professor Dr F Bender, former President of West Germany's Federal Institute for Geosciences and Natural Resources, Dr H de la Roche, Head of the Service Geologique National Francais, the President of the Royal Society (Sir Andrew F Huxley), the Lord Mayor and Lady Mayoress of Nottingham, the Sheriff of Nottingham and Mrs P Hardy and the great-great granddaughter (Mrs O Welbourn) of the Survey's first Director Sir Henry Thomas De la Beche. Speeches were followed by a tour of the exhibits and demonstrations.

The Open Day for educational establishments was well attended. Groups ranged in age and experience in geology from postgraduates to primary school children. The final open day for the general public witnessed a deluge of over 8,000 visitors in the short space of five hours.

Keyworth Official Opening

Over a decade of effort to unite the field mapping staffs of England and Wales and the specialist departments of the Geological Survey at a site in the English Midlands, was marked on 8 October when the Keyworth headquarters was officially opened by the Hon. Peter Brooke, MP, Parliamentary Under Secretary of State for Education and Science, who unveiled a commemorative plaque in the De la Beche Conference Centre. To commemorate his visit to the Survey, Mr Peter Brooke was presented with a slab of polished Precambrian Laxfordian Granite Gneiss, about 1600 million years old.

Speeches by Mr Brooke, Mr Hugh Fish (NERC Chairman) and by Professor Sir Malcolm Brown, FRS, Director of BGS referred to the foresight of the Survey's first Director, Sir Henry Thomas De la Beche, in stressing the many practical applications of geology and of the scope of 'modern' geology and its relationships with the work of many government departments. Sir Malcolm Brown outlined the Survey's activities in the form of the seven following broad categories.

1 300,000sq.kms of landmass geology to remap and reinterpret during the continuous emergence of new ideas

2. 400,000sq.kms of continental shelf territory to study.

3. Exploration of that territory – 700,000sq.kms, to a depth of 3kms.

4. Advancement of the knowledge base in geology, geochemistry and geophysics so that interpolation and extrapolation can help minimise the expense of deep drilling.

5. Attack the problem of information technology. There is 150 years' worth of information, growing daily, contained in the databanks. The opening of the National Geosciences Data Centre at Keyworth is designed to help alleviate this problem.

6. Remain active in the fields of energy, mineral and water resources, and on toxic, earthquake, constructional and other hazards.

7. Involvement in Geological Surveying Overseas, especially in Developing Countries.

BGS Activities

The British Geological Survey (BGS) is responsible for preparing and continually revising the geological database of the United Kingdom through the collection, interpretation and correlation of the available data and its publication in the form of maps and reports. This strategic surveying activity is mainly funded through the Science Vote (through the Department of Education and Science) with other government departments commissioning work in specific areas.

Commissioned Research Programmes

As in previous years, much of the Survey's work in 1985/86 (approximately 70%), was commissioned by UK government departments. Thus, the Department of Trade and Industry (DTI) continued to fund surveys for mineral resources while the Department of the Environment (DOE), in collaboration with the Scottish Development Department (SDD) and the Welsh Office, supported work towards planning and development, including environmental geology mapping. All investigations aimed at assessing the hydrocarbon potential of onshore and offshore UK were funded by the Department of Energy (D En) which also supported the assessment of geothermal potential onshore and geological and geophysical surveys of the UK Continental Shelf.

The Overseas Development Administration (ODA) continued to maintain a substantial programme of work overseas whilst the EC and the Department of Economic Development (DED – Northern Ireland) continued supporting research projects in the UK.

Science Budget Research Programmes

As has happened for the past few years the need to redeploy staff to assist the commissioned projects, coupled with reduced funding seriously affected those programmes financed by a grant – via Council from the Department of Education and Science (Science Vote). As a result important and often highly innovative, basic research has been jeopardised. Much of the UK remains inadequately mapped and the geological database in these areas is grossly inadequate to cope with problems when they arise, for example, Abbeystead Methane Explosion (see Page 18).

Progress has nonetheless been achieved, for example, in maintaining the multi-disciplinary regional surveys in Cumbria, Wales and the Worcester Basin. Thus in the Lake District a study of the Lower Palaeozoic rocks has continued, leading to an evolving structural model for the Skiddaw Group, a likely genesis and age for the Borrowdale Volcanic Group, a pre-cleavage age for the Eskdale Granite, and a hitherto undetected structural relationship between the Eskdale granodiorite and a major syncline.

In Snowdonia, a new model for the Ordovician volcanic rocks of the area (but with world-wide ramifications) has been devised to explain the associated volcanism, tectonism and mineralisation. In Central Wales, a pilot project has examined the possibility of developing relatively rapid survey techniques for use in areas with essentially similar rocks, using aerial photography and traverse mapping with some detailed surveying.

UK Landmass

From its inception, the Survey's primary role has been to survey the geology of the UK, and this work still continues as new data are acquired, geological concepts improve and requirements from industry, government and land-use planners change.

The mapping projects referred to below, some of them in summary form, represent the type of surveying currently undertaken.

In Central and Southern England, mapping in the Poole-Bournemouth area of a succession of Tertiary clays and sands has been carried out for the DOE, while in the Southampton area, the first phase has begun of a BGS/DOE funded project to develop a computerised databank – from which thematic maps can be generated by interactive interrogation.

Ocean Closure Tectonics and Mineralisation

A DTI-commissioned mapping programme in south Cornwall has identified an area showing evidence for closure of an ocean in Devonian times. Throughout the area, the volcanics associated with this tectonic event are sources of mineralisation. The DTI is promoting an extension of the programme into south Devon where a major objective will be to determine the detailed interrelationships between mineralisation, volcanism and regional tectonics.

Biostratigraphic Studies in the Craven Basin

Field work in the Garstang area is funded by a commission from the DTI and by the Science Vote. This district, which lies within the western part of the carboniferous Craven Basin, was last geologically surveyed in 1883.

Biostratigraphical studies, concurrent with the geological mapping, are helping to demonstrate the extent and age of lateral facies and thickness changes. For example, the oldest limestones exposed in the core of the Sykes Anticline are now known to be of Chadian age, overlain by a very thin Arundian sequence that thickens greatly southwards. Traces of hydrocarbons have been noted in several places. The lowest sandstone

in the Worston Shales, of possible reservoir rock potential, has also been found to be of Chadian age.

Several major north-east to south-west trending folds are being traced across the carboniferous outcrop, and in the cores of folds some of the folds are highly deformed. Several major NW-SE trending faults and a few new mineral veins have been mapped or recorded, but association with mineralisation of possible commercial significance has yet to be established.

The pattern of folding, faulting and facies distribution that is emerging as the field work proceeds will promote a better understanding of the overall structural history of the Craven Basin and will contribute to a predictive model of strata concealed by younger rocks, particularly to the west under the Fylde and the Irish Sea.

Abbeystead Methane Explosion

In May 1984 an explosion caused by methane gas in the valve house of a water transfer tunnel at Abbeystead, Lancashire, led to the deaths of 16 people and injuries to many more. The North West Water Authority commissioned the BGS, who had geologically logged the tunnel while it was under construction in 1976/77, to write a report on the geological background to the disaster. Since most of the area had been last mapped geologically in 1875/76, a new and detailed geological survey was immediately mounted. The resulting report details the structural pattern of the area. The 1100m thick sequence of siltstones, mudstones and sandstones contains several fossil marker horizons. These marine bands aided the interpretation of fold and fault patterns which had been recognised from surface mapping. A seismic survey was carried out to investigate the deeper geology beneath the tunnel. The seismic reflectors recognised have been related to the regional stratigraphy by various samples taken from the nearby Whitmoor Borehole, held at the National Geosciences Data Centre, supplemented by data from British Geological Survey operations in the Garstang and Lancaster districts. This survey allowed predictions to be made of the depth below the tunnel of sandstone beds which are likely to contain methane gas and local springs were also monitored for methane. The distribution and thickness of the widespread blanket of glacial deposits have been plotted in detail as a further aid to the next step in the investigation.

Deeside

In Deeside, a new project, partly supported by the Welsh Office, aims to produce a series of thematic maps useful to planners and developers, including maps related to mining and ground stability.

Correlation of Limestones in the East Grampians

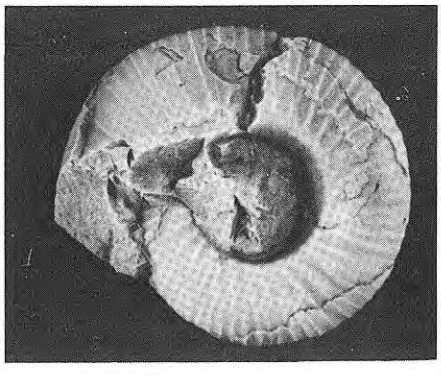
The Dalradian rocks of the East Grampians, Scottish Highlands, are the focus of a great deal of scientific attention, supported by the DTI, with a variety of geological problems under investigation. Stratigraphical correlation has always been difficult in that region, but the whole-rock geochemistry of limestones and pelites may offer a valuable guide to their relative ages. Following the analysis of 30 elements in 200 samples, the validity of this technique is shown by a high degree of correlation between limestones known to be stratigraphically equivalent. This technique provides a framework for the interpretation of data from strata of an unknown age. Early results, studied with more conventional field techniques, are encouraging. The variation in limestone geochemistry between different sub-groups within this area reflects their formation in contrasting palaeoenvironments.

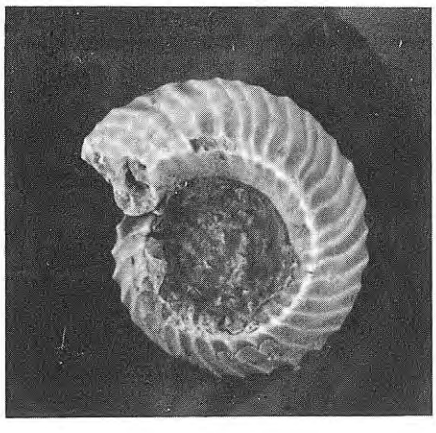
An adjunct to this work is the development of calcite-dolomite geothermometry to estimate temperatures of metamorphism. Results gained by using this technique provide a valuable comparison with temperatures estimated by other means of geothermometry.

In Central Scotland the Scottish Development Department (SDD) have supported applied research into ground and foundation conditions related to urban redevelopment, geothermal energy and the relationships between dykes cutting Old Red Sandstone conglomerates and potassium-rich magmatism in the late Caledonian.

Mapping in the Southern Uplands

The geololgical map is essentially a pictorial model and two-dimensional representation of a four-dimensional problem (area, depth and time). The map is also a statement of understanding based on available evidence (borehole, quarry and other data) interpreted in the light of current geological knowledge. However, it means as new data are acquired, or as geological theories are refined, maps need to be revised.





Goniatites (extinct Mollusca) from marine bands of Carboniferous age in rocks near the Abbeystead Valve Station.

Cytherelloidea ovata

Detailed mapping in the Southern Uplands has been supplemented locally by the experimental use of satellite imagery. In this area during the late Ordovician and early Silurian, greywackes were deposited in an extensional marginal basin and subsequently incorporated into a southwards-propagating, rising thrust stack. A foreland-style basin, that developed and migrated ahead of the thrust front, was the site of sedimentation and subsequent deformation in the middle and late Silurian.

This interpretation more readily explains the structural pattern recorded in the area, particularly the presence of back thrusts, than does any other currently accepted model. This new interpretation thus calls for a radical reassessment of the geological evolution of the region.

In Northern Ireland the Survey has worked largely for the Department of Economic Development (DED) in the fields of mineral exploration (principally for lignite) and hydrocarbon exploration and with the DOE (NI) on a hydrogeological programme in the Lagan Valley.

Hydrocarbons in the North Sea

Much of the Survey's effort offshore has been to provide the Department of Energy with an independent assessment of the oil and gas resources of the UK Continental Shelf.

Regional 1:50,000 mapping has been completed for most of the Central and Northern North Sea Graben system and detailed structural and stratigraphical problems are now being addressed.

In the west, modern data from the Minches, the Firth of Clyde, the North Channel and the Solway Firth are currently being interpreted and new insights are emerging into these structurally complex areas, especially the nature and amount of Tertiary uplift and erosion. The recently renewed interest in the Southern North Sea Basin has been stimulated by the discovery of hydrocarbons in the carboniferous strata at a lower level than the presently producing gas fields.

A regional survey of the inner part of the UK Continental Shelf, including the Faeroe-Shetland Channel and the eastern part of the Rockall Trough, has continued. Following a geophysical survey, initial geological sampling should be completed in 1986.

All of these studies are essential to the understanding of hydrocarbon generation, migration and entrapment and are contributing to a more fundamental appreciation of the mechanics of North Sea Basin development.

Deeper Water Geophysics and Geology

A suite of geological maps at 1:250 000 are being produced of the UK sector of the Continental Shelf. Off the north and west coast of Scotland extensive tracts of this area are at depths greater than 200m.

In the year under review the geophysical and geological sampling work has concentrated in the deeper water areas using the vessels MV *Gorsethorn* and the dynamically-positioned *British Magnus*. Working in these areas has required further development of existing equipment suites. The deep-tow boomer, manufactured by Huntex (70) Ltd was substantially redesigned and modified to increase its tow depth capability from 150m to 1000m.

This was particularly successful and a special high-resolution seismic survey has produced some spectacular results. Modifications to the vibrocorer (which allows a core barrel to be vibrated into sediments) have also been successful and good quality cores up to 6m long have been obtained in water depths down to 1500m.

Further developments are in hand with the installation of a sidescan sonar into the Huntec deep tow fish, and modification of the vibrocorer to carry in-situ geotechnical testing devices.

Soft Sediment Slumping

An assessment of the underwater ground conditions is necessary before any major construction for hydrocarbon exploration or production is assembled either on or partly within the seabed.

Geophysical survey work has substantiated earlier evidence from the reconnaissance mapping of extensive soft sediment slumping on low angle slopes. The results have confirmed the surface expression of what appear to be a series of deep-seated faults, which may extend for over 200km west of the Hebrides and control the morphology of that section of the shelf. Sedimentological and geotechnical studies of the cores also provide evidence of soft sediment failure.

The seabed displacement of soft sediments, apparently associated with reactivation of deeper faulting both to the west of the Hebrides and in the Faeroe-Shetland Channel, provides new insights into the stability and morphology of the troughs to the west and northwest of Britain.

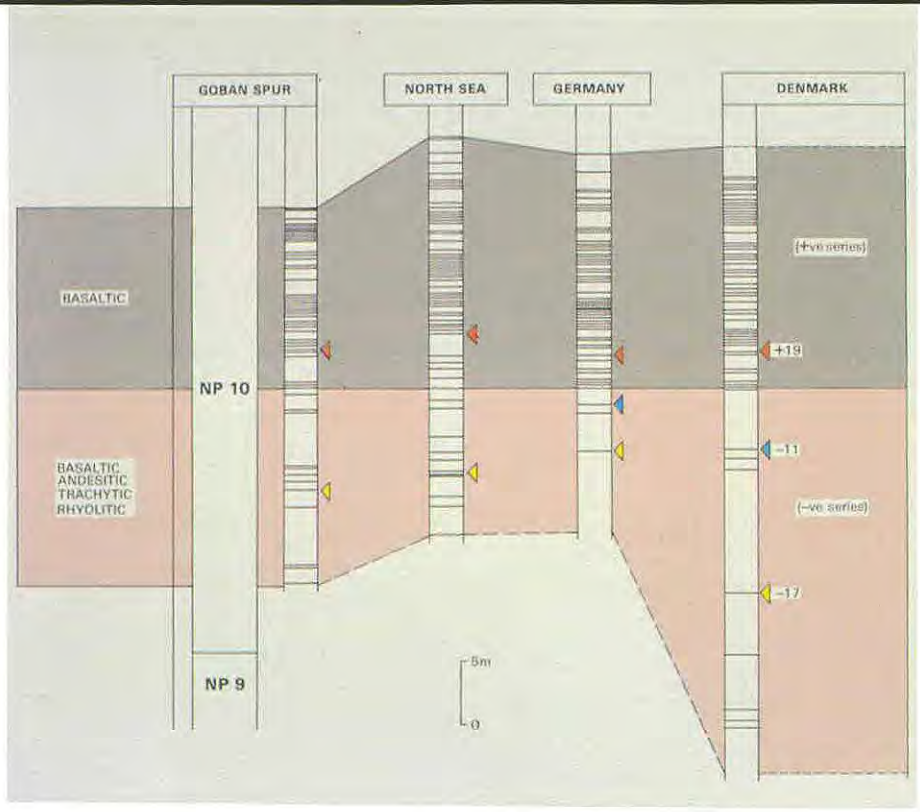
Fossils from North Sea Boreholes

Fossil plant and animal remains are valuable as indicators of past environments (for example, marine, freshwater or terrestrial). Because certain fossils occur in a limited vertical range of rock but have a widespread geographic range, they are important for correlation.

Microfossils and macrofossils from cored boreholes drilled in the North Sea, between Yorkshire and the Forth Approaches, may have important applications in hydrocarbon exploration where accurate age determinations are required for local and regional basin analyses.

Ostracoda (small arthropods) have proved valuable in a study of Upper Jurassic to Middle Cretaceous sequences penetrated by these boreholes. Species of *Galliaecytheridea, Macrodentina, Mandelstania* and *Eocytheropteron* are often found in the Upper Jurassic. Species of *Proctocythere, Paranotacythere, Schurelridea, Cythereis, Cytherelloidea* and *Saxocythere* can be used to subdivide the early and middle Cretaceous strata into more refined, mappeable units.

The resulting biostratigraphy is comparable not only with other British sequences, but also with those in Denmark, Germany and France. The distribution, composition and population structure of the ostracod groupings also provide information on environmental conditions. These ranged from anaerobic during periods



Early Eocene ash sequences in NW Europe and the NE Atlantic, showing individually correlatable ash layers (coloured triangles).

of Kimmeridgian oil-shale deposition, when mass mortality of the fauna took place, to well oxygenated during the Aptian, when diversity was large and no single taxon dominated.

Quaternary Channel Systems

In the Forties and Dogger areas of the North Sea, a study of Quaternary open and filled channel systems has provided new evidence for their genesis and subsequent development; some are probably analogous to the major sub-glacial channels of the North German Plain.

Ash-Bearing Beds in the North Sea

When volcanoes erupt they often eject a large variety of material ranging from gases to large fragments of rock. Great quantities of volcanic cinders and ash may be produced and, because the finest material will be blown high into the atmosphere it will settle out far from the erupting volcano.

Studies carried out in the North Sea Basin have identified a new means of dating poorly fossil ferous rocks by studying the presence of a series of volcanic ash layers that can be traced westwards into adjacent parts of the north-east Atlantic.

Equivalence of the ashes in the two areas is shown by the presence in both sequences of a lower group of sporadic layers of mixed basaltic, trachytic, and rhyolitic composition, and an upper group of abundant layers of almost exclusively basaltic composition. It has even proved possible to identify individual ash layers on the basis of the distinctive chemistry of their residual feldspars.

Since the Atlantic ash layers occupy the lower half of calcareous nannoplankton zone NP10, the ash-bearing beds of the North Sea Basin can be assigned to the same age. Furthermore, since the base of zone NP10 is widely regarded as marking the base of the Eocene, it is possible to draw an approximate Palaeocene/Eocene boundary at the base of the ash-bearing units (Sele Formation of the North Sea) and their lateral equivalents (Woolwich & Reading Beds) of Southern England.

A consortium of 11 oil companies and the Department of Energy provided funds for a shallow drilling project west of Scotland. The drilling vessels MV *Pholas* and *Bucentaur* occupied six agreed sites, one at the eastern end of the Wyville Thomson Ridge, four northwest of Lewis and another in the Minches. The results of this project are expected shortly.

Overseas Surveys

The primary role of the Survey's work overseas is to assist the developing countries of the world in all aspects of the Earth sciences, with particular emphasis on minerals, groundwater and energy. The greater part of this work is funded through the aid programme of the Overseas Development Administration (ODA) of the Foreign and Commonwealth Office and generally comprises either country-specific geological mapping and mineral/water exploration and technical cooperation projects, or regional applied research and development programmes. A small but increasing amount of similar work is carried out on a contract basis, funded either by various UN agencies or, directly, by some of the more prosperous overseas governments.

Crustal Evolution in South America

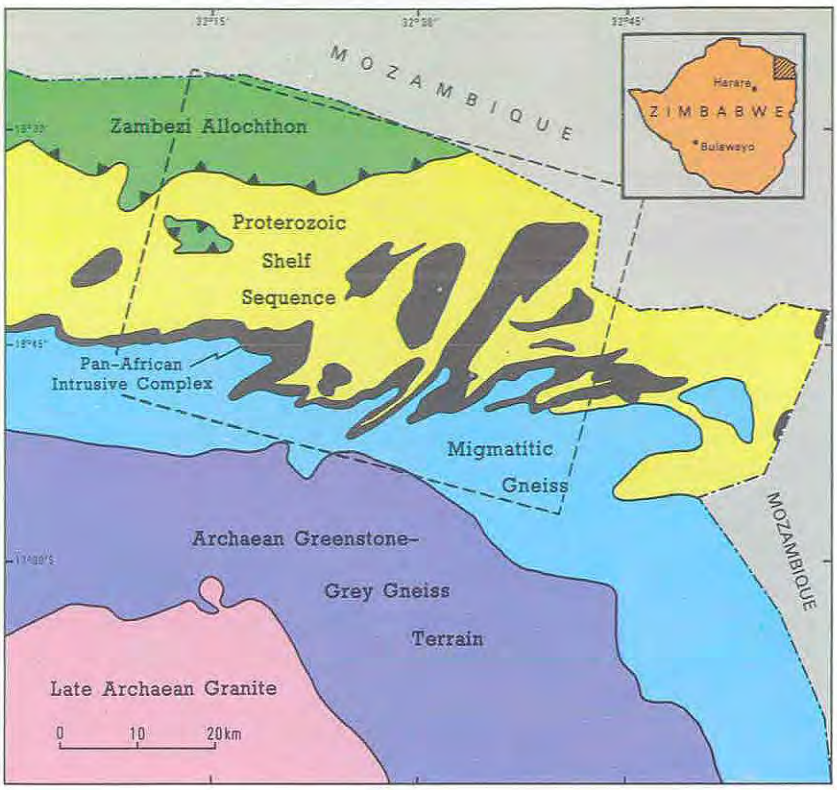
Mapping carried out in South America in recent years has produced exciting new evidence about the continent's structural evolution, its role in the closing of the Pacific Basin and the emplacement of metalliferous mineral deposits.

In support of the mapping and mineral reconnaissance surveys carried out in the Andean countries of South America over the last decade, more than 1000 isotopic analyses have been made. These contributed to an understanding of events which occurred along the South American destructive plate boundary – including the chronology of calc-alkaline magmatism since the break-up of Gondwanaland.

Fluid inclusion techniques and stable isotope studies of oxygen and sulphur have been used as temperature and process-dependent tracers to discover the origin and development of a range of mineral deposits. A detailed investigation has been made of one major gold deposit which it is hoped could contribute to improved artisan mining operation in the Andes. Gravity and resistivity methods were employed to map a gold-bearing moraine in Peru, prior to an extensive drilling programme.

A further topic of research in the Andes aimed at the pressing need to develop more efficient prospecting methods, has been an investigation into the application of rock geochemistry to mineral exploration in the tin and polymetallic provinces of Bolivia and Peru. The object was the detection of geochemical haloes in rocks surrounding known mineral deposits and the use of these haloes to direct prospecting activities for new deposits on both regional and mine scales. Field investigations of 11 ore deposits were carried out.

In some areas a close association was detected between the variation of silver, lead and zinc and ratios such as potassium/sodium which reflect the hydrothermal alteration associated with the sulphide mineralisation. Anomalously high trace element levels were detected over 300m away from major veins, thus providing a wide target for rock geochemical exploration. Geochemical indicators were shown to be more reliable and cheaper than traditionally used



Domain map showing margin of Zimbabwe craton with Zambezi–Mozambique orogen.

mineralogical indicators for mineral exploration.

In an ODA-funded investigation of the geothermal system at Miravalles volcano, Costa Rica, the energy potential was assessed using optical X-ray diffractometry and scanning electron microscope techniques, coupled with information obtained from fluid chemistry on well logs.

Geotechnical Studies in Cyprus

The application of geology to various problems and procedures in urban, industrial, and civil engineering development projects is essential if their safety and stability is to be assured.

An example of research applied to immediate development needs has been an investigation of the properties of cohesive soils derived from the weathering of ophiolites in Cyprus. The work has concentrated on the engineering behaviour of the clays of the Mamonia Melange and Kannaviou Formations in the seismically active and landslide-prone Paphos region. Recent earthquake shocks have resulted in most damage being caused by the activation of old and incipient landslides in these clays which have mobilised massive blocks of overlying chalk.

An integrated field sampling, laboratory testing and engineering geological mapping programme in two selected study areas has yielded a wealth of geotechnical data and the first systematic survey of slope stability problems associated with these soils. The geotechnical classification and methodology of landslip assessment established in this study will be applicable to other similar terrains and will guide planners and engineers concerned with both foundations on clays and regional urban and agricultural development in areas prone to landslip.

East African Rift and Precambrian Shield Areas of Zimbabwe

Mapping and mineral reconnaissance surveys in Kenya and Zimbabwe have provided opportunities to study the East Africa Rift System. Between Lake Turkana and Marsabit in Kenya, most of the Mozambique metamorphic basement is buried beneath a pile of sediments and volcanics locally exceeding 2kms in thickness. By comparing sediments of the Chalbi Desert area, with petroliferous sequences in southern Sudan, oil exploration targets are being identified.

Regionally, the area spans the gap between the Gregory Rift and the Ethiopian Rift to the north. On the Ethiopian border, where the north end of the Kinu-Sogo Rift abuts onto the Lake Stephanie graven, the Miocene complex features a newly-discovered iron formation and promising indications of gold.

In the semi-arid area of northern Kenya, Landsat Thematic data were found to provide a more reliable view of surface material than Landsat

Disruption of village access road due to rotational landslip in chalk talus and underlying Mamonia Melange clay, Paphos region, Cyprus

Multispectral Scanner (MSS) data and could be used for detailed geological mapping in suitable areas. Such areas need to have low relief with little outcrop, where differentiation depends mainly on the nature of the soil and the type and percentage of vegetation cover.

In a joint UN-Kenya-Italy-UK study of the geothermal potential of the southern part of the Kenya Rift, Landsat Multispectral Scanner data have been used to interpret the nature of fracturing in the Rift and the differentiation of the products of the various volcanic centres.

In Zimbabwe, geological mapping/mineral exploration has been carried out over two regions. The Archaean 'greenstone' belts show folding, and major shearing and hydrothermal and structural controls of gold mineralisation have been identified.

Structures preserved in siliceous iron-formation more than 2700 million years old, were probably formed by some of the earliest silica-secreting microbiota ever recorded. The Zambezi-Mozambique orogenic belt intersects the craton in NE Zimbabwe, one of the most geologically complex regions of the continent. One of the world's largest kyanite deposits is also found in this area.

The northern edge of the craton was buried to great depths below a crustal slab that formed part of the Zambezi orogen. Sequences within the zone crystallised at very high pressures and temperatures more than 830 million years ago. An immense body, possibly formed by high-pressure crustal melting, was intruded between the craton and the overlying shelf sequence soon after overthrusting. viscous monzonitic melts spread laterally along the interface, causing extensive deformation and emplacement of 'mantled gneiss domes'. Similar deep burial of continental crust below the Himalayan region is currently the focus of considerable geological research.

Petrological support for the Zimbabwe projects has aimed at characterising igneous rock suites and evaluating regional metamorphic conditions in the greenstone belt of Harare. As part of a hydrogeological study of regolith and basement aquifers in Africa, Landsat Multispectral Scanner data have yielded much information on the fracturing of the southern part of the Zimbabwe craton.

Tectonic Synthesis of Vanuatu

Modern concepts of plate tectonics and mountain building stress the importance between adjacent, but geologically distinctive, terrains.

In the Pacific, BGS scientists participated in a second international cruise sponsored by the Committee for Coordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas. Involvement was mainly in the region round Vanuatu which forms the major part of the New Hebrides Islands arc. The investigations were aimed at evaluating the offshore hydrocarbon potential of intra-arc basins, sampling close to submarine volcanoes and preparing geological hazard maps.

The results have indicated the presence of several promising sedimentary basins and, with the expertise available in BGS on the onshore geology of Vanuatu, it has been possible to use seismic data to extend the geological mapping offshore and produce a tectonic synthesis for the region. Three major events of arc volcanism, sedimentary deposition and carbonate formation, separated by major unconformities, have been identified.

Both compressional and extensional stress regimes were superimposed during these events, wrench tectonics playing a dominant role in the geological development and configuration of the island and intra-arc basins from middle Pliocene to Holocene times.

Water Supplies in Africa and South Asia

Much effort is now being spent on alleviating problems connected with water supply in the Third World. One aspect of research is focusing on improving groundwater yield in the vast areas of Africa and South Asia which are floored by crystalline basement rocks. Although the associated aquifers are not highly productive, they have a major potential in the shorter term for rural water supply. Alternative sources for higher order supply such as piped distribution or small-scale irrigation, are likely to be economically impracticable for the foreseeable future for much of the developing world.

Aquifers are of two main types, one occurring in the weathered sandy-clay and residual rock, the other in fractured bedrock. The overburden is generally less than 25m thick and dug wells are mainly completed in the associated aquifer. Well storage has an important control on yields since permeabilities tend to be low. Boreholes are typically drilled to deeper levels and may draw on aquifers of both types. The degree of interaction between the two aquifer types has an important bearing on longer term yields in boreholes.

Studies are being made on aquifers in crystalline basement rocks with emphasis on the wide range of controlling factors which include structure, bedrock type and texture, current and previous climates, geomorphology and land use. Exploration techniques are being researched with a view to identifying the most appropriate and cost-effective methods of borehole and well siting. Overall resources are being evaluated in selected study areas in Malawi, Zimbabwe and Sri Lanka using geochemical balances of rainfall, run-off and recharge and by observations of evaporative losses by groundwater discharge.

The research is also directed at improved well design. Motorised and manual horizontal drilling rigs have been developed. Using these rigs in the base of large diameter dug wells allows the drilling out of collectors to a radius of 30m. Such collector wells have been constructed in Zimbabwe and Sri Lanka and pump testing shows that the collectors can double or treble the dug well yield. The first full-scale development project is now beginning in Sri Lanka in which it is planned to enhance the yields of 50 existing dug wells by this technique.

As part of a hydrogeological study in Fiji, geophysical fieldwork was undertaken and, following the recent severe drought in Ethiopia, training was given and geophysical surveys conducted as part of a well drilling programme.

Radical drilling from the base of 3m diameter dug well, Sri Lanka.

Other Research Programmes

In addition to the contributions they make in the multidisciplinary research programmes already described, the staff of specialist research groups in BGS initiate research projects primarily devoted to advancing knowledge and techniques in their own disciplines. These groups are represented by the Geochemistry Directorate (subdivided into Analytical Chemistry, Mineral Resources and Applied Geochemistry, Applied Resources and Applied Geochemistry and Fluid Processes), the Geophysics Directorate (ie Regional Geophysics, Geomagnetism, Global Seismology, Deep Geology, Remote Sensing and Airborne Geophysics and Geothermal Energy) and a third grouping comprising Engineering Geology and Reservoir Rock Properties, Hydrogeololgy, Biostratigraphy and Stratigraphy and Sedimentology.

Systematic Geochemistry and Mapping in Scotland and North England

Geochemistry is the science of the distribution of the chemical elements present in the Earth, and of the physical, chemical, biological and other processes which cause those distributions. Such research has implications for metallic and non-metallic mineral and energy resource studies, hazard assessment, major engineering works, land-use planning, environmental geochemistry, and toxic and radioactive waste management.

Systematic sampling for the Regional Geochemistry Reconnaissance Programme (RGRP), funded by the DTI, has now covered the whole of Scotland and most of northern England. Results from the Borders region are expected to assist in clarifying the nature and evolution of the Iapetus suture as well as identifying areas warranting further investigation. Material from the sample library relating to the Argyll-Tiree sheet were analysed by specially developed methods to assist in the study of gold metallogeny.

A model for the evolution of the Grampian Highlands is being developed in collaboration with Edinburgh University with the aid of interactive image analysis. Data from the RGRP coverage of the Lake District sheet were made available in November through the new GISA (Geochemical Interractive Systems Analysis) facility at Farnborough by courtesy of the National Remote Sensing Centre. Customers will be able to purchase maps and colour prints of displays showing patterns resulting from interaction of chosen parameters.

Platinum and Palladium

In response to present interest in exploration for platinum group metals (PGM), a rapid analytical method to indicate levels of platinum and palladium in exploration samples has been developed. After acid decomposition of the samples and separation of the analytes, platinum and palladium are determined by graphite furnace atomic absorption spectroscopy. Research is continuing, in collaboration with the University of Surrey and with CEC support, on applications of inductively coupled plasma source mass spectrometry (ICP-MS) in analytical geochemistry.

Methods established to date include the determination of lanthanides (anyone of 14 elements, including lanthanium, yttrium and scandium, often grouped together as 'rare earths') in a wide variety of geological materials without separation from matrix elements; determination of minor and trace elements in limestones and manganese nodules; and determination of platinum metals (except osmium) and gold, after separation and concentration by fire assay.

Work on the Unst ophiolite, funded by the DTI, suggests that here concentrations of platinum and palladium are the result of hydrothermal processes as they are associated with low temperature nickel sulphides and arsenides that probably formed during serpentinisation of the ultrabasic host-rocks.

Geological Indications of Buried Minerals and Hidden Granites

As near surface mineral deposits become progressively mined-out, it is necessary to develop new procedures for the detection of buried deposits which are not readily detectable at the surface.

The projects being undertaken for the Second Raw Materials R & D Programme, partly funded by the CEC, were due to end in March 1986. Work aimed at the development of new exploration criteria for buried mineral deposits was successful in improving understanding of mineralisation mechanisms. Another project, aimed at identifying hidden mineralised granites, showed the value of lithogeochemical prospecting methods.

Advanced research into the application of fluid inclusion studies have identified a major difference in the gas composition of ore fluids transporting tin and tungsten. The distinction has been verified for important mining districts in western Europe and is a potential further exploration criterion. Investigations are being extended to other metals.

Mica Crystallinity

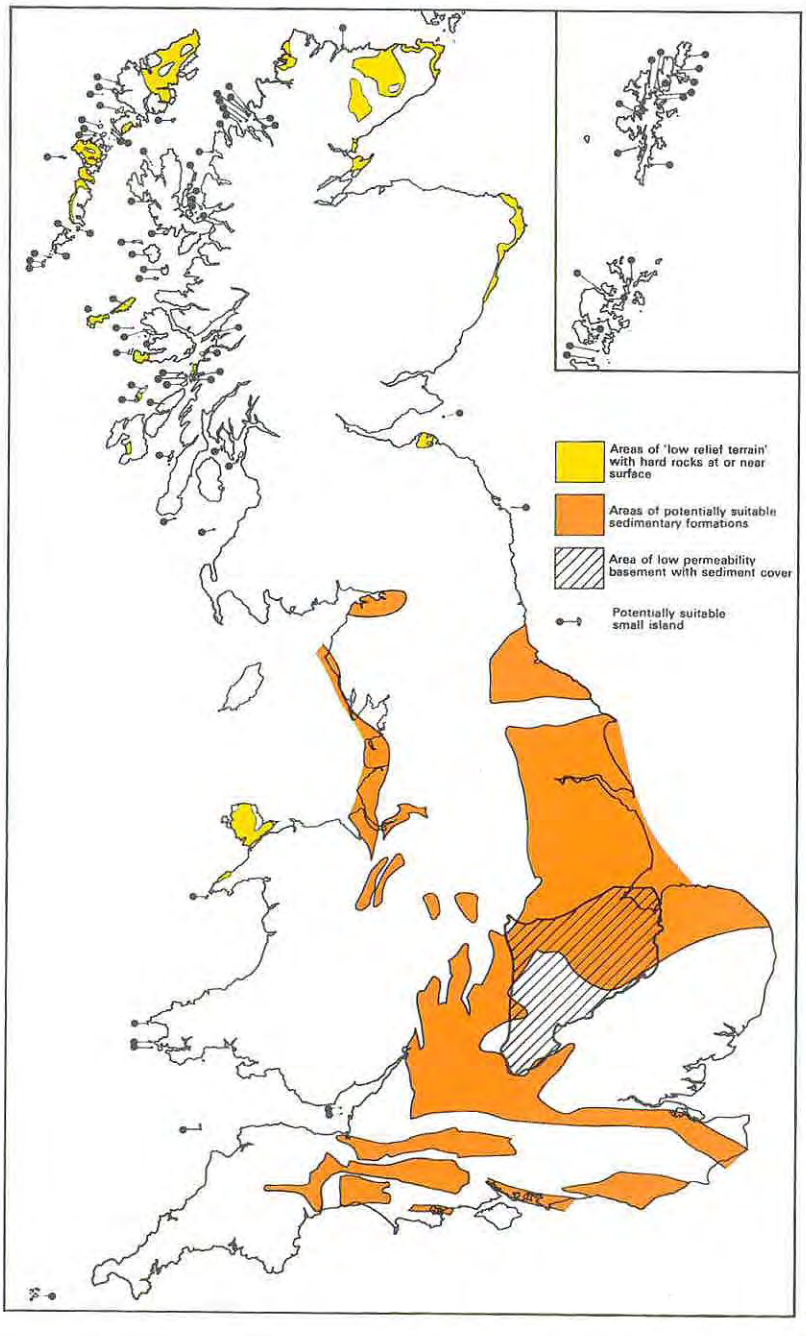
A study of mica crystallinity is important in understanding the thermal history of rocks and in assessing mineral geothermal resources in specific geological environments.

As part of the Snowdonia Regional Geological Survey, the processes controlling the transformation of mudstones and shales to slates were examined using the mica crystallinity technique. The Crystallinity Index, a measurement of fundamental crystallite size, decreases as white mica develops from clay minerals in response to deep burial and any subsequent deformation.

Maps of equal crystallinity contours (isocrysts) show that in North Wales the highest grades are commonly found in areas of high tectonic strain, typically in slate belts. Isocryst patterns suggest that a pre-Arenig burial metamorphism preceded the deformational metamorphism associated with Caledonian folding of the Welsh Basin. A similar study, forming part of the RGS of the Lake District, revealed considerable diversity in metamorphism which is generally of low grade, but locally much higher where it is related to a hidden granite.

Studies Related to the Safe Disposal of Radioactive Wastes

The BGS has been assisting the Nuclear Industries Radioactive Waste Executive (UK NIREX Ltd) in selecting sites for investigation for near-surface disposal of low-level radioactive wastes. Four sites in England are due to be assessed in 1986/87 in one of the most complex site investigations to be undertaken in the UK. BGS also gave advice to NIREX on those parts of Britain likely to be most suitable for deep burial of long-lived wastes (see map). This will lead to the selection of several sites for investigation in the late 1980s.



A compilation of areas containing all the geological environments considered suitable for the deep disposal of long-lived intermediate-level radioactive wastes.

Highlights of BGS' supporting research programme on the behaviour of radionuclides in deep groundwater systems included the completion of Phase Two of the Stripa Project (hydraulic testing in fractured rocks in a deep mine in Sweden), the start of an international investigation of uranium and thorium migration around natural ore deposits at Pocos de Caldas (Brazil) in Collaboration with Sweden, Switzerland and Brazil; the completion of a six-year project assessing the deep geochemistry and hydrogeology of mixed sediments in south Oxfordshire (Harwell) and the completion of work on geomicrobiology with respect to corrosion of buried structures. This work was funded by a number of organisations in the UK and abroad, principal among them being the Department of the Environment. The results will be used as the basis for new projects in 1986/87, including field experiments on the role of natural organic materials in modifying radionuclide mobility in aquifiers, and further studies of natural analogues for waste radionuclide behaviour in geological systems.

Regional Geophysics

The density, magnetisation and resistivity of rocks can be sensed by regional surveys – and these physical properties may be used to deduce the disposition of different rock types at depth.

Digital Data Programme

The programme to make all the UK regional gravity and aeromagnetic survey data more accessible for modern earth science investigations, by converting them to digital form, is nearing completion. These data are an important source of information on the deep geological structure of the UK and are already being used in integrated projects in the Lake District, Southern Uplands, East Midlands and the Welsh Caledonides.

Metallogenic Modelling

The East Midlands project is undertaking modelling in that area, based on a compilation of evidence on the deep geology funded by the EEC (CREST) and the DTI. Regional gravity and aeromagnetic data have been interpreted to provide information on the geology and structure of the basement rocks, with use being made of the NERC image analyser to process and enhance the data and combine them with other relevant information.

Deep Mineral Exploration

Two other contracts from CREST were successfully completed. The Transient Electro-Magnetic method was investigated to assess its potential for deep mineral exploration. Techniques developed and tested in controlled numerical environments included fast forward modelling, rapid in-field determination of dip, conductance and depth of burial and provision of criteria for survey design and interpretation. In a study of the use of down-hole and inter-borehole electrical surveys in the evaluation of known ore deposits, a prototype system was designed and tested establishing that the search radius of boreholes, as well as knowledge of the distribution of intersected mineralisation, can be improved.

Rock Mass Assessment

Work on the assessment of rock mass has progressed in the laboratory and *in situ*. New laboratory equipment has been constructed to measure compressional and shear wave velocities. In the field, the construction of a high frequency borehole sparker probe has been completed together with a clamped borehole three-component geophone array.

Geomagnetism and Magnetic Survey

The Earth has a magnetic field very like that of a bar magnet (a dipole). However, the field is constantly changing due to internal processes and those in the magnetosphere and ionosphere.

Progressively updated charts of the Earth's magnetic field and its variation, particularly important to those navigating by use of a magnetic compass, are produced from observatory data by BGS in collaboration with the US Navy Oceanographic Office (NAVOCEANO).

In recent years the models of the Earth's main geomagnetic field have become extremely accurate and comprehensive because of the large amount of data available from the MAGSAT magnetic survey satellite. The importance of satellites for global surveying is recognised in discussions currently taking place between the BGS and NAVOCEANO to formalise their collaboration on World Chart production. Collaboration in future satellite missions, likely to be the main source of global magnetic data in the next decade, is being considered.

The first full survey of the UK magnetic network for 30 years began in May 1985. Measurements have already been made at 14 carefully-selected sites in the UK. Eventually, about 40 sites will be occupied and the end result will be new UK regional charts for all the geomagnetic elements, but most importantly, the deviation of magnetic north from true north.

Global and regional surveying both rely upon the maintenance of a network of magnetic observatories. Those in the UK now operate and record continuously in digital mode and form the basis for all data analysis and publication. Progress towards full automation continues satisfactorily. All three UK observatories are now testing computer-controlled systems whose recorded data are retrieved over the public telephone network by an Edinburgh-based computer. Results so far indicate a very high degree of system performance and data reliability.

Magnetic Forecasting

The now rapid availability of observatory magnetic data greatly enhanced by the automatic systems, means that BGS can provide a daily magnetic forecasting service to commercial customers, the first being a survey company operating on the UK Continental Shelf.

Deep Crustal Iapetus Suture Zone

Integration of the results of electromagnetic induction studies in the north east of England and Southern Uplands of Scotland with BIRPS deep seismic reflection profiles offshore, provide a consistent geophysical image of the deep crustal structure of the Iapetus suture zone.

Remote Sensing in the UK

In areas of high relief (eg Snowdonia) and those sites polluted by old mine workings (eg Cornwall) or mantled by Quaternary deposits (Norfolk), remote

sensing techniques could make an effective contribution to geological mapping although difficulties were experienced in distinguishing between various lithologies and between some rocks and the vegetation cover

British Earthquakes

Aftershocks of the earthquake on the Lleyn Peninsula, 19 July 1984, are still continuing with over 300 having been detected and analysed so far.

The first earthquake known to have been felt on a North Sea offshore structure occurred in the Danish Sector on 10 June 1985. This event was felt on platforms and ships on the Gorm and Tyra fields. Although no damage was reported, the event increased the interest of engineers in seismic hazard

In cooperation with Norwegian oil companies and the University of Bergen, a seismic monitoring buoy was installed in the Statfjord field in September 1985. Data from this more seismically active region of the North Sea was required to assess environmental hazards faced by oil companies progressing farther northwards into deeper waters.

On land, a moderate earthquake, on 16 September 1985, aroused special interest when it was widely felt around the nuclear submarine bases on the Clyde. The seismometer record quickly allayed fears of an explosion by demonstrating the occurrence of an earthquake 5km deep near Dunoon

Three days later further press interest was stimulated by the destructive earthquake in Mexico. Seismograms from instruments throughout the UK supplied immediate data to enquirers and contributed to world data centres which provided the basis for investigations of the mechanism of the causative fault.

Seismic Anisotropy

All crustal rocks seem to have microscopic cracks aligned with the predominant stress field. The passage of shear waves is modified by such microcracks, making shearwave analysis an important indicator of microcrack (and therefore stress) orientation. Since cracks and stress are usually crucially important whenever the Earth's crust is drilled, mined or excavated, the ability to monitor the crack and stress geometry by analysing shearwaves has important potential applications. For example: stress-aligned microcracks have been identified by this method above small earthquakes in many parts of the world (eight places in three countries). Their variation might be used as an indicator of imminent earthquake hazard. Also, oil company data demonstrate the presence of microcracks in sedimentary basins, the existence of which affects their hydrocarbon productivity

Other applications include investigating the structure of hydrocarbon and geothermal reservoirs; predicting orientations of fractures; detecting changes of stress before rock bursts in mines, as well as having implications for all movements of the crust.

Hydrogeology

Groundwater Pollution

Groundwater is perhaps the world's most valuable resource. One of its great benefits has always been that it is cheap to develop and is of good quality, requiring minimal treatment. However, there is increasing evidence that this situation is changing. Groundwater resources throughout the world are being polluted by both urban and industrial developments and modern agricultural practices. As a consequence, a significant part of the programme of the BGS in this field is concerned with pollution problems. Studies of the impact of modern agricultural practices in Britain suggest that nitrate concentrations will continue to rise slowly in many areas for a number of years.

Pollutants and Aquifers

Because an increase in the occurrence of groundwater pollution by organic compounds is endangering aquifers, a system (the double packer system) for studying aquifers in Chalk and Triassic rocks has been devised which will examine permeability and head variations, the two most likely controlling factors in the movement of pollutants. A recent desk study for the Department of Transport on the movement of possible pollutants draining from a stretch of the M25 motorway has emphasised the importance of assessing these factors and of compiling information on regional aquifer behaviour.

Geothermal Energy

Whereas the UK is not generally considered to be an area with an obvious potential for geothermal energy, the heat from within its crust is capable of exploitation. Since the mid-1970s, the BGS has been commissioned to undertake an assessment of this energy source, funded by the Department of Energy and the Commission of the European Communities

In the UK, thermal energy may be retrieved from either hot groundwaters contained in permeable water-bearing rocks at suitable depths in sedimentary basins or indirectly from artificially fractured impermeable rocks at greater depths (4-7km) through the injection and subsequent extraction of water. BGS has completed an inventory of the total resource available within the UK and the geological factors affecting its exploitation.

In pursuance of this commission (and with the cooperation of the Imperial College of Science and Technology), further boreholes have been drilled into sedimentary basins in Scotland, northern England and Wales, a reassessment of heat flow in the Midland Valley of Scotland has been made and in the East Midlands, north east England and the Midland Valley of Scotland (where large conurbations exist), the potential for thermal energy at depths in excess of 4km has been investigated.

Sedimentology

Research has been carried out on the provenance, sedimentation, diagensis, stratigraphical correlation and economic significance of various sedimentary rocks in the UK.

Thin section studies have been carried out on sandstones from the Jurassic sequence of Yorkshire and from North Sea reservoir sandstones, with particular emphasis on post depositional changes in porosity characterstics. These porosity changes include: (i) porosity reduction resulting from compaction during burial and from cementation by the growth of authigenic minerals such as kaolinite, calcite, dolomite, quartz and feldspar, and (ii) porosity increase resulting from *in situ* dissolution of mineral grains, particularly feldspars.

Part of the storage hall of the core and sample store within the newly commissioned National Geosciences Data Centre at Keyworth.

Information Services

National Archive

The effective collection, collation, storage and retrieval of information is crucial both to the core activities of the Survey and to the handling of enquiries relating to all aspects of applied geology, including those dealing with mineral, fuel and water resources, environmental problems, civil engineering, natural hazards and land use planning.

An important step in the development of a National Geosciences Data Centre was the completion of a custom-built building at Keyworth to hold the national archive of borehole core and rock samples and the collections of geological records accumulated both from BGS activities and external sources. This has enabled the transfer of material to be made from core stores in London, Leeds and West Bridgford to a centrally-held archive representing some 5km of core and 3 million rock, mineral, fossil and drilling samples.

Facilities are now available for direct access to these collections for study and sampling, both for staff and members of the public. Work has continued on the integration of paper records from the former London and Leeds Offices, but a considerable backlog of registration, conservation and microfilming remains to be undertaken.

In Edinburgh, cores and cuttings derived from the DEn supported work on hydrocarbon resources of the UK Continental Shelf are held at Gilmerton Road Core Store – where they are available for public examination after release from confidentiality.

Digital Techniques Aid Information Dissemination

Early steps towards the longer term objective of a user-friendly information system of geological data have been taken following significant progress on an index-level database of information held by the BGS. The first products are a Data Collections Index, to aid access by topic, and an index of all available published and unpublished BGS maps, which is seen as an essential part of access to information by location, being linked to a digital gazetteer.

Digital techniques have also played an important role in the increased flow of memoirs and published maps; in the latter case rasterisation (a rapid method of scanning data sets) has proved particularly speedy and economical.

University Collaboration

Universities and polytechnics have continued to feature significantly in BGS activities. In addition to their collaboration in surveying and other research projects (whether supported by the Survey or some other funding body), BGS staff have been increasingly called upon to assist in lecturing and in the formal teaching of advanced courses. The Survey has also continued to be involved with post-graduate CASE studentships.

Central Enquiry and Mail Order

The public interface was improved by the establishment of a central enquiry desk at Keyworth (with a 24-hour answering service) to deal with *ad hoc* scientific enquiries, provide information about BGS activities and products, and to arrange public access to the collections.

The previously printed Map Catalogue was completely revamped and enlarged for easy reference. Steps were also taken to issue bi-monthly lists of new releases of documents of all kinds for mailing to interested parties.

In addition to this service, a mail order desk at Keyworth has been provided with extra staff and accommodation to cope with an increasing number of requests for copies of unpublished maps and open file reports. Other services have been introduced, such as the preparation of colour xerographic copies of out-of-print maps. Similar facilities also exist at Murchison House, Edinburgh.

London Information Desk

Within the Geological Museum, now a department of the British Museum (Natural History), a desk has been set up to deal with enquiries for geological information and with orders for BGS documents. The information desk will become a full Information Office when the library collections are finally transferred to Keyworth from London.

Library Facilities

Closely associated with the National Geosciences Data Centre are the office libraries, a bibliographic service for staff and a national reference collection for the general public. Whereas thousands of books, journals, maps (including all published geological maps of the UK and many foreign maps) and a reference collection of Survey photographs already exist in libraries outside London, a principal activity throughout 1985 has been the transfer of stock from London to the Survey's headquarters at Keyworth. Much new library stock was also processed throughout the year, thereby adding to what is regarded as one of the world's major collections on the Earth sciences.

The Survey libraries are used extensively by students from schools and universities, consultants and engineers, mining and exploration companies, and private individuals, over 2000, for example, visiting the library at Murchison, Edinburgh during 1985/86.

Marine Geology and Geophysics

The highlight of The Institute of Oceanographic Sciences (IOS) work in geology and geophysics this year was participation in the international ESOPE cruise mounted on the NO *Marion Dufresne* to obtain deep core samples from the floor of the Atlantic Ocean in the Madeira and Nares Abyssal Plains. Very high quality cores over 30m deep were obtained for almost the first time; they will be used for detailed stratigraphic, sedimentological, geochemical and geotechnical studies.

Another highspot was the discovery of a field of manganese nodules in the Madeira Abyssal Plain area. This was first seen using the IOS high capacity survey camera system WASP and then sampled by IOS biologists using a bottom-trawl. The field has also been correlated with a GLORIA (side scan sonar) image of the area, suggesting that it may be possible to use GLORIA more generally for surveys of nodule fields.

The Pop-Up Pore Pressure Instrument (PUPPI) was also used in several areas. The instrument is sensitive enough to detect tidal pressure 4m below the sediment surface.

GLORIA Surveys Around USA

Following the successful survey of the Exclusive Economic Zone (EEZ) of the West Coast of the USA in 1984, an agreement was signed to complete the coverage of the EEZ. IOS and the United States Geological Survey will take a further six years to carry out GLORIA surveys in the area out to 200 miles from the coast of the USA. In 1985 the chartered ship RV *Farnella* completed 105 days of GLORIA and profiling work in the Gulf of Mexico, around Puerto Rico and in the Cayman Trough.

The Texas-Louisiana slope is dominated by salt movements which are still active and form many hills and basins and also the 1000m high Sigsbee Escarpment. The most recent sedimentary history of the Mississippi fan was shown to include periods of sediment movement that had been previously unrecognised. It has also been shown to include enormous and far-reaching submarine slides. Submarine slope failures were also found near the West Florida Escarpment and around Puerto Rico. The Cayman Trough is an area of change in which a pattern of oceanic spreading was mapped.

The GLORIA sonographs will be processed to enhance the geological features. The processed sonographs of the 1984 West Coast Survey have recently been published in an atlas.

Sediment Geochemistry

Work continued on the Department of the Environment contract investigating possible disposal of high-level radioactive waste on or below the sea bed. This study has mainly concerned the geochemical processes affecting the sediments of the Great Meteor East (GME) study area west of the Canary Isles, in the northeast Atlantic. Here sediment accumulation is dominated by intermittent drifts rather than simply by the slow accumulation of organic debris.

Considerable geochemical modification occurs in these drifts due to the absorption of oxygen from the water above. The organic matter in the sediment also oxidises and a redistribution of redox-sensitive metals occurs.

These effects have been studied in both the most recent sediment drifts and buried ones. Elements such as copper, vanadium, zinc and uranium appear to be similar to the maximum oxidation in fossil cases, while elements such as manganese, cobalt and nickel are mainly remobilised in the fossil cases.

Of all the elements studied so far, uranium has been found to exhibit the most marked and reproducible concentration signals in response to progressive oxidation. Peaks in uranium content were found beneath the active and fossil levels in all GME drifts with an organic carbon content 0.5%. The uranium peaks have been found to be stable, once formed and buried, for at least 750,000 years.

Theories have been constructed for the processes of relocation of redox-sensitive metals using pore water and solid phase data obtained on RRS *Discovery* Cruises 129 and 149. One theory predicts the formation of iron-rich layers under certain circumstances of changing sediment accumulation. Such layers have been observed in sediments from many parts of the world and previously no satisfactory explanation of their formation was available.

Antarctic Earth Sciences

Geology

A successful field season on the Antarctic Peninsula saw 11 BAS geologists working on a variety of problems over a geographical range extending from Livingston Island in latitude 63°S to Alexander Island in latitude 72°S. A programme of landings from RRS *Bransfield*, and helicopter support from HMS *Endurance* greatly increased the area they were able to cover.

An investigation was begun of widely reported, but unquantified mineralisation associated with the Mesozoic-early Cenozoic magmatic rocks of the Antarctic Peninsula. None of the localities seen during a reconnaissance of western Graham Land is of economic interest but, being geochemical anomalies, they will yield important information on the hydrothermal processes in the peninsula crust during its long history of subduction, accretion and magmatism.

The bulk of Alexander Island consists of two main rock units, the LeMay Group, part of an accretion-subduction complex, and a late Jurassic-early Cretaceous fore arc assemblage (Fossil Bluff Formation) which rests unconformably on the former. Structural investigations of both rock units suggest that transcurrent motion, was a major control on the development of sedimentary basins such as that of the Fossil Bluff Formation.

Biostratigraphical studies of the late Mesozoic fore- and back-arc basin sequences continue to produce important new data. In Alexander Island, a major faunal break has been identified. It seems to represent a change to more restricted marine faunas in the southern polar area perhaps related to palaeoclimatic factors.

Important results continue to accrue from BAS/US Antarctic Program collaboration in studying the geological relationship between Greater and Lesser Antarctica. Multidisciplinary studies have

Dielectric measurements on an ice core to identify volcanic horizons.

identified five major crustal blocks within Lesser Antarctica on the basis of sub-ice topography and differing geology.

Field Geophysics
BAS geophysicists have been systematically gathering gravity and magnetic data from the Antarctic Peninsula over a long period. The continuing joint BAS/US programme is investigating the sub-ice continental blocks and their positions relative to the tectonic evolution of Lesser Antarctica. Results collected from the Ronne Ice Shelf have identified major geological boundaries and provided new evidence on ice thicknesses and underlying bedrock morphology.

The geophysical reconnaissance of the Antarctic Peninsula has led to the publication of two aeromagnetic and bouguer anomaly maps at a scale of 1:1,500,000. These maps provide the basis for a quantitative assessment of the more significant magnetic provinces. Of particular interest is a west coast magnetic anomaly traceable for over 1200km. A similar possibly related linear anomaly has been identified over the continental blocks of the Scotia arc and Southern South America. It is possible that this magnetic feature is an expression of a subduction-related batholith.

Marine Geophysics
One of the more interesting opportunities in earth science within British Antarctic Territory concerns the study of subduction-related phenomena along the Pacific margin on the Antarctic Peninsula. The Cenozoic history of the area has been unusually simple and is very well recorded. Subduction along the margin ceased with a series of collisions between the trench and ridge-crest sections of a spreading centre, an important but little studied process.

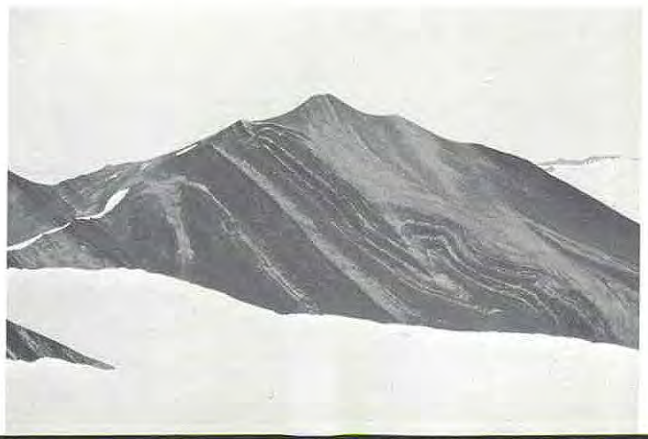
The BAS-funded marine geophysics group at University of Birmingham has been mapping the collision history and looking at some of the effects of collision on the continental margin, using data collected on the 1984/85 BAS cruise on RRS *Discovery*. In particular, data from the two-ship expanding-spread seismic experiment (ESSEX) conducted with HMS *Endurance* is revealing an interesting high velocity layer at the base of the crust near the shelf edge. The history of vertical movement of the margin before and after collision is emerging from further examination.

A much better definition of the relative motion of the South American and Antarctic plates derived from cruise data obtained east of the South Sandwich trench, will lead to a more precise and detailed model for Scotia Sea evolution. This is of interest because of its implications for the history of a deep water connection between the Pacific and Antarctic Oceans.

Glaciology
Polar ice sheets respond to climatic change but at the same time influence climate. Increasing levels of carbon dioxide, methane and flurocarbons in the atmosphere have led to speculation about ice sheet changes and their effect on sea level. The Antarctic ice sheet also has its own internal instability mechanisms which could react with the effects of man-made pollution. Records obtained from ice cores yield valuable data on past relationships between climate and the size of the ice sheet. BAS studies on cores drilled in the Antarctic Peninsula aim to connect records from the interior of Antarctica and those from low latitudes. A new electromechanical drill has been used to collect a 113m long core from Dolleman Island. Preliminary results indicate that the record extends back to about 1770 AD and includes the effects of several major volcanic eruptions including Krakatoa in 1883. Planned studies on the ice core will extend the climatic records available for the region to before the earliest instrumental readings.

Surface profiles established ten or more years ago by optical levelling across a number of glaciers in the Antarctic Peninsula were remeasured in 1986. Considered in relation to the annual net snow accumulation of around 500mm, there was no significant change in surface level. Glacier flow is evidently in close balance with present climate despite the general warming trend in the region over the last 30 years.

George VI Ice Shelf on the west coast of the Antarctic Peninsula is unusual: unlike other ice shelves which are underlain by sea water barely above freezing, the sea water under this ice shelf is up to three degrees above freezing. It provides an example of



Thrust zone in the Mesozoic Fossil Bluff formation of Alexander Island.

what might happen should warmer water, in a warmer climate, intrude beneath all ice shelves as freely as it does beneath George VI Ice Shelf today. Thermistor chains were installed in six boreholes to study heat flow from the underlying sea water and the temperature structure of the ice shelf. These showed that as ice flows towards the ice front it becomes warmer and ultimately its summer temperature exceeds the freezing point of fully saline sea water. A hole drilled through the ice shelf close to the ice front was unfrozen one year later, and ice cores drilled from depths below sea level were saline. At the upper surface it appears that heat liberated by the freezing of melt water maintains the ice at temperatures close to 0°C.

Ocean Drilling Programme

With effect from 1 October 1985 the UK joined the Ocean Drilling Programme (ODP), a US-organised international programme of deep ocean drilling and research. Other participants include Canada, France, the European Science Foundation, the Federal Republic of Germany and Japan and, the USSR is expected to join with effect from 1 January 1987.

The annual subscription is $2.5 million and NERC – through which the UK membership is co-ordinated – regard this work as high priority and contribute about £1 million p.a. towards this subscription, as well as providing support to British scientists participating in the research. The Department of Energy and major oil companies such as BP; Britoil, Burmah, Enterprise, Shell UK and Tricentrol also contribute to the subscription.

The ODP is an international partnership of scientists and governments who have joined together for the next 10 years to explore the structure and history of the earth revealed beneath the ocean's basins. Crucial to each cruise is the retrieval of core samples from the ocean floor and UK expertise in this field will be of great value.

Continued participation in such programmes as ODP is seen by NERC as an important aspect of its support for environmental sciences, particularly marine geology. It will give first-hand experience of deep water drilling technology, and maintain a qualified manpower group for UK industry. It will also allow UK scientists a chance to influence the direction of the programme and have immediate access to important scientific results.

Geodesy

Geodesy is the science of the shape and size of the Earth, the variation of its rotational motions and its gravity field. A 1984 Royal Society Working Party report noted that over the past two decades there had been a revolution in the techniques of geodetic measurements. Data could now be gathered relating to large areas of the Earth in a relatively short period of time and the data were, the report said of sufficient accuracy so that not only could gross features in the Earth's topology be revealed, but the data also permitted an improvement in the knowledge of the underlying deep structure and the physical processes that determine those features. The Working Party felt that these recent developments were not being adequately recognised and exploited by the UK scientific community.

In response to this report, the Science and Engineering Research Council and the NERC set up a joint initiative to encourage the development of the geophysical aspects of geodesy, linking solid Earth geology and oceanography. Sixteen proposals requesting funds of about £600,000 were received in response to the announcement of the initiative. A specially convened panel, chaired by Professor D P McKenzie of Cambridge University, was appointed to assess the proposals. As a result, seven research grants and four research studentships to UK universities and polytechnics have been awarded to stimulate research in this field. The grants awarded emphasise the use of new techniques, including the use of radar backscatter from satellites to produce accurate altimeter maps over land, in some areas to within 0.5m. The use of a satellite means that the data could be collected over the entire globe with a density and uniformity of measurements unachievable through traditional ground-based techniques. An objective of such work will be to lay the foundation for more advanced land altimetry missions in the future. Such research will provide a foundation which will enable the UK to take full advantage of satellites such as EAS's ESR-1 (to be launched in late 1989) and NASA's Topex (to be launched in the 1990's).

Deep Geology of the UK

The British Institutions Reflection Profiling Syndicate (BIRPS) is a collaborative venture of university, research institute (BGS) and oil company personnel; it was established by Council in 1981 to research into the deep structure of the UK and its environs through deep seismic profiling. The lead in the work is taken by a core group based at Cambridge University under the Directorship of Dr D H Matthews, FRS.

During 1985 the major activity undertaken by BIRPS was an experiment across the Western Approaches Margin (WAM). This was designed to investigate the Moho, the banding in the lower crust, basement faulting in the brittle upper crust and deep crustal control of near surface features. An object was to follow the transition to an oceanic Moho; and test the thesis that lower crustal layering increases in strength and continuity towards the continental margin as a result of crustal extension.

In addition, BIRPS with oil companies bought into a GECO-led speculative survey in the North Sea totalling some 1600m of seismic lines. Technical control of the processing of the seismic data is being determined by a group comprising GECO, BIRPS and Britoil. Unlike the BIRPS survey data which are publicly available within one year of acquisition, the group shoot data will remain proprietary until 1 January 1988 when NERC will be free to distribute them.

Of the scientific objectives set for BIRPS, progress has been achieved in the first of these, structural geology. With respect to the second objective, that of continental rheology, BIRPS has developed ideas on how the continents react to deformation and has identified the reflection time to the Moho almost everywhere where profiles have been shot. However, there has been little progress so far towards the third objective, that of imaging steeply dipping faults. The nature of the layering in the lower crust which may be the result of ultramafic layers, basic sills, flowage or fluids remains to be

explored. Computer modelling is the only way forward here and this is a high priority for future work within BIRPS.

Joint BGS/University Geological Mapping Programme

NERC wishes to initiate, encourage and effect increased geological mapping coverage of the UK by involving the universities, preferably in collaboration with the British Geological Survey; 18% of the UK land area has no 1:10 000 (or 6-inch) base map and approximately 90 1:50 000 (or 1-inch) sheets in England, Scotland and Wales were last geologically surveyed before 1870.

University and polytechnic geology departments were invited to propose the mapping of whole 1:50 000 geological sheets based on BGS priorities, and in those areas for which the department already has expertise and holds a good data base through, for example, existing postgraduate research theses which, with a minimum of additional work, might be built up into a 1:50 000 map of publishable accuracy and quality, and supported by base maps at 1:10 000-scale.

Invitations to tender were circulated widely and 18 submissions received, including three from polytechnics. As a result of extensive evaluation, including discussion with potential contractors, six contracts have been let and a seventh is under discussion.

Professor D Flinn (University of Liverpool) will concentrate on the mapping of Yell (Shetland). Dr W Ashcroft (University of Aberdeen) proposes to integrate outcrop data with magnetic survey methods (VLF) to trace the Dalradian stratigraphy and to investigate shear zones across part of the extensively drift-covered Sheet 65 (E) (Ben Macdui).

On Sheet 73 (E) (Foyers) existing BGS mapping with postgraduate research theses and new work to be undertaken by Dr P Haselock will allow a new 1:50 000 solid geology map to be rapidly compiled. Data will be collected to provide a structural, stratigraphic, metamorphic and igneous history of the area.

Under the leadership of Dr W R Fitches (University College of Wales, Aberystwyth) a team will concentrate on mapping the sedimentary succession of Sheet 149 (Barmouth).

Dr E B Selwood (University of Exeter) is leading a team to map Sheets 335 (Trevose Head) and 336 (Camelford). Separate studies of the north Cornish coast sections and mapping inland have led to the development of opposing theories concerning the direction of thrust transport and one of the results of the mapping work may be to resolve this conflict.

Dr W Gibbons and Dr C Harris (University College, Cardiff), in collaboration with BGS, will produce a geological map of Sheet 133 (Bardsey).

University Research in the Earth Sciences

As detailed in Appendix 4-7, NERC supports research by grants to academics in universities and polytechnics. Within the Earth Sciences some 126 grants were current at May 1986. A hint of the range of topics under investigation can be gleaned from the following few examples.

There has been a lively debate recently in geological circles triggered by the prospect that there is a 26 million year cyclicity to the course of evolution. One of the mainstays of this claim is the palaeontological database – yet proponents and opponents alike are agreed that this database is in dire need of refinement. One approach is to correlate rock sequences in different parts of the world by means of guide-fossils.

Professor J H Callomon of the Chemistry department of University College, London, has made a detailed study of the use of ammonites to establish a world-wide Jurassic biostratigraphy. He has worked particularly on Northern American material on which very little such work had previously been done. Callomon has found that the western part of the continent spanned four overlapping faunal provinces, and that most of the ammonites were indigenous. But sufficient are related to forms found in Europe for correlation between well-separated areas to be possible. In addition, many previous age assignments in the Jurassic were incorrect.

Looking about 200 million years earlier, in the Devonian rock record, Professor M House from the Department of Geology at Hull University is also addressing the problem of ammonoid evolution. If global mass extinctions have occurred, as many now think, one would expect to find similar faunal patterns in rocks of equivalent age from different continents, in this case Europe and North America. House's findings to date show marked dissimilarities and do not support the idea of periodic mass extinctions.

Coming nearer to home, Professor R G West (Godwin Laboratory, Cambridge University) has been looking at the sedimentary rocks deposited in East Anglia during and after the peak of the last Ice Age approximately 18,000 years ago. Specifically, he has been studying the pollen and plant remains to determine the vegetational history and hence the changes in climate that took place as the ice retreated. He has discovered that at the time of maximum glaciation, there was a rich flora within 40km of the edge of the ice sheet. As this ice sheet waxed and waned, the sea-level varied in response to the changes in the volume of water in the oceans and the changes in the weight of ice pressing down on the land. Such results as West has found are important because they can be used to compare changes in sea-level recorded in the sediments of East Anglia with those elsewhere in southern England.

Most people are aware that the Earth's magnetic pole wanders about the globe; less well-known is that the strength of the magnetic field also varies, usually at a rate equivalent to 10% per century. But because instruments to measure the magnetic field with any accuracy have only been available for 150 years or so, alternative schemes must be thought up to investigate further back in time. Professor R J Aitken, FRS, of the Research Laboratory for Archaeology and the History of Art at Oxford University has been looking at changes in the Earth's magnetic field over the past 5,000 years, using the fact that bricks, pottery and other clay artifacts preserve the magnetic field which existed at the time and place they were fired.

If samples of such materials are taken

from buildings of known age, or from established archaeological contexts, then the pattern of variation of the Earth's magnetic field through time can be revealed

Professor Aitken has studied a wide region spanning Egypt Cyprus, Italy, Sardinia, Greece and areas of China He has also carried out a substantial programme of sampling bricks from buildings in England which has provided a comprehensive dataset covering AD 1380 to the present day. Initial results show that the magnetic field in England has varied by less than 18% from present-day values over this period A similar programme with samples collected from Greek churches dating from AD 1100 to the present has revealed three very sharp peaks in the magnetic field, at AD 1150, AD 1300 (the highest) and at AD 1430. These features are especially remarkable because of the associated rates of change. For example, the peak at AD 1300 showed a rate of change amounting to 10% per decade - roughly ten times that detected in more recent times

As the Review Group for experimental mineralogy and petrology found (see later) there has been a change in direction in this field of research towards mineral physics and materials sciences NERC supports several research projects on mineral physics, for example that of Dr T J B Holland and Dr A Putnis at the department of Earth Sciences at Cambridge University.

Drs Putnis and Holland are looking at the thermodynamics and ordering of atoms in minerals characteristics of metamorphic rocks. It is these fundamental properties which determine mineral stability and the rates of chemical reaction between minerals.

In the same department, Dr M A Carpenter has been building a specially designed calorimeter to measure the thermal properties of reacting minerals. He has worked with both synthetic minerals made in the laboratory and with natural samples. This work is important because the crystal structure of a mineral is determined not only by the equilibrium ("steady state") conditions prevailing, but also by the rates of reaction etc (the kinetics of the system)

- **Review Group for Experimental Mineralogy and Petrology**

As part of its procedures for ensuring that the best science is supported, the Geological Sciences Research Grants Committee undertakes ad hoc reviews of major areas of expenditure. In 1985, support for experimental mineralogy and petrology was reviewed.

There have been two principal NERC supported research centres for experimental mineralogy and petrology – in the Departments of Geology at the Universities of Edinburgh and Manchester. The review group visited both these centres in October 1985 with the following terms of reference in mind

i) to review progress and scientific achievement during the period under review (1979-1985)

ii) to advise on scientific and technical developments expected in the next five years

iii) to study the range and balance of UK research on experimental mineralogy and petrology

The review group was very optimistic for the future of experimental mineralogy and petrology as an important subject within earth sciences It is desirable that the UK should remain involved in this area but because of the high research costs involved, it is imperative that UK research be first class. Internationally, experimental petrology is becoming revitalised and is moving away from those areas which flourished in the 1970s. In particular, major advances are anticipated in the fields of very high pressure (50-200kbar) experimental research and in the interface between mineral physics and experimental mineralogy. This latter would include the application of modern physical methods to the characterisation of geological materials and processes and the direct measurement of physical and thermodynamic properties, often at high temperature and pressure

The UK is poised to become very strong in this area for which the facilities available are excellent It is an important field in which NERC should be involved

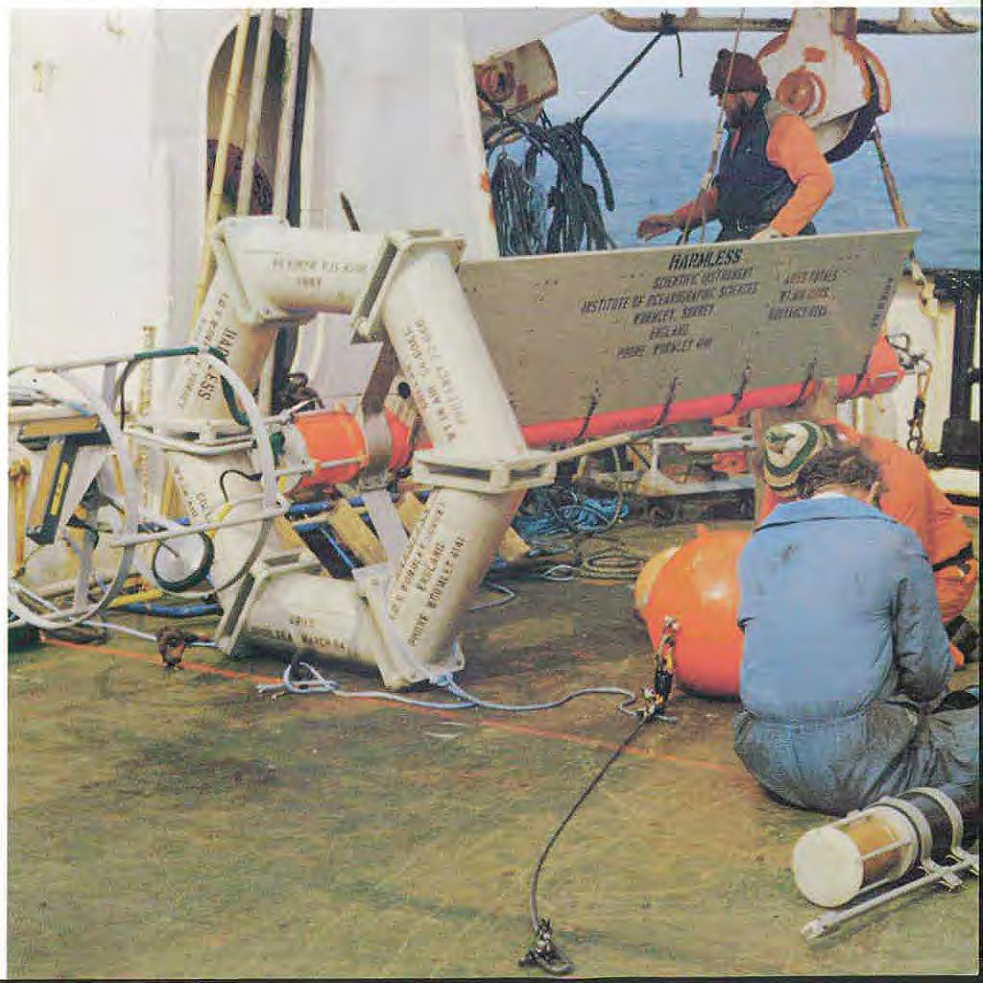
Marine Sciences

Research into the physics, chemistry and biology of the marine environment is co-ordinated within the Marine Sciences Directorate. Present studies are strongly multidisciplinary, involve a high degree of national and international collaboration, and span the whole range of the marine environment from estuaries, through coastal waters and shelf seas to the open ocean and abyssal depths. In-house research is undertaken at five NERC laboratories, the Institute of Oceanographic Sciences (IOS) at Wormley and Bidston, the Institute for Marine Environmental Research (IMER) at Plymouth, the Institute of Marine Biochemistry (IMB) at Aberdeen and the Sea Mammal Research Unit (SMRU) at Cambridge, and at two grant aided associations, the Marine Biological Association of the UK (MBA) at Plymouth and the Scottish Marine Biological Association (SMBA) at Oban. Marine research is also carried out by the British Antarctic Survey (BAS) through its headquarters in Cambridge. University and polytechnic research is supported in special units which include the Robert Hooke Institute at Oxford, the Rocky Shore Surveillance Programme at Newcastle and the Unit of Aquatic Biochemistry at Stirling. Support is also channelled through community projects and Special Topics which include Ocean Circulation Modelling and Estuarine Processes, and through the Aquatic and Atmospheric Physical Sciences (AAPS) and Aquatic Life Sciences (ALS) Grants Committees.

Effects of Ocean Turbulence

Until recently very little has been known about how momentum is transferred from the wind to the sea surface and down into the ocean. The same is also true of how heat from the sun is transferred. So far most work has been empirical.

It is known that turbulent motions play a dominant role in the transfer of heat and momentum into the ocean. One device developed by IOS for measuring the effects of turbulence in the upper ocean is ARIES, an Automatically Recording Inverted Echo Sounder. This senses the sound reflected from the clouds of bubbles



ARIES, Automatically Recording Inverted Echo Sounder, senses the sound reflected from the sub-surface clouds of bubbles produced by breaking wind waves.

An array of thermistors suspended below a small catamaran which is towed to the side of the ship and ahead of its wake records temperatures in the turbulence.

produced beneath the surface by the breaking of wind waves. How deeply these bubbles are distributed is dictated by the turbulence in the water so, by measuring their distribution, the effect of the turbulence can be inferred.

ARIES is moored underwater and can be left unattended for periods of up to three months. The records show that, typically, bubble clouds extend down about 20m beneath the sea surface in moderate to strong winds and that waves as well as wind are important in determining the turbulent diffusion.

Another IOS designed device detects the patterns produced by turbulence by measuring water temperature. A vertical spar bearing a number of sensitive thermistors is towed beside a ship.

The objective is to describe the structure of the turbulent eddies produced under different wave and wind conditions and to permit the construction of more realistic theoretical models.

Microwave Remote Sensing

During the year the requirements of the ERS-1 Satellite Data Centre were studied in order that oceanographic information may be extracted using the satellite's microwave sensors. Several types of information were defined by an IOS team, including data relating to wind surface, waves and ocean topography derived from the radar altimeter and to wave fields from the synthetic aperture radar imager.

Drawing on experience with the Seasat satellite, information from ERS-1 was divided into 'core' data, which it is believed can be extracted using previously tried techniques, and 'development' data which can possibly be extracted given a clearer understanding of the way radar signals interact with the sea surface.

The method for deriving core data, including significant wave height and wind speed, has been worked out in detail. Procedures still requiring development in order to extract other data including the skewness of the sea surface, wave period, percentage wave breaking and minimum swell have also been identified.

Research on the 'development' data, which could not be extracted from the Seasat record, is continuing. Similar procedures for the extraction of more sophisticated wind data were also developed.

Upper Ocean Fronts

Upper ocean fronts occur where two water masses meet, often creating a current which can be enhanced by winds and larger scale eddies.

In February 1986, scientists from IOS with Research Vessel Services (RVS) computer support, took part in the Frontal Air-Sea INteraction EXperiment (FASINEX) aboard the *RV Oceanus*. FASINEX, funded by the U.S. Office of Naval Research, was designed to observe the detailed structure of an upper ocean front, and how it was affected by storms. The IOS SeaSoar was towed behind *Oceanus* for a total of 11 days, building up a detailed picture of the frontal structure to a depth of 300m over an area 200km square.

Fronts can drive currents of one knot or more and they strongly influence the way sound travels through the water. They are hard to observe in detail, because changes take place within very short distances and periods, which may be a matter of days. The SeaSoar can, however, resolve these problems. As it is towed at eight knots it can measure the profile from near the surface down to 300m and up again in less than 2km.

A view aft on the starboard side of *RV Oceanus* shows the yellow SeaSoar on deck beneath the A-frame. In front is the winch carrying 600m of faired cable which enables SeaSoar to dive to over 300m

An important part of the IOS contribution to FASINEX was the ability to reduce and calibrate the data (about 8 million data cycles in all) within a few hours of collection. This allows sections to be contoured while a survey is underway. The ship tracks can be modified as a result of studying the contoured sections to make the best of expensive ship time: this technique was used to good effect for FASINEX.

Ocean Topography and Tides

The IOS programme on the tides of the ocean came to an end in 1985, having developed pressure recording technology for some 15 years from the UK continental shelf to deep abyssal plains, and with recording durations from a few days to over a year. Of about 205 oceanic tidal records taken around the world, over 90 were made by IOS. These have provided a unique data set for the calibration of computer models as well as measuring several interesting local tidal characteristics not previously suspected.

IOS expertise in this field has been diverted into two related activities. First, the pressure recording technology is being applied to monitor long-term changes in wave activity. Records show this activity to be coherent over thousands of kilometres of the ocean basins. Used with Inverse Echo Sounders which monitor the main features of internal wave motion, this information should provide useful 'sea-truth' data for exercises in satellite altitude measurements. This is an important component of the coming World Ocean Circulation Experiment (WOCE).

Removal of tidal signals is another important aspect of processing satellite altitude measurements. This

will provide useful input to the development of systems for WOCE. IOS scientists have explored various approaches to the analysis and elimination of tidal signals from the Seasat altitude measurements and the results, recently published, are very encouraging. They promise useful application to the European ERS-1 satellite and the USA/France TOPEX-POSEIDON satellite mission, both due to be launched in the early 1990's.

Hydrothermal Activity Along the Mid-Atlantic Ridge

The existence of hydrothermal activity including venting and hot springs along the Mid-Atlantic Ridge (MAR) has been established by a multidisciplinary team from Cambridge University. The study, carried out in collaboration with the National Oceanic and Atmospheric Administration (USA) and the Florida Institute of Technology, has revealed that high temperature hydrothermal activity is not limited to intermediate to fast spreading ridges like the MAR. This important discovery, made using a combination of techniques including analysis of images from a deep-sea photovideo camera, suggest a role for slow-spreading ridges in the processes which affect ocean chemistry, seafloor minerals, heat transfer and biological adaptation.

Trace Metal Distribution in Open Oceanic Waters

A team from Southampton University has established that different biochemical conditions in the Mediterranean lead to distinct chemical 'signatures' in Mediterranean outflow water. During their examination of waters over the Mid-Atlantic Ridge, the group detected high concentrations of dissolved manganese, believed to be further evidence of the hydrothermal activity identified by a Cambridge University team.

Heavy Metal Monitor for Seawater

Research at Liverpool University has led to the development of a metal monitor capable of measuring very low concentrations of nickel in seawater. The monitor is designed to be used at sea without the need to collect samples for laboratory analysis.

Shelf Circulation Studies

Further work at IOS has been carried out on theoretical models of currents north of Scotland. The source material used was weather and wave data for the winter storms of 1983 and 1984. Comparisons between the model and actual currents appear to be best on the continental shelf. Previous comparisons suggest improved results from finer detail over the steep continental slope.

The effects of waves on wind stress and its distribution have also been explored. However, surges in sea level in the theoretical model do not appear to be significantly more accurate as a result.

The modelling of fronts between the continental shelf and the sea and their development of meanders and eddies, has been improved. This was achieved by reducing small-scale irregularities to a minimum. There has also been some success in allowing certain items to leave the model area without creating false results.

Tracer Techniques

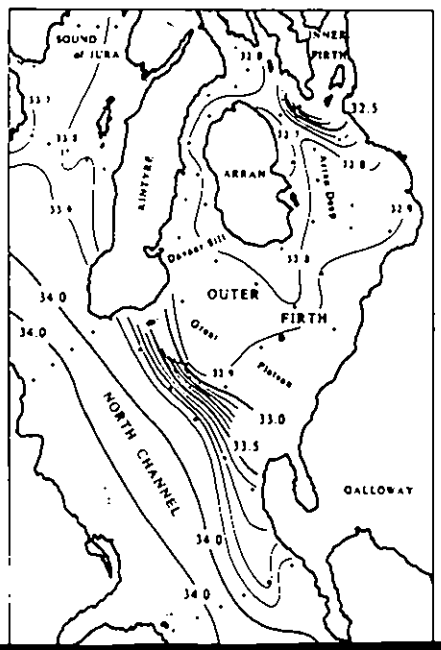
Studies are continuing at the Marine Biological Association of the UK (MBA) on perfluorocarbons as sensitive, long-term tracers for investigating the relationship between physical marine processes and the dispersion of dissolved components. Following initial trials in the English Channel a further release funded by the US National Science Foundation in collaboration with the Lamont Doherty Geological Observatory, USA, was made in the Santa Monica Basin off Southern California in September 1985. The vertical and horizontal dispersion of the tracers was followed during two cruises at two weeks and eight weeks after the release, with the data revealing suprisingly rapid vertical mixing in the interior of the basin. This is the first time that vertical mixing has been measured in the deep sea over periods longer than a few days, and the results obtained open the way to a wide range of interesting applications in the future.

Scottish Shelf and Fjord Hydrography

The Scottish Marine Biological Association (SMBA) has undertaken the recording of temperature and salinity across a section of the continental shelf west of Scotland. The use of radiocaesium as a tracer for Irish Sea water has been a continuing part of the work, carried out in conjunction with the Chemistry Department, University of Glasgow. Seasonal readings taken on the shelf since 1983 are clarifying several aspects of the study. For instance, it is now known that the front west of Islay persists as a salinity front in winter, even though temperature differences have disappeared at this season.

Recordings have also continued from a current meter moored at the Tiree Passage. These show that though the annual cycle of wind strength plays a dominant role in the strength of the coastal current, inter-year variations must have other causes. These may be variations in the wind field over other parts of the coastal current system or variations in the input of fresh water in regions lying to the south.

In the North Channel the water sampling and bottom core sampling continues, in conjunction with the Ministry of Agriculture, Fisheries and Food (MAFF) Fisheries Laboratory, Lowestoft. However, the programme of current measurements ended in June 1985 after a year of observations. The data demonstrate the intense mixing produced by the strong tidal currents and the large variability in the non-tidal currents which again appear to reflect wind conditions in the area.



Surface salinity distribution in the North Channel and Firth of Clyde

A logical progression by SMBA from these recent investigations of both the North Channel and the waters between Islay and Cape Wrath was to make surveys of the Clyde Sea area which exchanges water with both regions. In collaboration with the Department of Agriculture and Fisheries for Scotland (DAFS) Marine Laboratory, Aberdeen, a considerable volume of data has been collected during the past year, and the study is now being extended to the sill between Kintyre and Ayrshire. A very interesting description of the dynamics of this fjordic area is emerging

- **Environmental Radioactivity**
Under a contract with the Department of the Environment, IMER is examining the concentration and distribution of 'hot particles' in the Esk Estuary, Cumbria and adjacent areas derived from British Nuclear Fuels (BNFL), Sellafield. A variety of techniques have been developed to identify radionuclides and the stable element compositions which particularly distinguish BNFL 'hot particles' from those which occur naturally. In general, the particles of highest radioactivity contain small amounts of partially depleted uranium, presumably derived from the BNFL fuel storage ponds. The BNFL particles tend to be much smaller and about 100 times more radioactive than those which occur naturally. Residence time in the marine environment is about three months, although the long range transport of such materials is under consideration. The distribution of hot particles, in historically deposited (1950-66) sediments of the Esk is also being examined. During the last 20 years the highest concentrations measured are associated with fine grained sediment which is deposited in the summer months: the relative abundance of 'hot particles' shows a distribution which is similar to the BNFL releases of radionuclides. Since the recent reduction in the releases of radionuclides by BNFL at Sellafield the abundance of 'hot particles' in the Esk has decreased dramatically.

  It is clear that once trapped in accreting sediments the 'hot particles' are permanent although there is some evidence that a small proportion does not survive the sedimentation process.

- **Sediment Processes**
Marine sediments are important sites for the oxidation and remineralisation of dead organisms. Without this release of nutrients primary production would eventually cease. Coastal sediments are particularly important as they are responsible for 83% of all remineralisation in the ocean bottom, although they only represent 8.6% of the total sea-bed area. These sediments also play a dominant role in the global cycling of elements due to their intense biogeochemical activity. However, the same sediments receive a large amount of man's industrial and domestic effluent and hence may be sensitive to human impact despite the high buffering capacity of the ocean as a whole. There is a need to understand the processes within these sediments so that we can better appreciate any potential impact of man's activity on such an important system

  Work has continued at SMBA on quantifying the remineralisation of marine life within sediments receiving organic material from different sources. Three sites were investigated: Loch Etive, which receives a large terrestrial input, Loch Eil, influenced by paper mill effluent and Kingoodie Bay on the Tay Estuary, which receives domestic effluent.

  The results show that the remineralisation rates in the Tay Estuary were much higher than in either Loch Etive or Loch Eil and that the microbial processes involved were very different. It also seems that the large amount of organic matter in the sea loch sediments is not readily susceptible to microbial attack, in contrast to that in the Tay Estuary. This result is being further investigated in the laboratory

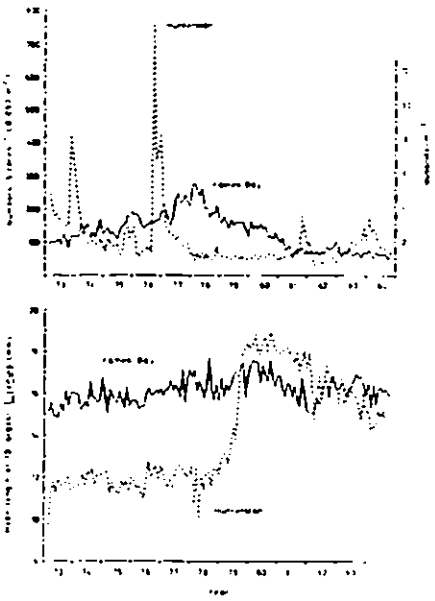
- **Molecular Organic Tracers of Estuarine Particles**
The nature and behaviour of some naturally occurring and pollution derived organic components of estuarine particles are being researched at IMER as part of the Estuarine Processes Special Topic, in collaboration with the Department of Oceanography, Liverpool University. Analytical techniques necessary to quantify specific indicators of sewage oil and carcinogenic pollutants and terrestrial plant inputs have been established and successfully applied to sediments and particulates from the Tamar, Mersey and Dee estuaries. When combined with source/compositional information, the source-specific indicators can be used to budget the contribution of pollutant inputs to the organic matter in natural environments.

- **Taxonomy of Harpacticoid Copepods**
Harpacticoid copepods are small crustaceans which are notoriously difficult to identify. Due to their abundance, they play a key role in ecological processes taking place in soft sediments. These processes cannot be worked out in detail without reliable means of identifying the species involved. Research at Heriot-Watt University has produced a revision of the genus *Haloschizopera* which will enable the use of these copepods in ecological and pollution orientated studies

- **Nutrition of Benthic Animals**
The sediments and rocky substrate of the sea bed form the habitats of diverse associations of plants and animals. The changing balances in these communities reflect responses to natural cycles of climatic or other natural environmental change, or to changes brought about by man's activities. Fieldwork on the south coast of England and at two sites in Norwegian fjords forms part of a continuing study at MBA of animals which obtain a substantial part of their nutrition from internal bacteria. Analysis of sulphur-oxidising bacteria in the gills of certain bivalve molluscs suggests that these species are responsible for the oxidation of excess sulphide in their habitat.

  The collapse of a previously abundant bivalve population in a sewage polluted Norwegian fjord seems to have been responsible for the build-up of toxic concentrations of hydrogen sulphide in the sediment. It is believed that irrigation of the sediment by these bivalves may previously have prevented gas accumulation

- **The Role of Bacteria in Bivalve Nutrition**
Dr T H Birkbeck and a team at the University College of North Wales have established that bacteria play a significant role in the nutrition of bivalve molluscs (eg mussels, clams,



Hunterston investigation. Changes in a) population densities and b) mean maximum shell lengths of *Tellina tenuis* at mollusc sampling sites on the sand beaches at Kames Bay (Millport) and Hunterston

cockles, oysters). Bacteria are rapidly degraded and their constituents assimilated into the body tissues. Experimental work has confirmed that the digestive gland plays an important role in the storage and distribution of assimilated nutrients. Applied research linked to this study could have important commercial implications.

Adaptive Ecology of Inshore Benthos

A part of the Scottish west coast subject to organic enrichment is Garroch Head in the Clyde Sea area, which has long been used as a sewage sludge dumping ground. Monitoring of this area by SMBA continued during the year, with financial support from Strathclyde Regional Council. The study has included comparing the effects of sludge disposal in dispersive and non-dispersive areas of the British coast. As part of the Garroch Head study, the distribution and ecology of free-living nematode worms along the gradient of organic enrichment has been assessed.

In the Clyde Sea area generally, benthic populations of some of the inner sea lochs were found to be particularly enriched.

A joint study with Scandinavian colleagues of the Oslofjord and the Skaggerak used quantitative techniques similar to those of a survey made early this century. Considerable differences were found between the present communities and those of 1915, suggesting that the central and outer parts of the area are now enriched.

Thermally-Enriched Inshore Sand Habitat

A long-term benthic study at SMBA has continued in the Firth of Clyde. Since 1960 the Hunterston Investigation has examined the biological effects of the heated effluents from the Hunterston electricity generating stations on the local marine fauna.

Hunterston 'A' power station was completed in 1964 and Hunterston 'B' in 1980. Each discharges about 20 million gallons of heated seawater per hour raising the temperature by 8.5° and 12°C respectively above ambient. Considerable attention has been devoted to the biology of the bivalve mollusc (*Tellina tenuis*) which inhabits the sand beaches in great abundance at Hunterston and at Kames Bay, Millport, a control site unaffected by heated effluent. Annual variations in the seasonal cycles of settlement, growth and abundance of this species show some correlations with natural and man-made variations in seawater temperature.

It is now clear that in good years, settlements of young animals at Hunterston were considerably greater than those at Kames Bay, despite the fact that for most of the time the Hunterston population was significantly less abundant than in Kames Bay. Despite the higher temperatures, Hunterston animals generally attained significantly smaller maximum sizes. The exception occurred in 1979 when the combination of higher than normal food abundances in the Firth of Clyde and the higher Hunterston temperatures produced exceptional growth.

Chemical and Biological Indices of the Impact of Sewage Sludge Disposal

Experiments at the Institute for Marine Environmental Research (IMER) on the sewage sludge disposal area off Plymouth have been conducted in order to interrelate chemical and biological indices of water quality in a situation where there is a single known input. One element of a recent experiment indicated interesting spatial and temporal behaviour of sewage sludge following discharge.

A series of samples was taken at the centre of a patch of sludge over a period of about an hour after release from the vessel. Water quality bioassays from surface samples were carried out with a colonial hydroid, while bioassays with oyster larvae were conducted by MAFF, Burnham-on-Crouch. The pattern of the biological effects and the chemical data indicated reduced water quality in the surface samples alone, although there was a rapid recovery to virtually predischarge levels after about one hour. More specifically, the results suggested that the impact of sewage sludge in the disposal area is transient in that dispersal is rapid and, under the calm conditions (Beaufort Force 0-1) at the time of the experiments, there was little vertical mixing.

Biological Effects of Contaminants on Bivalve Molluscs

There are many thousands of potentially toxic organic contaminants released into the marine environment which are accumulated in the body tissues of marine organisms and it is not feasible to determine the sublethal toxicity of every compound. An alternative approach is to use quantitative structure-activity relationships (QSARs) which relate chemical structure/physico-chemical properties of organic contaminants to their bioaccumulation and sublethal toxicity in order to develop a generalised model capable of predicting a substance's toxic effects from environmental and, more specifically, tissue concentrations. Furthermore, the grouping of toxicants into those exhibiting similar QSARs suggests a common mechanism of toxicity, whilst compounds with fundamentally different QSARs indicate a different and perhaps more specific mode of toxic action.

To date, research at IMER has been directed towards compounds that are found in oil. This is an important starting point because they represent a model group of compounds with a wide range of chemical structure, and also because petroleum hydrocarbons are an abundant and widespread group of contaminants reaching significant concentrations in estuarine and coastal waters thus forming a prominent component or 'background' to the total chemical residues in the tissues of marine biota.

A consequence of a common mode of toxic action is that the toxicity of complex mixtures of hydrocarbons should be simply additive. This is implied by the apparent agreement between the high and environmentally realistic tissue concentrations of total aromatic hydrocarbons that are required to produce similar sublethal toxic effects. Future experiments will be designed to test this hypothesis and will examine the sublethal toxicity of a wider range of organic contaminants.

Genetic Toxicology

The wide variety of contaminants entering the natural environment brings a high risk of genetic damage for humans and also for populations of lower organisms. The level of this risk is not clear, although there is evidence of harmful effects from a variety of sources. These effects may include congenital abnormalities, reduced fertility, decreased life-span, senility and cancer. Screening the environment for mutagens and carcinogens has become a high priority research area.

Work has continued at IMER on the study of genetic damage in the chromosomes of developing eggs and embryos of the marine mussel. A test is under development in which developing eggs within the reproductive tissues of female mussels are being examined to assess chromosomal damage following exposure to mutagens and carcinogens. This test is particularly relevant to the consequences for the population, since it involves the reproductive cells, and genetic damage to these can be evaluated in terms of offspring viability following spawning and fertilisation.

Investigations of mutation in chromosomes have included a study of the effects of tributyl tin oxide (TBTO), an active biocidal component in antifouling paints. TBTO was not found to be genotoxic in mussels, although there was a marked concentration-related reduction in larval survival and development rate. It has been concluded that, apart from any directly toxic effects that TBTO residues may have, there was no indication of any accompanying increase in the level of genetic damage.

Heavy Metal Accumulation by Marine Organisms

Imposex is the phenomenon of male characters being superimposed onto the female. A survey by MBA of several thousand dogwhelks, *Nucella lapillus*, from around the south west peninsula from Weston-super-Mare to Portland Bill revealed that imposex is widespread. This is especially so along the south coast near centres of boating activity. Comparison with an earlier study in Plymouth Sound has shown an increase in imposex since 1969 which coincides with the increased use of antifouling plants.

Although no correlation was found between imposex and the level of most heavy metals in the dogwhelks, a clear relationship was found with the level of tin especially in its tributyl form. Laboratory experiments in tidal tanks have revealed that imposex can readily be induced by exposure to TBT. The decline in dogwhelk populations appears to be due to low recruitment as a result of reduced ability to breed rather than an increased mortality rate.

Deep Sea Biology

The practical and technical difficulties of sampling at great depths have meant that there are few data available relating to deep sea biological processes. The deep sea is, however often described as an environment with low rates of biological activity. Contrary results are being obtained by SMBA from the Rockall Trough to the west of Scotland and Ireland. Because the Trough is relatively accessible it has become a convenient focus for long-term studies of the biology of the deep ocean.

A unique series of samples of deep-sea fish, midwater plankton and bottom-dwelling animals has been collected since 1973. For the first time the rates of growth and reproduction of individuals and of populations have been studied and produced surprising results. Study of a variety of sea-bottom invertebrates, molluscs, crustaceans and fish have all shown growth and reproduction rates much faster than previously suspected. They appear to be equivalent to the rates in comparable organisms in shelf and coastal waters.

Previous work on deep-sea urchins in the Rockall Trough was followed up through the study of two further species by SMBA scientists in collaboration with the University College of Swansea and Exeter University. Samples taken at different times of the year indicated that both species breed seasonally. Growth measurements also indicated an interesting intermediate position between the apparently longer-lived deep-sea species and the larger but considerably shorter-lived inshore species.

Investigation of two other urchin species appears to show that growth is seasonal. This is perhaps due to the springtime bloom of plankton in the upper layer of the ocean producing a fast fallout of organic particles which, as studies at the Institute of Oceanographic Sciences (IOS) have shown, may ultimately fuel the deep-sea ecosystem.

Preliminary studies on the age structures of deep water bivalve molluscs indicate that growth rates are not markedly different from shallow-water species. These findings challenge the widely held view of exceptionally low rates of biological activity in the deep sea. Clearly such data require corroboration from further studies involving direct measurement of growth by marking and recapture, but potentially have great significance for predictions of the biological effects of the dumping of noxious wastes and the impact of mineral exploitation in the deep-sea environment.

Offshore Mesocosm Studies

Since the early 1960s the experimental enclosure has become an established tool in studies of the marine environment. However, these enclosures have usually been cumbersome, stationed in relatively sheltered environments and not suitable for short term deployment from research vessels. Furthermore, few studies have attempted to mimic a stratified water column.

IMER is now using an enclosure which is an open tube 40m long and 3m in diameter (280m³). A skirt of cotton-reinforced PVC is supported at the surface by a flotation collar/working platform. The whole structure weighs approximately one tonne in air and can be assembled on the deck of a moderately-sized research vessel. Once deployed, the enclosure is free-floating. Sampling is achieved by small water bottles, self-contained sensor packages with data recording or by pumping while connected to the research vessel.

Initial results obtained during a 24 hour deployment in the thermally stratified water of the Celtic Sea revealed that the structure of the thermocline including small scale inflections was trapped and retained almost exactly as

The IMER mesocosm deployed in the Celtic Sea. RRS *Charles Darwin* in the background.

that measured outside the enclosure; there was little evidence of 'pumping' of sub-surface water into the surface mixed layer.

Such a mesocosm will be of considerable value in many studies in offshore, stratified seas and enable meaningful repetitive sampling and manipulative experiments to be carried out.

Production of Heterotrophic Bacteria

In the last decade it has become clear that there are significant numbers of bacteria in the sea, usually about one million per millilitre. It has been reported that bacteria can utilise a significant proportion of phytoplankton production and possibly more than 50% of the daily primary production may be consumed by bacteria. What is the fate of this bacterial production? New hypotheses have been formulated which integrate bacterial production into a separate food web involving the protozoa; this food web has become known as the microbial loop.

However, measurements in the Celtic Sea by IMER since August 1982 have identified low rates of bacterial production. It is clear that bacterial production was found to be only a few percent of total primary production in the Celtic Sea during the spring diatom bloom, and less than 10% of the production of the photosynthetic picoplankton. In the Celtic Sea therefore, there does not appear to be a significant flow of carbon through the heterotrophic bacteria, suggesting that the microbial loop cannot be a significant pathway in this pelagic ecosystem.

Dinoflagellate Taxonomy Using Electron Microscopy

Dinoflagellates are unicellular organisms which can be particularly abundant in marine plankton. They can produce 'blooms' resulting in 'red tides' and have caused poisoning when digested by mussels and other organisms. Scientists at Royal Holloway and Bedford New College have undertaken a taxonomic study of dinoflagellates using scanning electron microscopy. This technique has allowed clear and unequivocal identification of the 230 species which now form a reference collection of scanning micrographs. This is proving a valuable resource for related environmental studies.

Biogeochemical Studies

Laboratory studies at the MBA on the composition of organic material entering marine sediments have continued in collaboration with Bristol University.

Cycling of lipids in the marine food web has been shown to be enhanced due to feeding by zooplankton on the faecal pellets of smaller planktonic organisms. The bigger and faster sinking 'repackaged' pellets of the larger species contained higher concentrations of cholesterol and almost complete removal of hydrocarbons and polyunsaturated fatty acids.

A direct input of lipids to bottom sediments is inferred from research at Bristol University which has shown that marine copepods metabolise chlorophyl products, leaving the remains within their faeces. The grazer involved, be it microzooplankton, copepod, or fish, imprints a recognisable 'fingerprint' of its own lipids on its faeces. Hence, wherever such grazers have been active in the sedimentation of biolipids in the oceans, it is likely that the sediment will record the fact.

Plankton and Young Fish

Regular sampling has continued at the MBA of macroplankton and young fish off Plymouth. Analysis has confirmed that there was a major shift in the planktonic ecosystem after 1979, the year when conditions had at last seemed to have returned to stability and pre 1930 production levels. In 1985 pilchard spawning was more intense and the stock of macroplankton remarkably low compared to earlier decades.

Feeding Habits of Inshore Fish

During the summer further observations were made at MBA of the predator/prey interactions of free-ranging inshore fishes, particularly pollack and sand-eels. It was found that at certain times of the year pollack will take a wide range of food items, indicating that they are flexible in their hunting and foraging tactics.

This occurs when water conditions are most turbulent and when either different food sources, which include burrowing worms and small crustaceans, are disturbed and become available, or conditions prevent pollack from employing their usual hunting methods and capturing their normal prey. This behavioural switch in feeding in adult pollack had not been previously recorded.

Fish Nutrition

A major growth industry in the west of Scotland and the Western Isles is fish farming, principally of Atlantic salmon. However, farmed salmon are particularly prone to a variety of diseases, the most important being pancreatic necrosis.

A deficiency of vitamin E and/or selenium has been thought to be directly or secondarily involved in that disease. Vertebrate cells possess a multi-level defence system that acts to prevent tissue damage which may arise from uncontrolled production or leakage of free radicals, mainly toxic metabolites of oxygen. Nutritional factors in that system include the lipid soluble anti-oxidant vitamin E, copper, zinc, manganese, and selenium.

Scientists at IMB have verified the supposed role of selenium-dependent glutathione peroxidase in salmon by perfusing isolated livers of control and selenium-deficient fish with hydroperoxides and measuring uptake of the hydroperoxide and output of oxidised gluthathione by the liver. The technique demonstrated reduction of lipid hydroperoxides and of hydrogen peroxide in isolated perfused livers of control fish, but not selenium deficient fish.

It has also been demonstrated at IMB that in selenium-deficient fish there is an increase of glutathione transferase

activity. This compensates for the decrease in selenium glutathione peroxidase activity in the fish because glutathione transferase can render organic hydroperoxides non-toxic.

Bait Acceptance by Cod

Although long-line fishing is in decline in the U.K., there are still extensive fisheries in North America, Japanese and Scandinavian waters. Automatic baiting machines have been developed but these cannot cope with traditional natural baits and no artificial bait has yet been developed which approaches the efficiency of natural bait. These artificial baits presumably fail because the texture, taste or some other factor, such as interaction between the chemical senses, is incorrect.

A study has been conducted at the Institute of Marine Biochemistry (IMB) in collaboration with the DAFS Marine Laboratory, Aberdeen, on the chemical nature of the bait acceptance stimulus for cod. Experimental work used casein-based diets with the addition of an extract of squid in one and a synthetic squid mixture in the other. The results indicate that most of the stimulant to feeding is in the neutral L-amino acid fraction of the chemical mixture, although some of the non-amino acid components increase the effect.

Fish Pathology

The SMBA Aquaculture programme is based on the needs of the fish farming industry, particularly in relation to the huge expansion in the farming of caged salmon.

A particularly significant development this year was the toxicity testing of a new antifoulant coating developed by Shell Research, principally for the offshore oil industry. This work was undertaken in collaboration with the Institute of Aquaculture at Stirling University, using tank-reared Atlantic salmon.

The usual action of antifoulants is due to their toxicity to settling organisms, but Shell's new product is quite different. The outer layer of fish skin contains a defence mechanism (slime-secreting cells) against surface-invading organisms. Using this principle Shell Research has produced a synthetic 'fish skin' coating, containing within its structure, tiny 'cells' capable of releasing over very long periods minute amounts of a non-toxic material onto its surface. This results in a smooth surface upon which settling organisms are removed under their own weight in the early stages of growth.

Detailed analysis has shown no evidence of change in the tissues examined from the test fish exposed to the coating. This development has significant potential for aquaculture and other marine industries, where the removal of fouling by orthodox means can be very expensive. This also highlights the value of pure research in areas where the spin-off will provide considerable financial savings.

Phytoplankton and Mariculture

The SMBA continued their work on toxic micro-algae and their influence on aquaculture on the Scottish west coast. This has included studying the importance of physical processes in the Sound of Jura and associated sea lochs in determining the potential for the growth of phytoplankton blooms. This should help assess the potential for the development of high levels of algae and also help site selection to avoid the risk of toxic blooms.

The Effect of Detergents on Fish Gills

Researchers at Exeter University, have examined some effects of detergents on fish, revealing valuable and detailed information on the mechanisms by which pollutants can affect marine life.

Adaptations in Antarctic Fish

The British Antarctic Survey (BAS) and its collaborators from St Andrew's University, University College of North Wales, Bangor, and Leicester Polytechnic have been investigating the adaptations of Antarctic fish to the polar environment.

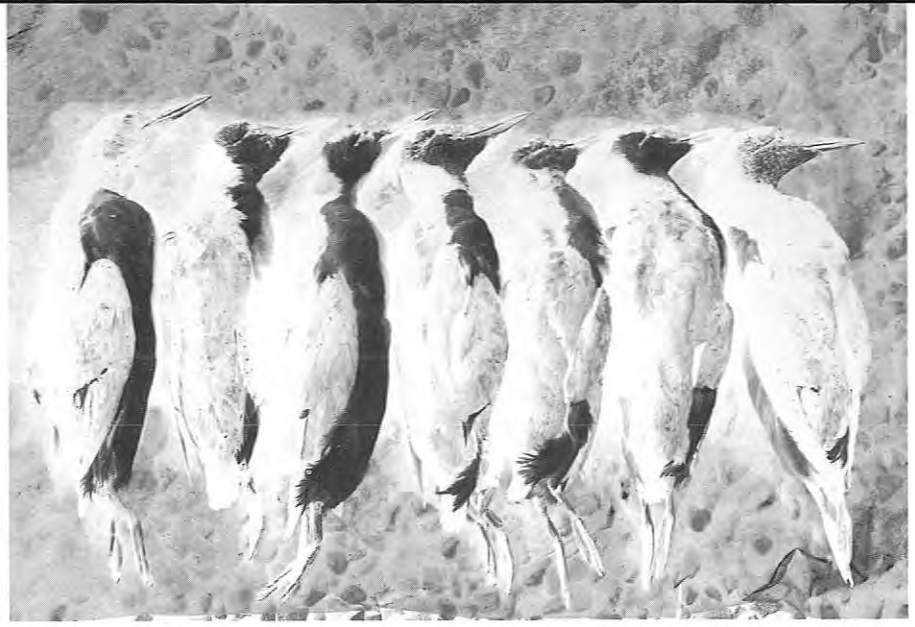
Fish inhabiting low temperature environments were previously reported to have negligible immunological responses. Work at Leicester Polytechnic has now shown that Antarctic fish are immunocompetent; the initial induction by antibodies is temperature dependent and therefore develops slowly but the subsequent immune response is not retarded. Comparative histological studies on the thymus in selected Antarctic species from differing habitats and temperature ranges and different stages in their life history have shown that the organ develops more slowly and is more exposed to the environment than in a warmer water fish. Experimental research is planned to examine the details of the immunological system in polar fish.

Antarctic icefish are unique amongst vertebrates in having no functional haemoglobin. Oxygen transport is achieved by direct solution in the plasma. Antarctic icefish have evolved a whole range of physiological and anatomical adaptations to compensate for the lack of haemoglobin and a detailed investigation of the vascular system and its hormonal control is being carried out at Bangor. One initial observation is that the hypobranchial system is well developed. The presence of a functional hypobranchial circulation probably ensures adequate circulation to the pectoral muscles.

Investigations of enzyme kinetics and muscle performance in Antarctic fish show that their metabolism is well adapted to function effectively at low temperatures and to achieve activity levels equivalent to those of fish at higher temperatures. There do, however, appear to be differences in the partitioning of the energy budget because although maximal tissue metabolism rates are high, the whole body resting metabolic rates are low. The patterns of biochemical organisation appear adapted to limit the fraction devoted to activity and thus to conserve energy resources, rather than reflecting any limitation imposed by low temperatures.

Cephalopod Diet, Food Intake and Growth

Serological techniques developed at Aberdeen University (Dr P R Boyle) to study the diet of cephalopods (octopuses and squids) have allowed the detection of stomach contents at a much more advanced stage of digestion than was possible using other methods. Serological techniques will be particularly useful in answering specific questions on the diet of commercial species of squids and on the importance of cephalopods as predators of commercial crustaceans and fish.



Dead guillemots

Seabirds

Seabirds are as much a part of marine ecosystems as cod or crustaceans yet they are rarely studied at marine laboratories. This omission has been imposed more by tradition than by sound scientific principles. The vital but tenuous links which bind seabirds to marine food chains were dramatically emphasised in mid-July 1985, when thousands of guillemots, razorbills and kittiwakes were washed ashore dead and dying on the holiday beaches around Oban. There was considerable local and national interest, and the SMBA helped to investigate the cause. All 2891 corpses mainly guillemot, that were counted had died of starvation.

It appears that these exceptionally high seabird mortalities, although exacerbated by high rainfall, were primarily due to a local shortage in 1985 of small fish such as young sandeels and herrings on which the seabirds are entirely dependent during the breeding season. The reasons for such fluctuations in the fish populations are unknown, but one factor which must be considered is the Hebridean sandeel fishery which began in 1980 and has increased considerably each year.

Breeding Performance of Antarctic Blue-eyed Shags

Over 25% of individuals in the breeding population of blue-eyed shags at Signy Island, South Orkney Islands, are of known age. With support from a NERC Research Studentship to Durham University, a 3-year study of factors affecting breeding performance in this species has recently been concluded by BAS.

In common shags in Britain, the main determinant of breeding success is nest site quality. Older birds return earlier, obtain the best nest sites and lay earlier than younger birds. In blue-eyed shags, however, neither clutch size nor egg and chick survival show any relationship to nest site quality or position. Furthermore, there is no relationship between female age and laying date. The only age-related effects detected were increased breeding success (chicks hatched and fledged) in the first few years of breeding (birds aged 3-5 years) and a decrease in the size of eggs and chick weight at hatching in the oldest categories of birds available (aged 10-12 years).

Reproductive output in shags is strongly influenced by the fact that eggs are laid and subsequently hatch at intervals of 2-3 days. The resulting difference in the age of the chicks within the brood may result in a weight hierarchy, whereby the oldest and heaviest chicks are favoured and the youngest ones may die. This situation is usually interpreted as an adaptation for adjusting the brood size to the prevailing environmental conditions. However, the detail of how this is actually achieved has rarely been studied. In blue-eyed shags brood reduction is common: 78-84% of first and second chicks fledge, compared with only 11% of third chicks (hatching 2-4 days later than their siblings). In broods that were artificially synchronised with respect to hatching date, chick survival overall was similar to normal broods but there were significantly more cases of total brood loss. The weight hierarchy is most highly developed during the first 12 days of chick-rearing when most deaths of third chicks occur. At this stage, however, the total food requirement of the brood of three is only 10% of that of a brood of two near fledging. Consequently it is hard to believe that the adults are able only to meet the energy requirements of the two oldest chicks. It appears, therefore, that the supply of food is limited by the parents, or by the ability of the third chick to compete with its siblings, rather than by the environment itself.

Conserving the Mediterranean Monk Seal

The Mediterranean monk seal is one of the world's rarest mammals; only 500-1000 animals survive, most of them in Mauritania, Greece and Turkey. Although monk seals have occurred in close association with man for thousands of years, remarkably little is known about their biology. For the last five years SMRU has been studying monk seals in Greece for the Commission of the European Communities in order to provide the biological information needed to design suitable protection measures. A major breakthrough was made in 1985 when an automatic camera system was developed to photograph seals when they visit the caves used for resting and breeding. With these devices it is possible to determine with the minimum amount of disturbance how many seals there are in a particular area and which localities are used most frequently. This monitoring is being combined with studies of the competition between the seals and the local fishermen, with the aim of developing management schemes that will, hopefully, protect the surviving seals.

Elephant Seal Populations at South Georgia

The southern elephant seal is a major consumer of fish and squid in Sub-Antarctic regions. Estimates of most populations of this species are based on surveys conducted in the 1950s; more recent counts have indicated that populations are in decline. Recent studies at South Georgia have provided revised data for the construction of life tables and the estimation of population biomass and food consumption, but emphasised the need for accurate counts of populations. In 1985 a private yacht was chartered by BAS in order to undertake such a census at South Georgia, which has the largest population of elephant seals in the world.

Over a period of six weeks every seal beach on the island was visited. Most counts were made from the yacht which was normally able to approach to 20-40m from the shore. Landings were, however, made at a number of locations and ground counts conducted. A total of 88,000 breeding

Elephant seals and King penguins at South Georgia during the 1986 Elephant seal survey from the chartered yacht, *Damien*.

females were counted, representing an annual production of about 100,000 pups. This figure is remarkably similar to that produced from more limited census work in 1951, and suggests that, in contrast to the stocks in the Indian Ocean, the South Georgia stock is, at present, maintaining its population level.

International Studies of Minke Whale Numbers

The SMRU is actively involved with the international effort to estimate the size of the Antarctic minke whale population and has taken part in each of the four cruises organised by the International Whaling Commission since 1982 as part of the International Decade of Cetacean Research. A new method of recording data from whales sighted during the cruises has been developed. The number of whale blows seen and their spatial distribution relative to the vessel ('cue-counting') are analysed to produce an estimate of whale abundance. A recent refinement of this technique uses video recording of the observers in the crow's nest and on the bridge to determine the exact time that each blow is seen. These data are analysed daily, using a computer, to identify those blows seen from both positions. These 'duplicates' are analogous to recapture in a mark-recapture experiment, and can therefore be used to estimate the number of blows occurring per unit area per unit time. Early trials have been encouraging and further surveys in 1986/87 will be carried out using this technique.

ATMOSPHERIC SCIENCES

Research in atmospheric sciences is mainly concentrated at the British Antarctic Survey (BAS), the Robert Hooke Institute at Oxford University, and through research grants awarded by the Aquatic and Atmospheric Physical Sciences Grants Committee.

Ionospheric Physics

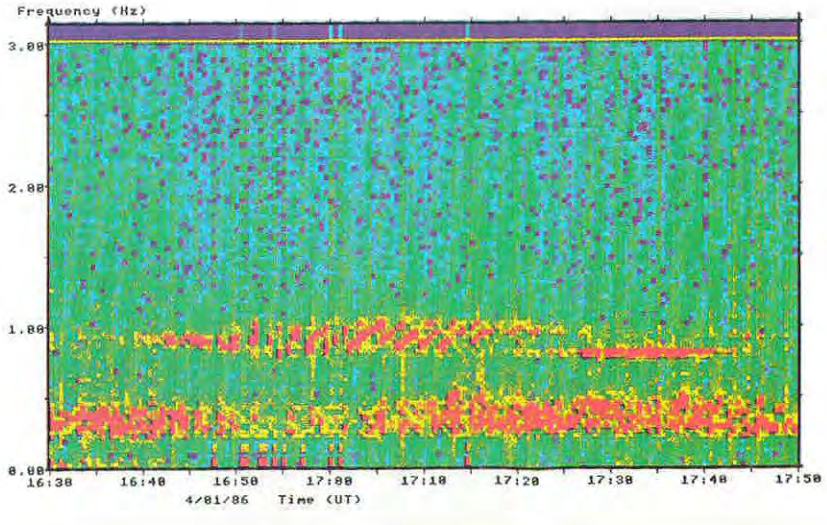
An important new international ionospheric research project spanning both polar regions, known as the Polar Anglo-American Conjugate Experiment (PACE), has been started with joint funding by NERC and the US National Science Foundation. The aim is to study the way in which the ionosphere and the magnetosphere are coupled over the auroral zones and polar caps, viewed simultaneously for both polar regions.

Two radars, each with a viewing area of 500 000sq.km and a maximum range of 2500km, will be employed. Such a radar already exists in Goose Bay, Labrador, and early in 1988 an identical one is to be installed at Halley Station in Antarctica. The geographic South Pole will be in the viewing area of the Halley radar, resulting in many exciting possibilities for collaboration with the upper atmosphere programmes conducted there, as well as with northern hemisphere programmes. The experiment will be uniquely valuable for studies of solar wind/magnetosphere/ionosphere coupling processes.

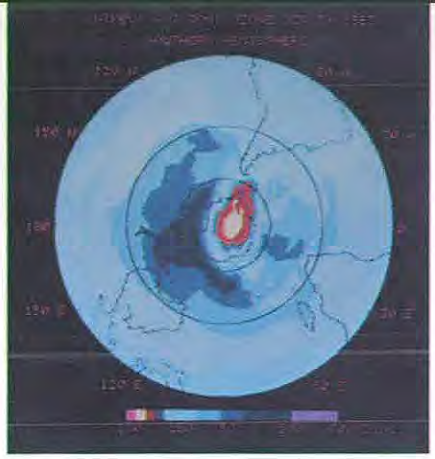
The influence of solar wind and magnetospheric variability on the main ionospheric trough, an important feature of the sub-auroral night-time ionosphere, has been investigated. A rare day-time trough has been identified in Advanced Ionospheric Sounder data at Halley, and studied with satellite data. Rapid ion flows resulting from magnetospheric electric fields are believed to heat the thermosphere, so changing chemical reaction rates to cause the reduction of plasma concentration observed in the trough.

Space Plasma Physics

Theoretical research at BAS on the generation of magnetospheric radio emissions yielded exciting results in 1985/86. The source of the previously unexplained X mode electromagnetic nonthermal continuum radiation observed by satellites to coexist with the O mode in the Earth's magnetospheric cavity has been identified. In collaboration with the Radio Astronomy Department at the University of Cambridge, BAS scientists have discovered that the magnetopause is the most likely source of both X and O mode radiation. These results are directly relevant to nonthermal continuum observed within Jupiter's magnetospheric cavity, where the radiation is predominantly in one mode, which is as yet unidentified. In a collaboration with the Section d'Astrophysique, Observatoire de Paris and the Space Research Institute, Austrian Academy of Sciences, it has been shown that the magnetopause is the most probable source of Jupiter's nonthermal continuum. Preliminary full-wave computations indicate that the continuum is in the electromagnetic X mode. This may lead to an estimate of the plasma density gradient at Jupiter's



A Geomagnetic Pc 1 pulsation detected on the magnetic sensors of the new ULF/VLF experiment installed at Halley, Antarctica. The Pc 1 has a rising tone structure centred near 1Hz indicating wave pockets travelling on geomagnetic field lines and last for approx. 30 mins. The data were returned from the Antarctic and processed on the NCS Vax 8600 computer at Keyworth.



The Antarctic ozone hole as recorded by the Nimbus 7 satellite (courtesy of NASA).

Manoeuvring a weather buoy into position on an ice floe in the Weddell Sea. The buoy is drifting with the pack ice and will contribute data from the centre of the Weddell Sea during the 1986 international Winter Weddell Sea project.

magnetopause; it has proved impossible to determine this using data derived from spacecraft.
The theoretical research is well balanced by an active experimental programme to study magnetospheric radio emissions which can be received both on satellites and on the ground. These emissions are at very low and ultra low frequencies (VLF and ULF) and their measurement allows a determination of the state of the plasma through which they have propagated and in which some have been created. In addition to the continuing work on VLF emissions, whistlers and Trimpi events, two new experiments deployed in the Antarctic in 1985 and 1986 are now yielding interesting preliminary results.

Ozone in the Stratosphere

The dramatic depletions of ozone in the Antarctic spring reported by BAS in 1985 have aroused intense interest. Re-examination of data derived from the Nimbus 7 satellite has enabled NASA to confirm the rapid growth of the effect from 1979 to date and has shown the spatial and temporal variations of the depletions. In 1985 the depletion at Halley station amounted to some 40% relative to 1957 values. The fastest loss rate approaches 1% per day.

There has been surprisingly little agreement on the causes of these depletions. In order to gather more reliable data, the United States is mounting a National Ozone Expedition at McMurdo, started in August 1986. BAS contributes to this programme through ozone-sonde balloon flights from Halley station.

Resolving Anomalies in Satellite Data

In collaboration with the Atmospheric Physics Department of Oxford University, BAS carried out a seven-month experiment on board RRS *Bransfield* to determine the source of errors in sea surface temperatures (SST) derived from satellite radiometers.

The experiment involved suspending a highly sensitive, downward looking radiometer forward of the bow of the ship on passage from the UK to the Antarctic and back. The SSTs derived were compared with those obtained from satellites passing overhead and also with direct thermometric measurements. To ensure that reliable atmospheric corrections could be applied to the satellite radiometer data, temperature and humidity profiles of the lower atmosphere were obtained using balloon-borne apparatus released at times to coincide with satellite passes overhead. This is the most wide-ranging experiment conducted to resolve anomalies in SST retrieval from satellite data. An improvement in the accuracy of SSTs is important for global climate research.

Meteorological Data and the Movement of Ice Floes

As part of a joint BAS-Scott Polar Research Institute venture an ice strengthened weather buoy has been embedded in the centre of a substantial ice floe in the Weddell Sea. After drifting generally westwards for three months, the buoy moved northwards in dense pack ice; at the end of June it was at a position not far from that of Shackleton's ill-fated *Endurance* at a similar date in 1914. Information on position, air pressure, air temperature, ice or water temperature and wind speed are being transmitted to the northern hemisphere by the Argos satellite system. These data appear to improve significantly the detail for the Weddell Sea area shown in the Meteorological Office numerical analyses. Winter depletions. In order to gather more reliable data, the United States is mounting a National Ozone Expedition at McMurdo, started in August 1986. BAS contributes to this programme through ozone-sonde balloon flights from Halley station.
temperatures in the pack ice have fallen below −40°C. The pack ice has moved in several loops, each of which was associated with the passage of a large, slow-moving weather system.

Modelling the Lower Atmosphere

Work at the Meteorology Department at Reading University has concentrated on modelling the southern hemisphere troposphere (lower atmosphere) and the impact made on this by the Antarctic land mass. Starting with a simple two-dimensional model it has been shown that Antarctica may be the major force in determining the long wave structure of the southern atmosphere poleward of 40°S. In particular, it may account for the blocking pattern which develops near New Zealand. An axisymmetric baroclinic model has generated the other features of the high latitude circulation including katabatic (downhill) winds, easterly winds at low levels around the continent and westerly winds at middle levels.

Numerical Modelling of the Atmosphere

1985 saw the final phase of a 14 year programme funded by NERC which was designed to provide UK universities with a global atmospheric modelling ability. Over the period of the grant, work has concentrated at Reading University and has centred on developing an understanding of fundamental dynamical processes in the atmosphere. Special studies of the dynamics of baroclinic waves, frontal structure, mountain forcing and tropical heat sources form part of the body of knowledge which has gained an international reputation for the group at Reading. Several new ideas and techniques developed by the group have been taken up by other researchers elsewhere in the world.

Atmospheric Radiation and Dynamics

A long-term programme now centred at the Robert Hooke Institute in Oxford has involved the development of a two-dimensional model of the atmosphere as an interpretation of data derived from satellite instrumentation. The model has been used to simulate certain features of middle atmosphere behaviour and to test current understanding of various aspects of the interplay of dynamics, radiation and photochemistry in that region. Three-dimensional satellite data reflecting levels of methane and nitrous oxide in the middle atmosphere have indicated the existence of a rich eddy structure, but this cannot be simulated by the two-dimensional model. In collaboration with the Meteorological Office, a three-dimensional model is to be developed. This will make use of data generated by the Institute's Improved Stratospheric and Mesospheric Sounder (ISAMS). ISAMS will form part of the instrumentation of the Upper Atmosphere Research Satellite, which is now due to be launched from the US Space Shuttle in 1991.

Terrestrial and Freshwater Sciences

Terrestrial and Freshwater Sciences Directorate has a particularly varied area of operation. The study of wildlife in its broadest sense, encompassing the population biology and ecology of vertebrate and invertebrate animals, plants and microbes in the natural environment, is probably the most central aspect of the Directorate's work. The Institute of Virology (IOV) is a specialist organisation, at present studying viruses of insects and plants and is heavily involved in genetic engineering of viruses. The Directorate is by no means confined to biology, in that the Institute of Hydrology (IH) deals with surface and soil water, floods, drainage and allied questions, and the Institute of Terrestrial Ecology (ITE), the Freshwater Biological Association (FBA), and the Unit of Comparative Plant Ecology (UCPE) have major interests in the chemistry of the atmosphere, water and soil.

The Directorate thus deals with the use of the land surface of Britain for non-agricultural purposes, though there are many close links with agricultural research. Research on forestry and on upland vegetation and wildlife in particular has implications for land use.

Many types of pollution impact on the subjects of the Directorate's work and are consequently studied: included are pesticides, oil spills, atmospheric pollutants (including 'acid deposition') and radionuclides. This type of work is frequently of topical public interest, and requires rapid responses and careful and sensitive handling. Similar comments apply to biotechnology and genetic engineering, which are subjects for research in IOV and FBA.

Many other bodies have interests in the same subjects, and the Directorate aims to form and maintain active links and where appropriate co-ordinate activities wherever this advances the overall progress of research. In particular, a very large number of University departments, of biology, botany, zoology, geography etc, undertake related work and collaboration with our own Institutes has been much improved by joint Special Topic Schemes.

Remote Sensing and Mapping of Sahel Vegetation and Rainfall

Information derived from Earth observation satellites is becoming increasingly important for managing rangeland in different parts of the world. In the Sahelian region of Africa, there is particular interest in the use of this information for monitoring grassland condition to minimise the effects of drought.

For the last three years the EEC has been funding eight national teams who are studying the dynamics of desertification in West Africa using remote sensing. The UK contribution, managed by the Institute of Hydrology (IH), involves groups from the Institute of Terrestrial Ecology (ITE), Reading and Bristol Universities and Cranfield Institute of Technology. They are developing methods of estimating rainfall and monitoring rangeland production in Niger.

This project has extended existing work (funded by the Overseas Development Administration) at Reading University to estimate rainfall and soil moisture from geostationary satellite data.

Field trips have been made in the wet and dry seasons to obtain measurements on vegetation. Daily rainfall data have been obtained from ten stations in Niger and from about 100 supplementary stations.

Results obtained from a dense network of 36 gauges at a spacing of 2km have confirmed the great spatial variability of rainfall in this region. Only remote sensing from satellites can hope to give accurate estimates of the local rainfall.

The visible and infrared surface temperature data obtained from the weather satellite Meteosat approximately every hour during the wet season have been used to define the extent and height of precipitating clouds.

The ITE contribution to the project involved the mapping of vegetation. The field trips showed that the perennial vegetation covered less than 10% of the ground and tended to be concentrated in clumps which could be readily identified on the Landsat images. During the wet season a dense cover of grass develops if the amount and frequency of rainfall are adequate. Eventually these studies will

Map of green biomass derived from the Perpendicular Vegetation Index.

be combined with those of IH to forecast rangeland productivity and to provide information which can be used locally with the affected areas.

So far independent checks on the estimates of rainfall and vegetation biomass based on the satellite data have been very encouraging. It is hoped that the project will be further supported by the EEC, when an operational system to forecast the locations of drought areas will be developed after further research and validation of the methods of estimation.

Antarctic Terrestrial and Freshwater Communities

For terrestrial and freshwater biologists the Antarctic provides the chance to study unique and rather simple communities, whose adaptations to their environment are accentuated by the rigour of the climate.

The British Antarctic Survey (BAS) has been carrying out joint research on rock weathering with the University of Natal. Rock water content is known to play a critical role in the mechanism and rate of rock destruction and this has been confirmed by studies on Signy Island. An important area of study is the relationship between microhabitat and colonisation by micro-organisms. These studies have suggested that ice formation in cracks may control the penetration by algae and bacteria into the rock.

Freshwater bodies (lakes, pools and streams) are an important study area on Signy Island as they show an integration of the biological and chemical features characterising the land. In the relatively simple systems found at Signy Island, significant information can be gained from comparison of various interactions between the land and the lakes.

The lakes are small and most are surrounded by primitive 'soil' environments called fellfields. Unlike temperate systems the fellfield catchments are not affected by factors such as sewage, agriculture and forestry: this facilitates their characterisation for each lake.

Research is centred on the input and incorporation of a range of elements into the lakes. Each fellfield soil has its own particular association of minerals. Release of nutrients from these is controlled by such factors as flow rates of water through the 'soil' and frequency of freeze-thaw cycles. These data will be invaluable in generating nutrient budgets and interpreting the transfer of nutrients through fellfields. This work is also proving important in the verification of current theories on the evolution of Antarctic lakes.

Alongside these chemical studies, information has been gathered on the interaction of terrestrial and lake

An undulating moss turf near the Australian Casey Station, Bailey Peninsula, Wilkes Land, Antarctica, composed of *Schistidium antarctice* (dark green) and *Ceratodon purpureus* (brownish green) with *Bryum algens* (golden green) in the moist depressions.

microbe populations. There are profound differences in the population composition and biochemical characteristics of microbes from these two environments. High nutrient concentrations and fluctuating temperatures favour the typical terrestrial flora while low nutrient concentrations and constant low temperatures favour lake micro-organisms. At low temperatures, lake bacteria appear to have a higher affinity for nutrients present in low concentrations than terrestrial bacteria which in contrast can respond faster to sudden increases in nutrient concentration. Fungi, and particularly yeasts, are the dominant microbial group in terrestrial environments of the area. Despite being washed into the lakes in large numbers during the spring melt, they cannot compete with bacteria for the available organic carbon in the constantly low temperatures of the lakes. Detailed investigation of the biochemical characteristics of these two environments is now in progress at Signy and Cambridge.

The largest ever collaborative botanical research programme in the Antarctic has been undertaken between BAS staff, West Germany and Australia. Ten weeks were spent at Casey Station investigating aspects of the fellfield ecosystem. This field and laboratory research was designed to make direct comparisons with the Fellfield Ecology Research Programme on Signy Island.

These studies involved ecophysiological investigations of the dominant species and changes in community structure. The terrestrial environment of Casey Station is unique in continental Antarctica in terms of the exceptional development of the vegetation while other neighbouring areas are almost devoid of vegetation. Investigations of growth and colonisation potential were made both *in situ* and using plant fragments in laboratory culture experiments. Unvegetated soils were studied by culturing samples treated with various combinations of nutrients. The water relations of the dominant macrolichens were assessed in terms of moisture uptake from a saturated atmosphere and moisture loss at low relative humidity. These data will support an intensive study of photosynthesis and respiration in lichens. The analysis of these fellfield communities will provide a detailed insight into the composition and structure of the region's vegetation.

An Improved Data Base for the Antarctic Flora

BAS holds a considerable herbarium of Antarctic and sub-Antarctic flora. From its inception in 1979 the herbarium had a computerised data base which enabled information to be sorted and retrieved in many ways, for example by species, by collector or by locality of collection. However, the system used numeric codes for data items, making it relatively difficult to use. In addition, the data base was stored under contract on commercial mainframe computer, so that searches were usually only possible at monthly intervals.

The data base is now held at the Institute of Oceanographic Sciences, Bidston, and may be consulted frequently and at short notice. The system is accessible not only to BAS staff but also to members of the academic community, who may extract and input data. The computer is capable of producing a variety of outputs, including distribution maps and specimen labels.

The data base holds details of nearly 50,000 specimens, including a large number held in herbaria other than that of BAS. It is probably the most complete record of Antarctic and sub-Antarctic flora in existence. Recently it has been used to provide data to

The BAS research station on Signy Island where a wide range of biological studies are undertaken, including marine, freshwater and terrestrial programmes.

facilitate the designation of several Sites of Special Scientific Interest in the Antarctic, which are now protected under the International Antarctic Treaty.

BBC Domesday Project

To commemorate the 900th anniversary of the Domesday Book, in October 1984 the BBC arranged to carry out its own Domesday Project, using a staff team supported by outside consultants, including the ITE. The project aimed to create a data base giving a wide-ranging 'snapshot' of life and resources in the UK in the 1980s. New videodisc technology was used, linked to microcomputers used for the storage and retrieval of the information. This large project required the successful commercial production of software capable of dealing with the text, pictures, graphs and mapped spatial data.

The information was recorded on two discs. The 'community' disc contains text, photographic and spatial data on land use and amenities supplied mainly by schools' project groups, each reporting on a block 4km × 3km. Some of these data are incorporated into the 'national' disc, which also includes photographs and press cuttings describing life in the UK in the mid-1980s, spatial data at scale between 1km × 1km Ordnance Survey grid squares, and administrative counties and regions.

The ITE is one of four groups which supplied spatial and statistical data for the national disc and the ITE's project leader is a member of the Project Editorial Board which advised on disc content and production schedules. The ITE has been particularly concerned with the production of spatial environmental data for the national disc. Data bases were already held by the Institute giving information on land characteristics, land use and on plant and animal species distribution. Additional material was provided by other NERC institutes and external organisations including the British Trust for Ornithology.

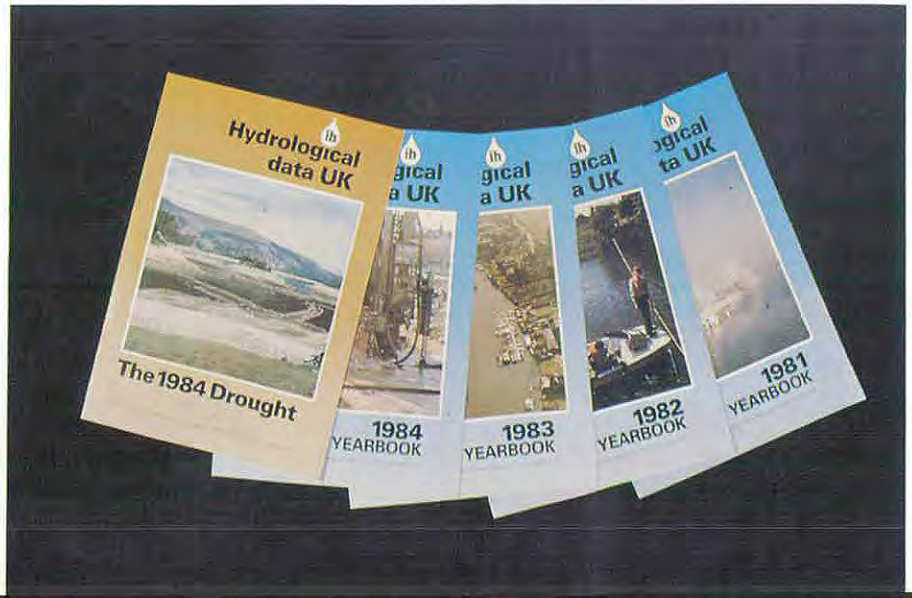
The production of these data in the format required by the Project was a considerable task, requiring data files to be constructed covering the UK in 10km × 10km blocks. Each data file was cross-referenced to three text files: a descriptive file carrying details of data sources and acknowledgements, a technical file describing methods of data compilation and a private file giving sufficient definition of each data item for the user to appreciate the displays capable of being generated by the data. In addition, boundary definitions of natural regions were supplied in order that the user can frame queries on the basis of areas such as The Weald or the Snowdonia National Park. Data and accompanying text files were prepared for 555 data items.

The execution of this pioneer project has involved considerable problems, as hardware, software, data availability and data input have all had to be advanced to a very tight timetable and on a scale not previously attempted.

Hydrological Data – United Kingdom

In April 1982 responsibility for the National Archive of Surface Water Data was transferred from the Department of the Environment's Water Data Unit (which was disbanded) to the IH. At the same time, BGS took over the National Archive of Groundwater Level Data. Close co-operation between staff at IH and BGS led to the decision to publish a single series of yearbooks and reports dealing with nationally archived surface and groundwater data. The new series – known as Hydrological Data: UK series – was launched at a seminar in October 1985 (held at the IH) to commemorate the 50th anniversary of the creation of the Inland Water Survey which instigated the collection and publication of river flow data in the United Kingdom. The main publication series will be annual yearbooks, but every five years a catalogue of river flow gauging stations and of groundwater level recording sites will be published as a companion volume. All six volumes in each five year cycle will be available individually. The series also includes occasional reports relating to significant hydrological events: the first of these reports concerned the 1984 drought.

The yearbooks provide a great variety of data. Particular emphasis is placed on ready access to basic data, both within the individual volumes and through complementary data retrieval facilities operating from IH. Responsibility for collection and initial processing of the data rests primarily with the ten water authorities in England and Wales, the seven River



Hydrological data – UK.

Purification Boards in Scotland, and the Department of the Environment for Northern Ireland. The majority of the rainfall data and much of the meteorological information are supplied by the Meteorological Office.

Publications in the Hydrological Data UK series are designed to appeal to anyone with an interest in water, ranging from the assessment of resources and their sensitivity to climate to the environmental implications of changing patterns of river flow and groundwater storage. The data are of practical value to those concerned with hydrometry.

Flow Regimes from Experimental and Network Data

In 1985 a six man team was established at IH to undertake a three year study as the major contribution to Project 6.1 of the Third International Hydrological Programme (IHP). In addition to three IH scientists, the project team comprised a member seconded from each of Norway, the Netherlands and the Federal Republic of Germany. The project team is liaising with a number of research institutes and universities in north-west Europe. The project has been initiated by the IHP with the objective of analysing hydrological data from small research and national network basins to investigate natural and man made hydrological regimes. Although numerous individual basin studies have previously been carried out in the study area of north west Europe, there have been few attempts to compare results from different countries or to provide techniques for generalising or extrapolating research results beyond individual catchment boundaries. The study seeks to overcome this deficiency by applying statistical analyses and modelling techniques to a large European data base.

The project will have three major areas of research: first, the use of physically based models for studying land use change and water management problems; second, the systematic analysis and comparison of data from small European research basins and third, the regionalising of flood and low flow behaviour of European rivers.

The main activity in the first year of the project has been to extend existing archives of mean daily and annual maximum discharge data with data from over 2000 catchments including an intensively monitored subset of 50 small research basins. The figure shows some examples of initial data analyses from individual catchments and from pooling data in different regions. By providing techniques for calculating these summary statistics at ungauged sites, the results of the project will be of direct use for flood design and water resource planning. This regional approach will be complemented by using physically based catchment models to examine the effect of land use change on the frequency of low flows, using data from the Institute's experimental catchments in central Wales.

The Effects of Vegetation on Fluvial Processes

A research team at Southampton University has been examining the influence of vegetation on hydrology. The team has met with considerable success in establishing a stratified system of hydrological monitoring by concentrating its study on sub-areas of individual catchments rather than comparisons of one catchment with another.

The very strong influence of vegetation on the generation and the routing of run off in the Highland Water catchment and in the New Forest has been established. As a result, run-off and possible flooding can be estimated from the composition of vegetation present in the main flood-producing areas, without the need for soil or geology maps.

Riverflow Reconstruction from Rainfall and Tree Rings

A group of scientists at the University of East Anglia has been funded by a NERC grant to reconstruct riverflow over a period extending back to 1754. This reconstruction provided a data set considerably larger than any previously available. The UK Meteorological Office archives contain rainfall data covering the period from 1860 but earlier reconstructions were primarily derived from analyses of tree ring widths and historical sources including diaries and newspapers.

Analysis of the reconstructed data showed that long (18 month) periods of extreme low flow were three times more likely to have occurred between 1925 and 1979 than between 1870 and 1924. Riverflow severity maps have been constructed showing return periods for severe low flow events similar to the 1975/76 drought. It is also possible to assess the effects of land use changes on riverflow during the period covered by the project. Study of daily rainfall data available from 1890 made possible the reconstruction of flood events in earlier periods, providing useful dates for the investigation of extreme events documented in local archives.

Acidification

Several NERC institutes (ITE, IH, FBA, BGS) and NERC supported university groups are engaged in research designed to improve our understanding of the causes, processes and effects of acidification of the terrestrial and freshwater environment.

Modelling the Effects of Acidification

As part of the joint British/Scandinavian project on surface water acidification and the Environmental Protection programme of the EEC, the IH has established a catchment monitoring and modelling research programme. This project has brought together scientists from Norway, Sweden, Germany, USA, Canada and the UK. Collaborative hydrochemical catchment studies have been set up in the uplands of Wales and Scotland and the data are being used to develop hydrochemical models. The timescale of the models varies from short term forecasts of acid storm events to long term prediction over many decades. The models include hydrological and chemical processes and are being used for predicting the sensitivity of catchments to acidic deposition and the effects of land use change, such as conifer afforestation. Preliminary results suggest that certain upland catchments with acidic soils overlying base-poor bedrock are often afforested with conifers and are particularly vulnerable to acid deposition. The long term trend since 1940, reconstructed by the model, supports the finding of ecologists who report major increases in acidity in certain upland catchments during the past 50 years.

The models have also been used to predict future change in catchment

acidity and the reduction in emissions which would be necessary to maintain the current stream chemistry. It is also possible to estimate catchment weathering rates and soil properties, providing an extremely useful method of integrating information on catchment behaviour.

Cloudwater: A Pollution Deposition Mechanism

Reports that forest decline in Germany and the USA occurred initially at high elevations have led to many theories implicating stresses attributable to air pollution. Three pollution deposition pathways seem likely to be of particular significance: nitric acid vapour and other pollutants deposited in dry conditions; heavy and episodic rainfall which carries pollutants; and the capture by vegetation of very small wind-driven cloud drops which contain high concentrations of pollutants. This last pathway has been investigated by the ITE.

Wind-driven cloud droplets are trapped inefficiently by standard rain gauges, so samples were collected by fine-filament apparatus. After impact on the filaments, the fine droplets coalesce into drops large enough to flow into collecting funnels. Some of the gauges were sheltered from rainfall by a covering lid, in order to assess the diluting effect of rainfall.

Samples derived from these gauges were analysed and compared with rainfall collected in a standard glass funnel gauge. The comparison showed that cloud droplets typically contained two to five times more acid than rain, particularly in the case of droplets gathered in sheltered gauges. The highest acidic concentrations occurred in airmasses from continental Europe.

The cloudwater was frequently brownish-black and when examined with an electron microscope was found to contain spherical particles typical of pulverised fuel ash produced by industrial or domestic combustion of coal or wood.

Tall plants with 'fine' foliage, such as conifers, are likely to be efficient collectors of cloudwater. Trees growing at high altitudes will experience cloudwater events more frequently and thus are likely to receive a heavier pollution load from this source than those growing at lower levels.

It now seems likely that some vegetation receives high levels of pollution more frequently than was previously concluded from studies of rainwater. Further study will be required to determine the frequency of such levels of deposition.

A related study has shown that the stomatal antechambers of Scots pine leaves can become choked with pulverised fuel ash particles. Experiments are in progress to determine the combined effects of particle accumulations and intensely acidic solutions on foliar exchanges of carbon dioxide and water vapour.

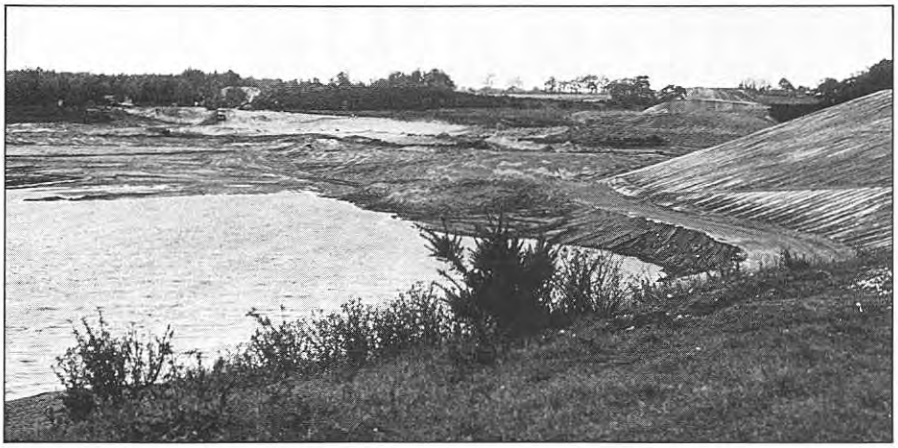
- **Pollution Abatement Technology Award Scheme**

The Freshwater Biological Association (FBA) shared a commendation in the 1985 Pollution Abatement Technology Awards. This award scheme is sponsored by the Environment Foundation and promoted by the Confederation of British Industry, the Department of the Environment and the Royal Society of Arts.

A senior chemist of the FBA and a representative of British Industrial Sand Ltd received the commendation in 1986 from the Duke of Gloucester. The work commended by the award involved the development of a low-cost treatment for the reclamation of acid waters in disused sand workings.

- **Amount of Phosphorus Entering Loch Leven**

Fresh waters commonly become increasingly enriched with mineral nutrients, particularly phosphorus and nitrogen, leading to eutrophication. Algal growth caused by these nutrients may, in standing water, affect man's use of the water for drinking and industrial supply, as well as fishing and other activities.



Golf Course Quarry during excavation and subsequent landscaping for use as a Sailing Centre.

The water of Loch Leven has been under survey since the late 1960s, but recently there has been increased interest in phosphorus levels in the loch and its associated waters due to a continuing deterioration in water quality. The Nature Conservancy Council, one of the concerned parties, commissioned the ITE to undertake desk studies to assess the loading of phosphorus in the loch, the various contributions to total input and implications for their control.

The study, which took account of earlier work on this subject, concluded that point sources continued to contribute the major part of the total loading, but new measurements would be required to determine the relative contribution of each source. Several factors had changed since measurements were last taken in the late 1970s. It was believed that increases in amounts of sewage and industrial effluent released were reflected in increasing phosphorus levels. In addition, phosphorus contributed by rainwater falling directly on the lake, by run-off from agricultural land and by wildfowl faeces was not reliably quantified.

As a result of these findings, a new project was set up funded by several public bodies including the EEC. This project involved the sampling of the loch and all its inflows at eight-day intervals. This interval was chosen because concentrations of phosphorus were considerably higher on Tuesdays to Fridays than on other days. Levels of phosphorus downstream of the sewage treatment works were found to be considerably higher than those upstream.

The study also found that dissolved phosphorus is a characteristic of larger rivers receiving treated sewage, whereas particles containing phosphorus are more likely to be found in smaller streams where road drainage is the major source of the pollutant.

Water from the mouths of various streams was also sampled to measure levels of nitrate and dissolved silica. This is part of a larger study relating river height and chemical concentrations. Other related projects focus on inputs of phosphorus from rainwater, wildfowl faeces, selected agricultural areas and through natural recycling taking place in the loch itself.

The Effects of Decontaminating Gruinard Island of Anthrax

Gruinard Island was contaminated with long-lived spores of a virulent strain of anthrax during biological warfare trials in 1942/43. This contamination precluded occupation by man or livestock. Studies since 1978 had shown that viable anthrax spores are only present over an area of 3ha and this area can be effectively disinfected using a solution of formaldehyde.

The ITE was commissioned in 1983 to advise the Chemical Defence Establishment on the likely ecological consequences of applying a solution of formaldehyde in sea-water.

Main concerns were damage to the vegetation, the possibility of subsequent peat erosion and run-off pollution of the seashore. Several small experiments were carried out to determine the scale of these effects.

The experiments indicated that the vegetation of the treated area would be almost entirely destroyed by the formaldehyde. Main species involved were grasses, heathers and mosses. However, about 2% of buried viable seeds would survive, enough to begin regeneration. The burning of the vegetation was also recommended prior to disinfection, as burning aids germination and moss development.

Experimental plots showed that erosion would not be significant, because of the shallow slope of the site. Soil microbial populations and soil decomposition processes will recover within a few months as formaldehyde, while toxic, is also biodegradable. The re-establishment of these processes will be enhanced with the application of NPK fertiliser.

Antibiotic Resistance in Bacteria

FBA scientists were surprised by the results of a study undertaken in 1985 into antibiotic resistance in the natural environment. Resistance to antibiotics in bacteria was chosen as a convenient genetic marker, as some bacteria are known to develop a resistance to the antibiotics used in medicine and agriculture. Contrary to expectations, a higher incidence of resistance was found in bacteria isolated from Windermere than in those deriving from the sewage sludge entering the lake. Still more surprising was the even higher incidence found in two remote upland farms. It appears that bacteria possess or can develop resistance to antibiotics by a mechanism other than the transfer of genes. The nature of that mechanism is the subject of further investigation by the FBA.

The Effects of Heavy Metals on Invertebrates

Woodlice play an important part in the decomposition of woodland leaf litter. They are also known to accumulate high concentrations of zinc, cadmium, copper and lead in their hepatopancreas and were thus chosen as the principal subject of a study of the effects of heavy metals on invertebrates, carried out by a small team of researchers at the University of Bristol.

Decontaminating Gruinard Island of anthrax.

Laboratory studies showed that there were no differences between the growth, fecundity and survival of woodlouse *Oniscus asellus* from contaminated and uncontaminated sites. Woodlice appear to be able to store heavy metals in the hepatopancreas until that organ becomes overloaded and begins to show abnormalities. Storage capacity varies for different metals: copper is retained permanently, whereas zinc is excreted when the woodlouse is fed on uncontaminated litter.

The dynamics of heavy metals in centipedes, millipedes and spiders were also studied by the team, the first time this has been undertaken. Even when fed on contaminated woodlice, the centipedes were shown to possess mechanisms which prevent potentially toxic metals from reaching vulnerable organs.

Animal/Microbial Interaction in Soil Biological Processes

At Exeter University scientists have demonstrated that even small animal populations can have a significant effect on mineral element fluxes in acid, deciduous forest soils. Specifically, animals disrupt the time-course of microbial mineralisation processes. Litter-feeding fauna may have a critical role in effecting an early release of nitrogen from fallen leaves, thus allowing them to enter the humus layer in a shorter time than would occur in the absence of feeding invertebrates.

Tick-Borne Viruses

To understand the factors governing the maintenance of arthropod-borne or arboviruses, studies are being carried out to examine the interaction between tick-borne viruses and their hosts. These studies are being carried out both in the field and in the laboratory.

Arboviruses are the largest ecological group of viruses. They replicate in vectors (or carriers) which include mosquitoes, midges or ticks, and are transmitted to a vertebrate host when the vector takes a blood meal. Although many arboviruses cause important diseases of man and domestic animals, such as yellow fever and encephalitis, nearly all of them circulate in a cycle involving wild animal populations. Most studies on arboviruses have focused on mosquito-borne viruses and an attempt is now being made to redress the balance by investigating tick-borne viruses, the second largest group.

Field studies involve the circulation of tick-borne viruses in seabird colonies. Ticks are collected bi-annually from a study site at St. Abb's Head, Scotland. These ticks have been shown to carry several different types of virus. One group in particular has developed an ability to bypass immunity developed in an animal population. The systematic collection of ticks from the same site enables examination of the development of this ability.

Genetic studies are also being extended to determine whether viruses from St. Abb's Head can interact genetically with similar viruses from seabird colonies in Iceland, Newfoundland and the Sub-Antarctic.

The Taxonomy of Large Amoebae

Scientists at the ITE's Culture Centre of Algae and Protozoa (CCAP) have completed an extensive study of the taxonomy of the family Amoebidae. Sixteen strains of amoeba were collected from seven countries. Specialists taking part were based in the UK, the USSR, Denmark and the Netherlands. The Leningrad Institute of Cytology provided several isolates for the study, as well as contributing to collaborative papers.

Amoebae are widely used for cell biological work. They also attract attention due to their ingestion of both algae and protozoa. Despite these interests, little attention has been paid to the identities and relationships of different strains.

Of the various characters studied in order to classify the amoebae, those concerned with morphology or form were studied in the UK and non-morphological (eg chemical or behavioural) characters in the USSR. Although the study involved the use of sophisticated or lengthy tests to confirm taxonomic distinctions, the results obtained were used to identify characters which are easily discernible using microscopes widely available to interested scientists.

The 16 strains studied proved to be ten species belonging to six genera. Several other discoveries were made including the establishment of a new genus, the re-classification of organisms closely resembling *Amoeba proteus* into several species and the previously unrecognised close relationship of two genera.

The validity of characters identified for use in the classification of species was tested using strains of *Amoeba proteus* gathered in the USA and the USSR. They duly proved indistinguishable using the tests established by ITE scientists.

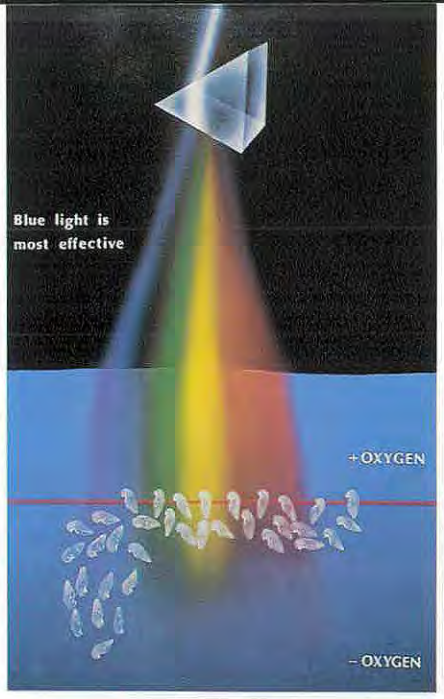
Loxodes

Loxodes is a large (0.1-0.6mm), primitive, freshwater ciliated protozoon. It feeds on algae and most other organic particles bigger than about 5μm. It can be extremely abundant in productive lakes where its total weight may be several times that of fish. It was studied to determine the principal factors controlling its distribution in lakes, and to understand how the underlying physiology relates to its ecology.

Loxodes leaves the sediment of a pond or lake when oxygen there becomes exhausted. Cells migrate into the water and they become most abundant close to the boundary between water with some oxygen and water without. However, significant populations of *Loxodes* are also found where oxygen is not present and peak abundance is often in such water. After investigation, it was found that *Loxodes* is able to respire nitrate when deprived of oxygen, an ability not otherwise known in such organisms.

The characteristic vertical distribution of *Loxodes* observed in ponds and lakes could also be produced in test-tube cultures in the laboratory. Individual *Loxodes* were then observed to swim upwards when in water devoid of oxygen and downwards when oxygen levels were high, so *Loxodes* was capable of responding to both gravity and the oxygen tension. Gravity response is otherwise unknown in protozoa. When oxygen was present but at low levels, and in the dark, motility decreased and the cells aggregated in such conditions.

Further investigation revealed that a series of complex sub-cellular organs containing minerals present in *Loxodes* were probably sensing gravity. The mineral concerned is



Loxodes response to blue light.

barium sulphate and the barium in *Loxodes* accounts for most of the barium occurring as particles in the water bodies studied.

Loxodes is also sensitive to light and when oxygen is present, high light levels lead to the death of *Loxodes*. Both light absorption and the organism's responses to light of different colours indicate that the pigment involved senses blue light. Relatively low light levels will initiate a variety of behavioural responses including movement downwards in response to gravity which propels *Loxodes* into water without oxygen. These observations explain the frequent absence of *Loxodes* from the oxygenated water of lakes during the day. Light and oxygen probably influence *Loxodes* through a common receptor (cytochrome oxidase) which responds to fluctuating intracellular levels of an oxygen radical (e.g. superoxide). Gravity, light and oxygen are clearly the principal interacting factors controlling the distribution of *Loxodes*. The detailed nature of the interactions remains to be unravelled.

Environmental Influences on Dace

The dace is a member of the carp family and is found over a wide area of England, Wales and mainland Europe in clear, fast-flowing rivers and streams. In the upper reaches of the chalk-streams of southern England, its population is at a level which occasions culling, as the dace is supposed to compete with the brown trout for food and space. Further downstream, where fishing is predominantly for salmon, the dace is rarely culled as it is itself fished during the salmon close season.

A characteristic of the chalk-streams inhabited by the dace is their relatively stable flow regime. This is because these rivers are fed by springs and boreholes in the chalk and not by surface run-off after rain has fallen on the surrounding area.

The relative importance of abiotic (i.e. non-living) and biotic factors on fish populations is disputed. The interaction of these factors is complex and quite small fluctuations in conditions can have an important effect. A study was conducted into the environmental factors influencing dace populations.

The age-structure of the dace population in the River Frome was analysed over a 12 year period: the results showed that fish from some annual spawnings were disproportionately represented in the total population.

The strength of these year-classes is determined in the first year of life and so the study concentrated on factors which may affect dace at the egg and larval stages.

Dace caught and marked on a site at East Stoke on the River Frome showed that although spawning grounds tend to be used over a period of years, the same fish do not always return to the same location.

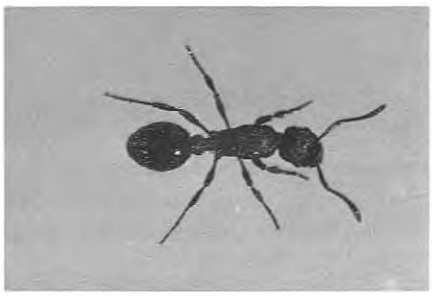
Dace lay adhesive eggs on gravel beds in March or early April. In 1979 mortality at the East Stoke site was estimated to be in the range of 78 to 91%. Although some eggs were washed away and others eaten by invertebrates or fish, most egg mortality was attributed to oxygen starvation as a result of eggs having been deposited on an unfavourable substratum or being covered by silt deposited during incubation. Water temperature affects the length of the incubation period, but fluctuations from year to year either in temperature or in the risk of predation were not sufficient to account for the wide variation in year-class strengths.

Dace larvae first appear in the River Frome during mid-April to early May. They are washed downstream to areas of lower water velocity. After two or three days they start to feed on plankton, chironomid larvae and other small invertebrates. The availability of food did not constitute a limiting factor for the dace larvae. However, the size of dace during their first winter varied considerably from year to year.

This was found to have some correlation with summer temperatures, warm summers producing faster growth rates; this effect was not uniform, however, as two years with similar summer temperatures produced widely different growth rates. Water temperature around hatching was found to have another indirect effect in that smaller larvae were found to be more likely to fall victim to invertebrate predators.

Dace.

Red Ant Queen (*Myrmica sulcinodis*).



The influence of temperature alone was found to be insufficient to explain variations in year-class strengths. Other factors were involved, including the availability of refuge areas from fast-flowing water and variations in temperature in different areas of the river.

A study of older dace revealed that, in general, high water temperatures resulted in fast growth rates. This was also true of the abnormally hot summer of 1976, although eggs produced the following spring were considerably reduced in number and size. The older a dace is, the more energy it is likely to put into reproduction rather than its own growth and survival; this is likely to result in increased mortality.

River Frome dace are an important food source for the pike. However, variations in the number of dace consumed from year to year are thought to be small.

The variation in size of dace year-classes is largely the result of the influence of abiotic factors, chiefly water temperature. Such variations are offset by the long breeding life of the female, which may last for as many as nine seasons. Young breeding dace tend to put more effort into their own growth than into reproduction, and this probably enhances their chances of survival. The dace is also able to vary the number and size of eggs it produced, although the advantage of this is not yet known.

The Psyllids of the Panamanian Rain Forest

Based at Liverpool Polytechnic a project team has produced a description and classification of the psyllids (jumping plant lice) of Panama. Thirty-five genera were identified, containing 139 species of which 101 are new to science. Those species present in the lowland rain forest were found to be similar to those of the Amazon basin. However, psyllids occupying more mountainous sites included north temperate, Andean or South American groups. One unusual species has its closest relative in New Guinea.

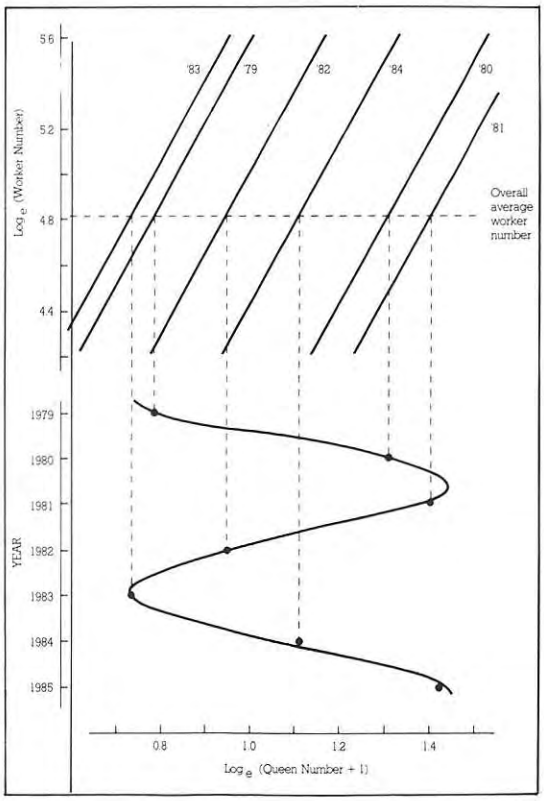
The data collected during the study give a fascinating insight into the evolution of the Psylloidea, suggesting that the fauna of temperate South America is closely related to psyllid groups found in southern Africa. The project team has been awarded further funding to examine the relationship between psyllids and their host plants.

Red Ants

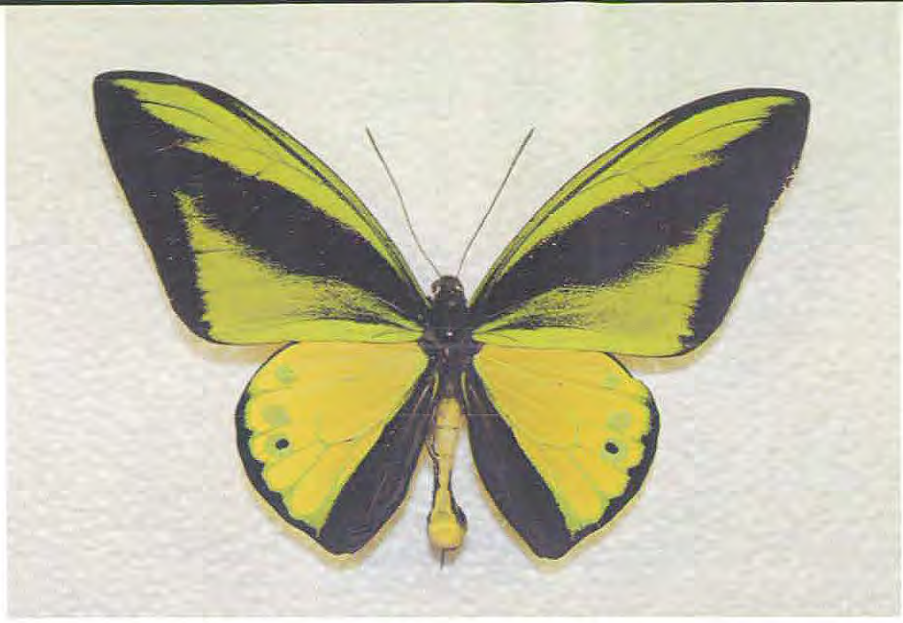
Ants, bees and wasps (Hymenoptera) are haplodiploid: that is, males develop from unfertilised eggs and females from fertilised eggs. Workers are females that fail to achieve their full sexuality. If the colony is monogynous (has a single mother queen) the average relatedness of all individuals is 3/4. This degree of relatedness had been used to explain the social behaviour of many species of the Hymenoptera. However, this theory is somewhat weakened by the existence of any colonies, living as highly organised societies, where there is more than one fertile mother queen and average relatedness is 3/8 or less. This type of organisation is known as polygyny: it is currently best explained as an adaptation to meet the challenge of new or difficult habitats.

In 1979 a study was initiated of red ant colonies occurring in Scotland and southern England. The Scottish ants were largely monogynous and the English polygynous: it was expected that the reasons for this would be related to habitat. However, test samples taken from two sites in Dorset showed that the number of queens in both colonies had changed dramatically and very similarly from one year to the next. This forced the abandonment of the original study and the Dorset sites were sampled subsequently on an annual basis.

The regression of queens against worker numbers was calculated and plotted for the years 1979-84. The two sites gave results so similar that they were combined into a single data set. The predicted queen number at the overall average for worker number for each year is projected downwards on to a time scale. A sine wave accounts for about 90% of the variation between these predicted means. The chance of two waves of the same form being obtained randomly at two separate sites is about 0.3%.



Regression of queens against worker numbers in colonies.



Male Birdwing (*Ornithoptera goliath*)

Furthermore, this wave was used to predict 1985 queen numbers, which fitted well with data obtained from the field.

It appears likely that the average number of queens in these ant colonies in Dorset varies in cyclic manner with time and is also linked to worker numbers.

The most likely explanation for the cycle in queen numbers is the periodic recruitment of new queens with a short life span. However, it is difficult to understand why most colonies should be in phase with each other. This phasing could be caused by a past environmental catastrophe or some other continuing cyclic environmental pressure: the explanation has yet to be determined.

This work has shown that it is doubtful whether the level of polygyny of a species can be accurately assessed from one sample of nests. It also questions the value of data used in the past to support theoretical debate on the role of polygyny as most of these are for single species from single sites, gathered in a single year.

Butterfly Farming in Irian Jaya, Indonesia

Irian Jaya, the western half of the island of New Guinea, is the poorest and most sparsely inhabited province of Indonesia. Mindful of the concept of 'conservation for development' as formulated in the World Conservation Strategy of 1980, the World Wildlife Fund joined with the ITE and the United States Agency for International Development (USAID) to undertake a study of the potential for a butterfly farming scheme to be established in Irian Jaya.

The butterfly fauna of south-east Asia is exceptionally rich, with large populations of both swallowtail and birdwing butterflies. This situation has been used to advantage in Papua New Guinea, where the Insect Farming and Trading Agency (IFTA) has assisted individual butterfly farmers to supply the specialist and also part of the decorative market without damaging wild faunas.

In early 1985, four field trips were made into undeveloped areas of Irian Jaya in order to assess their potential for butterfly farming. Only in one area was there any trade in butterfly specimens and no farming was undertaken. Interest in the project was shown by mission organisations and other bodies working to improve the welfare of the indigenous people. Discussions were also held with expatriate funding bodies and with government agencies including the Directorate-General of Forest Protection and Nature Conservation.

The study group concluded that an agency similar to IFTA in Papua New Guinea should be established in Irian Jaya. This agency would need to offer considerable support to farmers if butterfly farming were to become a source of income for the rural poor. It seems likely that such an agency will be established, funded 75% by USAID and 25% by the Catholic Church in Irian Jaya.

Birdwing butterflies are protected under both Indonesian law and international convention. However, it has been proposed that either the planned agency be granted an exclusive licence to trade in these species or some might be removed from the protected list. There are substantial reserves in Irian Jaya, which would remain as a protection for these species.

Dispersal of Young Sparrowhawks

The population dynamics and ecology of the sparrowhawk have been the subject of extensive research by the ITE for many years. One aspect of this bird's ecology recently investigated was the post-fledgling period and dispersal of the young. Eight young birds from four different broods were marked with back-mounted radio-transmitters while in the nest and their activities monitored for a period of six weeks. At the study area, in Rockingham Forest in the East Midlands, sparrowhawks had previously been absent for about 20 years, probably because of pesticide use. The objectives of the study were to discover the duration of the post-

Young Sparrowhawks

fledgling period and to learn of subsequent movements and distances travelled on reaching independence.

The young left the nest some 26-30 days after hatching and remained within the nest vicinity for a further four weeks. They were thus dependent on their parents for a total period of about two months.

Immediately prior to dispersing, the young were noted to be constantly calling for food, suggesting that their parents had reduced their food supply and that this action initiated dispersal. One bird dispersed at about 65 days after joining an adjacent brood and leaving when it did. Such incidents are not uncommon in sparrowhawks and further support the idea that the parents control the date of dispersal. Stopping the supply of food appears the most obvious method. To test this idea, in 1985 a further four broods were experimentally provided with additional food at the nest for some weeks beyond the normal dependence period. Compared with unfed broods, these birds remained in the nest vicinity for a further two to three weeks, apparently relying entirely upon the experimentally provided food. They dispersed when food was no longer given.

Energetics of the Annual Cycle in Birds

The interim results of a study led by Dr D M Bryant of the University of Stirling on the energy expenditure of a number of bird species indicate that the size and mass of a bird, together with the length and nature of its activities are of greater importance to its annual-cycle patterns of energy expenditure than are climatic influences.

Analyses of the energy used by dippers and robins in pursuing their annual cycle of activity showed the rearing of young to be very demanding of these birds' energy resources. However, ringed plovers showed particularly high energy use in the incubation period. A provisional interpretation of this result is that the bird suffers considerable heat loss in incubating large eggs on stony ground.

The Effects of Population Density on Red Deer on Rhum

A team from the University of Cambridge reported in November 1985 on its study of red deer on Rhum. Among the team's findings was that the early development of the female has pronounced and probably irreversible effects on reproductive performance and breeding success. Early development is itself profoundly influenced by climatic conditions and thus climatic differences between years produce substantial variations in reproductive success between year-groups of red deer. This effect may be an important feature of the population dynamics of many long-lived vertebrates. NERC has agreed to continue the funding of this research up to 1988.

Reconciling Conservation and Amenity with Timber Production

The UK imports 91% of its timber needs at a cost of £4000 million per annum. In common with other EEC countries, consumption is forecast to increase by 50% by the year 2000.

As world demand for timber rises, there have been calls for an increase in the afforested area of Britain. These have been strengthened by recent moves to reduce agricultural surpluses within the EEC, which are likely to release agricultural land for possible afforestation.

Coincidentally, as these economic pressures have been building, so has concern for conservation of the natural environment. A 1985 amendment to the 1967 Forestry Act has enhanced the Forestry Commission's role in the conservation of the beauty, wildlife and general amenity of the countryside, with particular attention given to the planting of broad-leaved trees.

A large-scale afforestation programme must be based on sound ecological data if all parties are to be satisfied that damaging influences concerned with commercial forestry will be kept to acceptable levels. Indeed, the interests of agro-forestry, surrounding agriculture, conservation and recreation may all be in conflict at some point.

The ITE is equipping itself to provide sound advice on the design and management of new and existing plantations, in order to retain or increase specific conservation or amenity features.

In order to meet this need, the woodland research of the ITE needs to be restructured and to this end the Institute intends to undertake a review of conservation and amenity in plantation forests. This will detail the current state of national and international knowledge and assess priorities for research. In order to canvass opinion, discussions have been held with staff of universities, the Forestry Commission, the private forestry sector, the Ministry of Agriculture Fisheries and Food, the Nature Conservancy Council, the Countryside Commission and the Royal Society for the Protection of Birds.

Shade Tolerance of Woody Seedlings
In 1985 the University of Lancaster conducted a one-year study into the possible link between the shade tolerance of woody seedlings and the maintenance of cell rigidity due to the uptake of water (turgor). Shaded beech seedlings were found to exhibit only half the leaf turgor of those exposed to a higher level of irradiance. The growth of low irradiance seedlings was shown to be restricted as compared with those receiving greater amounts of light. This was particularly evident in root growth, a factor which could be critical in the maintenance of turgor when beech seedlings are in competition with other species. Some interesting differences were found between the species studied with regard to shade tolerance, suggesting that lime seedlings may be most tolerant of deep shade and that processes other than turgor maintenance contribute to the shade tolerance of woody species.

Resource Capture and Utilisation
The Unit of Comparative Plant Ecology (UCPE) has undertaken a series of studies to determine the part played by resource capture and utilisation on the survival of native herbaceous species

One study involved the physiological consequences of switching grasses from one set of growing conditions to another, these simulated conditions being approximately typical of the four seasons as actually measured in the field. The three plant species studied were assessed for growth, inorganic mineral nutrition and biochemical composition over a period of seven weeks, with a change in 'season' effected after three weeks.

The experiment itself was completed within two months, but analyses of the 58,000 data required a further nine months

The greatest dry-weight increase was found in those plants subjected to a spring/summer regime, followed by those subjected to summer/autumn, winter/spring and autumn/winter regimes respectively. This effect held for all three species studied. Where the second phase of the regime was either summer or spring the rate of dry weight increase was maintained or increased, while a second phase of either autumn or winter led to a marked reduction (see fig).

Although one species showed consistently lower weight gain over the seven-week period, it tended to fare better than the other two when the first phase of the regime was either autumn or winter.

Root Growth and Plant Survival
A second UCPE study examined the relationship between soil temperature, root growth and phosphate uptake in two grass species, in order to assess the importance of root growth for the survival of plants growing in heterogeneous and infertile soils.

The soil around the roots of a plant acts as a buffer from seasonal changes in air temperature. This effect is more pronounced at deeper levels and thus creates a vertical temperature gradient which varies in magnitude and will reverse with seasonal change.

Seeds of the two species studied were sown in September 1983. The air temperature and the soil temperature at two levels were recorded. Root and shoot growth were measured as dry plant weight at monthly intervals. Phosphate uptake was also estimated

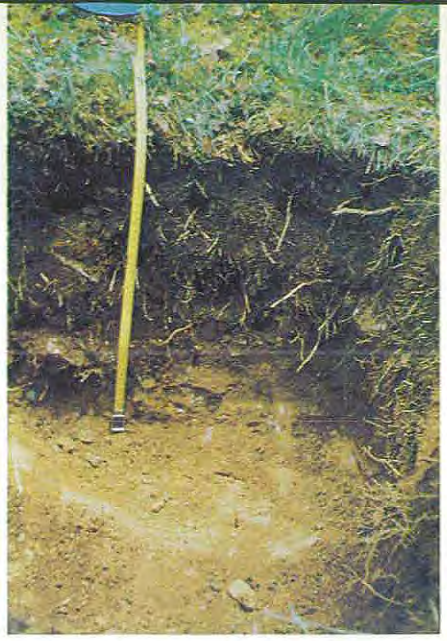
The results showed that there was no significant difference in overall phosphate uptake by the two species. However, the more shallow rooted species produced a smaller dry weight of root biomass and was therefore more efficient in its uptake per gramme of root. Although this species took longer to establish deep roots, it also tended to cope better with winter conditions, deriving more phosphate from its lower roots in the winter months and resuming both root and shoot growth earlier in the year

The Cycling of Nutrients from Dying Roots
At the University of Bristol a study has been conducted of the transfer of phosphorus between the roots of adjacent grassland plants. It has discovered that infection of the roots by fungi forming a symbiotic association with the plant (mycorrhizas) substantially increases phosphorus transfer between intact plants. When roots are detached from their shoot, a substantial proportion of their phosphorus can be transferred to an associated living plant as a surge completed with two or three weeks. If the plants are mycorrhizal the surge is larger and completed sooner. This is believed to take place through the filaments of the fungus. Such a rapid transfer mechanism could be an important factor in phosphorus cycling in grassland.

Life Cycle Strategies of Annual Salt Marsh Plants
A team at the University of East Anglia has found interesting genetic differences between populations of annual plants growing in different zones of a salt marsh. The study involved both predominantly in-breeders (*Salicornia species*) and out breeders (*Svaeda maritima*). Numerous genetically differentiated populations were found to be characteristic of particular microhabitats within the environmental mosaic and gradients of the salt marsh. Although in the main these populations are morphologically similar for most of their life history, they show significant differences in behaviour. These differences in life history trait have been shown from transplant experiments and reproductive success, to be adaptive.

Heat and Water Relations in Tree-line Vegetation
At the University of Edinburgh the ability of dwarf woody plants to survive at higher altitudes than taller vegetation is being studied. Results obtained in 1985 tended to confirm the theory that short vegetation, being aerodynamically smooth, retains more heat than taller plants. However, in collecting a considerable volume of data on both the weather and its effect on vegetation at the sites studied, it was found that the variation in net radiation at different altitudes when the sun is shining was considerably greater than anticipated. Also unexpected was the difference of 6°C between air temperature and that of the apex of the pine trees studied. Further investigation of the aerodynamics of pines using a wind tunnel is planned.

A humus-iron podzol developed under heather.



A brown podzolic soil developed under birch, similar to profiles characteristically developed also under bracken, juniper, and bent-fescue grassland.

Soils in the Scottish Highlands

In the Scottish Highlands, as elsewhere in the UK, vegetation patterns have been changing since the end of the last ice-age as a result of climatic changes and, more recently because of interference by man. Below the mountain tops, the different vegetation types owe more to past management for sheepwalk, deer forest and grouse moor than to differences in underlying soils. Indeed, the direction of influence has tended to reverse as vegetation changes can profoundly alter many soil properties including pH and nutrient cycling rates. These plant influences can have major effects on the poorly buffered, relatively freely drained, sandy soils of the Scottish Highlands, whereas on well-buffered soils typical of much of the lowlands, their effects are minimal.

Two contrasting types of soil change tend to take place on well-drained soils in the Highlands. Stands of birch, aspen, bracken, bent-fescue grassland and probably juniper tend to make soils less acid, with relatively high rates of nutrient cycling and also restore the leached surface layers of podzolic soils through biological mixing. In contrast, stands of Scots pine, most exotic conifers, heathers, gorse, broom, mat-grass and wavy hair-grass acidify and impoverish the surface soil.

This study by ITE of land use and vegetation in the Highlands has revealed three patterns of change. Low grazing pressures and little or no burning of the vegetation will encourage the re-establishment of both birch and pine woodlands: this appears to be the most natural pattern for the Highlands today, with the species exerting alternating influences on the soil. In contrast, where high grazing pressures and/or frequent burning occur, the trend is towards the development of bent-fescue grassland. Between these two extremes, trends are much more varied and opposing effects on soil condition may tend to cancel each other out.

Further study is being carried out to determine the rates of vegetation and soil change and their frequency in a given area. It is hoped that the results will provide a better understanding of the vegetation changes resulting from different land management practices and that this can be used to model future changes on a small or large scale. It is also planned to combine the results of this study with others to provide an integrated picture of changes not only in soil types but also in bird and animal populations.

Scientific Services

NERC Scientific Services (NSS) co-ordinates the provision of a number of specialised services in support of NERC science. Although the organisation structure for the provision of these services will change at the beginning of next year to that shown in the Appendices it has remained basically constant throughout the year in question as follows

- NERC Computing Services (NCS) responsible for computing and image analysis production facilities;
- Headquarters Technology Division (TD) responsible for the equipment pools and analytical services, aircraft, cruise programme and marine planning functions and the technology audit. This division is also responsible for the administrative computing and the office and library automation projects
- Research Vessel Services (RVS) responsible for the provision of research ships and marine equipment;
- NERC Unit of Thematic Information Systems (NUTIS) responsible for research into the management, analysis and display of remotely sensed and digital map data. This is a specialist research unit and is based at the University of Reading

During the year the Services and Facilities Committee was set up to take responsibility for all the services and facilities supported by Council. As a sub-committee of Council it met twice last year and set up ad hoc groups to advise on the provision of isotope facilities, on replacement options for RRS *Discovery* and on autonomous submersibles

The NERC Computer Services

In May 1985 Council agreed a new strategy for scientific computing with an investment of £8.5m spread over five years. This is a major commitment to computing intended to provide NERC scientific staff with a significantly improved capacity and quality of service. The objective is a distributed computing environment, using the JANET network, which is responsive to the needs of the science programme.

Over five years most of the major NERC sites will be re equipped with facilities appropriate to their needs. There will be larger levels of investment at Keyworth and Wallingford and the computers at these sites will be available to all NERC scientists who need either a higher level of processing power or other special services

The new strategy is based on restricting all equipment to conform either to IBM or DEC VAX architecture. This will improve long term planning and will allow access to the wide range of readily available software already developed for these major systems. The use of industry structured software products will enable NCS developed software to be phased out of service with resultant savings on staff and support costs

So far a DEC VAX 8600 has been installed at Keyworth and an IBM 4381/3 at Wallingford. The combined capacity of these is five times that of the Honeywell which they replace. Four microVAX computers have also been installed

Major software purchases have also been made. ORACLE has been purchased for both systems and will form the basis for the development of NERC scientific databases for the next few years. The GKS Graphics Kernal Software has also been installed on both systems.

Network services have continued to improve and demand for new connections is increasing rapidly. Reliability is of the utmost importance and older equipment, which has been unreliable in the past is being phased out.

Image analysis systems have been deployed at Keyworth and Bangor and the services at Swindon continue to be heavily used. Problems with the quality of the image analysis software have now been resolved and the service across all three sites improved.

The existing GEC systems have been enhanced to accommodate more data storage. Peripheral equipment such as plotters and terminals continue to be purchased, especially to replace older equipment. The number of personal computers in use in NERC has increased considerably, with the IBM PC and its compatible rivals becoming the standard

The use of external computing

services has remained at a constant level and NCS continues to provide support for this. Although the facilities at London and Manchester are inconvenient to use, new facilities to be provided under the Programme for Advanced Research Computing may prove more attractive.

In order to deploy staff more effectively NCS is no longer undertaking to develop applications programs for institutes and has ceased to develop special purpose hardware.

The new computer strategy has resulted in redeployment of staff away from Swindon. At the same time, the overall level of staffing has been substantially reduced.

- **Technology Division**

This Division is responsible for all the services listed below. During the year it advised Council on NERC's response to the UGC/ABRC/ Computer Board Committee on the requirements for Advanced Research Computing and its involvement in the new British National Space Centre. A member of the Division is seconded to the Policy and Planning Group of the BNSC. It is also responsible for the introduction of personal computing and automation into offices and libraries.

Marine Planning group formulated the 1986/87 ship cruise programme and are involved with the consultants and the shipyard responsible for the conversion of the RRS *Challenger*. The Technology Audit group continues to monitor and advise on the purchase of major capital equipment and undertakes 'technology audits' on-site to ensure that NERC gets the best value possible for its purchases.

- **Radio Carbon Dating**

The Radiocarbon Laboratory (RCL) is now in its second decade. A publication entitled 'NERC Radiocarbon Dating' summarises the RCL's contribution to environmental study and highlights its international reputation.

This year 248 age measurements were supplemented by over 500 determinations of stable isotope enrichment, 20% higher than 1984/85. Thirty-one individual research titles were supported covering sites ranging from Iceland to Antarctica, and such diverse topics as: 'Hydrological and Geomorphological aspects of flash floods in Upper Teesdale', 'Investigations into the Upper Quarternary vegetational and climatic history of East Africa' and 'Organic matter diagenesis in pelagic sediments of the equatorial Atlantic'.

In-house research has advanced on several fronts. Improved experimental procedures for the quantitative separation and recovery of carbon, oxygen and nitrogen from organic materials were developed and the long term study of carbon and nutrient cycling in forest soils was extended. Another project questioned whether differential peat growth can significantly prejudice the interpretation of pollen diagrams and radiocarbon age measurements.

At the request of the international radiocarbon dating community, the RCL is collaborating with Glasgow University in a comprehensive inter-calibration exercise. A suite of reference materials is being prepared for worldwide distribution to at least 50 participating laboratories.

- **Equipment Pools and Analytical Facilities**

Demand for stable isotope analyses from universities, BGS and IH has remained high. The BGS laboratories completed over 3000 carbonate, organic carbon, silicate oxygen and sulphur analyses and 1500 hydrogen and oxygen analyses.

Replacement of the mass spectrometer for sulphur at Gray's Inn Road remains outstanding, and only very restricted use of this equipment has been possible. Until the mass spectrometer for sulphur is replaced, the Scottish Universities Research and Reactor Centre has kindly made available facilities to Gray's Inn Road customers.

Meanwhile, the Stable Isotope Facility for Terrestrial and Freshwater Life Sciences, based at ITE Merlewood, became fully operational during the year.

Loans of equipment for ten projects were made during the year from the Seismological Equipment Pool and during the summer months, every item of pool equipment was in use on major projects in Iceland and Kenya.

Conversion to digital recording technology has progressed, with completion of a batch of event-triggered recorders.

Two prototype continuous video recorders under development should be available next year. A satellite position-fixing system is now available for loan from the pool to make best use of the increased accuracy of the digital recording systems.

Fifteen applications for loans of equipment from the Geomagnetic Equipment Pool were approved for use on projects in the UK and Europe, including participation in the EEC Geothermal Programme. The newly acquired SPAM Mk II has been in continuous use and a second system will be available for loan in 1986/87. An improved low-cost fluxgate magnetometer developed by the pool will be replicated to replace existing equipment. Meanwhile the pool has been moved from Hartland, Devon to Edinburgh and merged with the Seismological Equipment Pool to take advantage of common expertise.

The Automatic Weather Station Equipment Pool now has 14 complete weather stations for loan. Projects supported have ranged from the energetics of bat communities to evapotranspiration from a Tunisian salt marsh.

- **Remote Sensing Planning and Co-ordination**

National developments, in particular the formation of the British National Space Centre (BNSC) and the US invitation to Europe to participate in the International Space Station programme, have focused attention in space systems and remote sensing. NERC, as a founder member of the BNSC, has been fully involved in assessing the value of the proposed Space Station elements for remote sensing missions.

Other national developments have concerned Geographic Information Systems and NERC has submitted evidence on current arrangements and future issues to the DOE Committee of Enquiry into the Handling of Geographic Information.

Airborne remote sensing continues to be important and the NERC aircraft has been used as the basic platform for

The NERC Piper Chieftain used to support airborne remote sensing campaigns in the UK.

a series of multispectral scanner campaigns. Additionally the aircraft has been used for aerial photography for ITE land-use projects and grey seal counts for SMRU.

NERC also participated in the joint Australian airborne remote sensing programme carried out over test areas in Australia. Scientists gained experience in the NASA Advanced Imaging Spectrometer (AIS) and the Thermal Infrared Multispectral Scanner (TIMS) instruments.

The satellite receiving station at the University of Dundee continues to acquire data with increasing emphasis placed on the Advanced Very High Resolution Radiometer (AVHRR) on the NOAA satellites as the Coastal Zone Colour Scanner (CZCS) on the Nimbus 7 satellite reaches the end of its useful life.

Much of remote sensing is still experimental and methods continue to be developed to use the improved capabilities of sensors flown on such satellites as SPOT and Landsat-5. The NERC remote sensing special topic plays a key role here and significant progress was made by the university teams carrying these projects in demonstrating the utility of the new generation of satellites for NERC science. A new special topic programme aimed at analysing microwave backscatter mechanisms over the land surface will be carried out jointly with the Royal Aircraft Establishment at Farnborough.

Administrative Computing
The new financial and personnel systems on the joint NERC/SERC computer at Swindon are in the later stages of implementation. The personnel data is established and a live system is available in Polaris House and to ITE, IOS and BAS. During the next year other sites will be equipped with terminals and access to the system will be extended. Individuals will be given the opportunity to confirm and correct their own records.

The new financial system will go live for headquarters and selected sites during 1986/87, with general ledger, bugetary control, accounts payable and costing systems available.

The NERC Unit of Thematic Information Systems
This new Unit based at Reading University is concerned with developing techniques for the management, analysis and display of remotely sensed and digital map data. The objectives of the Unit include the improvement of storage, retrieval and manipulation of spatial data. Also, developing techniques to take advantage of remotely sensed data and improving methods of cartographic display. The research programme is monitored by a steering committee.

Collaborative works are being carried out with universities, government departments and private companies including NASA and SPOT projects. The range of interests covered is wide including: the Role of Thematic Mapper Data in Monitoring Sediment Transport systems in a Semi-Arid Desert Environment; a UK Alvey Information Technology project on Knowledge-Based Segmentation of Remotely-Sensed Images; and Expert Systems for Automated Map and Image Product Design.

The Unit has a VAX 11/750-based image analysis system, a microVAX-based mapping system and a PERQ-based colour graphics workstation.

Research Vessel Services
RVS faced keen financial pressures so three of the four vessels operated from Barry were laid up for much of the year. RRS *Discovery* was refitted in this period while RRS *Challenger* began a conversion to diesel-electric operation. RRS *Frederick Russell* was laid up from December to mid-March 1986, when her propulsion system was damaged. Meanwhile a 12km long deep-tow electric cable and the first phase of a containerised ultra-clean chemistry laboratory were installed on board RRS *Charles Darwin*.

RRS *Charles Darwin* undertook eight cruises through the year. Four for IOS and one each for IMER, University College London, Leicester University and SMBA. The work covered physical oceanography, geophysical and geological investigations of the Earth's crust, biochemical studies and equipment trials. *Charles Darwin* was also exhibited at the Pool of London and at the Oceanology International Exhibition at Shoreham.

RRS *Discovery* undertook three cruises – one for Cambridge University investigating geological/geophysical data in the North Atlantic and two for IOS investigating plankton. Following its refit the vessel returned to service in March 1986.

RRS *Challenger* undertook seven cruises during the year. Three for SMBA and one each for IOS, Aberdeen University and University of East Anglia. DAFS Aberdeen also chartered the vessel for one cruise. The projects included physical oceanography, seasonal investigation of fish populations, benthic biology, live fish sampling and sediment investigations.

RRS *Frederick Russell* undertook 12 cruises of which four were for MBA, one for IMER, three for IOS, one for SMBA, one for Queen's University Belfast, one for University College of Wales Aberystwyth and one charter for Racal Surveys. These included biological, biochemical, hydrographic, geological and benthic investigations. Following damage to the main gearbox, *Frederick Russell* was taken out of service in late March for repairs.

Charter Vessels 1985/86. Six vessels were also chartered for BGS: *Ardneil* to undertake sea trials of a towed seabed spectrometer probe; *Venturous* to continue geological sampling of shelf waters; *Gorsethorn* and *British Magnus* to continue the geophysical survey of shelf waters and *Bucentaur* and *Pholas* to continue the drill sampling for the geological mapping programme of the Continental Shelf.

Institute of Hydrology

Report for the period 1 April 1985-31 March 1986

Institute of Hydrology

The programme of research at the Institute of Hydrology (IH) at Wallingford addresses a broad range of problems concerned with water; problems which are very relevant to society in developed and less developed countries alike. Floods, droughts, pollution, erosion and sediment transport are examples of problems which require understanding, leading on to their prediction and forecasting. Such an understanding comes from studies of, in broad terms, the physics and chemistry of water, mainly in its liquid state, but also in its solid and gaseous phases.

Some of the research is concerned with basic hydrological studies into the storage and movement of water, such as in a peat bog; other research topics involve the practical application of hydrological skills, for example, in designing a reservoir. Indeed, much of the Institute's research is focused on applied hydrology; estimating the water resources of an area, assessing the optimum level of irrigation, or providing a forecasting system for the control of water quality in an important river system being three such topics. These applied areas of research keep the hydrologist closely in touch with the community and its needs. In some countries this need is simple – a reliable wholesome supply of water. In others it can be very complex where there are conflicting interests in and uses of a particular water resource.

Underpinning applied hydrology are the basic studies where research now may provide the solutions to as yet unforeseen problems. The skill of the hydrologist in anticipating where these future questions may arise, largely determines where the current basic research programme is directed.

Many parts of the Institute's programme interact with those in other terrestrial and freshwater areas, while there is a very strong link between the hydrology and hydrogeology in IH and the hydrogeology in BGS.

Hydrochemical Studies at Plynlimon

Approximately 7% of the UK is afforested, mostly in upland areas. There is economic pressure to increase conifer afforestation, particularly in 'the economically marginal' upland regions, since the UK produces only some 10% of its timber requirements.

However, conifer afforestation/deforestation has in part been detrimental both to the water industry and the environment. Afforestation of moorlands has approximately doubled evapotranspiration thus reducing run off into reservoirs by approximately 15%: consequently, such water supply loss, caused by the forest, could be twice the economic value of the timber crop. Afforestation/deforestation programmes also affect water potability: land disturbance increases sediment loads and fertilizer applications increase nutrient loadings which promotes algal growth, costly to the water industry since it increases water treatment requirements. Severe land erosion as a consequence of the introduction of forest drainage ditches has also been observed on a local scale. Recently, conifer afforestation programmes have been shown to have a deleterious effect on invertebrate and salmonid fish populations.

Since 1968 the Institute of Hydrology has undertaken an extensive study at Plynlimon, mid Wales, of water yields from a forested (Upper River Severn) and a natural moorland (Upper River Wye) catchment. Chemical studies are now in hand to establish the consequences of a deforestation programme on stream water quality. The first part of the study has been to identify natural variations in stream water chemistry prior to deforestation.

Variations in the Hafren forest streamwater chemistry are in general due to mixing of water from a near surface 'soil zone' and a deeper groundwater zone.

Within the soil zone the chemical and hydrological processes operating are complex, uncertain and interactive. However, organic reactions predominate to generate

acidic conditions and high CO_2 partial pressures whereby the easily hydrolysable transition metals and aluminium are mobilised, accentuated by organic complexation and the generation of reducing conditions. Precipitation of hydroxy aluminium sulphate, hydroxy aluminium silicates and aluminium hydroxide may occur in this zone.

Evapotranspiration and dry deposition processes are important in increasing the salt concentration in solution, and during storm events waters from the various soil horizons mix and enter the streams via surface ditches, along present root channels developed by trees swaying in the wind, old root channels and natural pipes. During baseflow periods, flow is restricted to micropore movement and the transfer of water to the lower soil and bedrock horizons.

Within the bedrock zones the predominant reactions are inorganic, involving the breakdown of chlorite, mica and carbonate minerals, consumption of H^+ from the near-surface soil zones, adsorption of H_4SiO_4 onto quartz surfaces and possibly precipitation of amorphous hydroxy aluminium silicates, iron and manganese oxides/hydroxides, hydroxy aluminium sulphates and aluminium hydroxide, together with conversion of dissolved CO_2 from the 'soil zone' to HCO_3^-.

The rapidity with which streamwater chemistry reverts from storm to baseflow values, even during the winter when the soil zone is water-saturated, emphasises the importance of water movement through ditches and macropores.

Hydrology and Wetland Conservation

The wetlands of Britain, (Fig. 1) as remnants of an ancient landscape that preserve relatively unmodified habitats, are of special interest for nature conservation, but the spread of development in agriculture and industry, and in the infrastructure of transport and housing, has imposed new stresses. Not only has financial support and drainage technology become increasingly available for farming and forestry, but the demand both for green-field industrial sites and for the restoration of derelict land has raised land values and brought reclamation projects, previously not thought worthwhile, within the bounds of feasibility.

Such is the dependence of wetlands on an excess of water that most threats to wetland sites are hydrological in nature. For several years IH has been advising the Nature Conservancy Council (NCC) on the assessment of threats, the protection of sites and their management. The variety of problems is immense: from opencast coal extraction, and the consequent disturbance to the flow and quality of water, to the long-term drainage effects of the reclamation of regions such as the Somerset wetlands and the Fens. Sites investigated have ranged from peat bogs, through fens and riparian marshes to coastal saltmarshes, the only common factor being the need to draw conclusions from very little hydrological information.

On occasion the short contract involving advice to NCC on a pressing problem has led to a longer-term commitment. For example, the Institute is currently involved in a hydrological study of West Sedgemoor, Somerset, commissioned by NCC and the Wessex Water Authority. Measurements of water levels in open channels and groundwater levels in adjacent fields are to be used in the planning of optimal water management of the Moor in the interests of pastoral agriculture, nature conservation and water resources.

Other sites are also yielding long sequences of hydrological data: the Institute is receiving regular water level data from wetlands in Anglesey, in South Wales and East Anglia. The setting up of a hydrological database for wetland management is an important theme in a project commissioned by MAFF. The Institute has worked with NCC and other organizations to set up data collection schemes on as many wetland sites as possible, using NCC and voluntary workers to make the routine measurements, usually of groundwater levels. The collation of data from these sites to form a usable database is in an early stage.

The derivation of a water balance for wetland areas, often a crucial step towards long-term management, is complicated by the difficulties of measuring evaporation. Fen plant communities in particular tend to be tall, and to increase in height over the summer, retaining a stand of dead stems over the winter. Lysimetry, in which a stand of vegetation is enclosed and studied intensively, can provide an answer, but a lysimeter must be large enough to contain a fair sample of the

Figure 1 Bulwick Alder Carrs, Northamptonshire: a spring-fed marsh bisected by the route of a proposed trunk road

community, yet cause as little disturbance as possible to the soil and plants. The fen habitat also commonly experiences a significant lateral flow of groundwater and surface water, which must be taken into account in lysimeter work.

The first of a series of fen lysimeters has been installed on a soligenous bog at Plynlimon, mid-Wales. The lysimeter is constructed as a bottomless tank to enclose a block of undisturbed peat, with its surface vegetation, in situ. To prevent leakage through the open bottom, a microcomputer senses water levels inside and outside the lysimeter, and operates pumps to maintain equal levels, thus giving an accurate measurement of the lateral flow that would occur in the absence of the lysimeter walls. The resolution of the water level measurement is adequate to demonstrate the diurnal variation caused by evaporation from groundwater and the recovery in levels overnight induced by lateral flow. A short sequence of records was collected in autumn 1985, and this operating period was used to test and improve the control system and operating procedures in preparation for the summer of 1986.

The lysimeter technique is to be compared with a simpler method, which has been applied to data from Wicken Fen, Cambridgeshire, and can be used to determine evaporation rates from continuous records of groundwater level. The response to rainfall is used to give an estimate of the effective porosity, which varies with depth, and diurnal fluctuations in water level are then used to estimate the evaporation rate. Lateral flow is compensated for by observing the recovery of water levels during the night. The advantage of this method is that it uses simple field equipment, a raingauge and a water level recorder, which can be installed and operated as an integral part of the management of a wetland reserve.

Flow Regimes from Experimental and Network Data (FREND)

In 1985 a six man team was established at IH to undertake this three year project as the major contribution to Project 6.1 of the Third Phase of the International Hydrological Programme. In addition to three Institute scientists, the countries of Norway, the Netherlands and the Federal Republic of Germany have each seconded one member to the project team which is liaising with a number of research institutes and universities in north west Europe. Research workers from Sweden, Finland and Belgium are also joining the team for shorter secondments of up to three months.

The project has been initiated by the IHP with the objective of analysing hydrological data from small research and national network basins to study the natural and man made hydrological regimes. Although a number of individual basin studies have previously been carried out in the study area of north west Europe, there have been few attempts to compare results from different countries or to provide techniques for generalising or extrapolating research results beyond individual catchment boundaries. The study seeks to overcome this deficiency by applying statistical analyses and modelling techniques to a large European database.

The project will have three major areas of research:

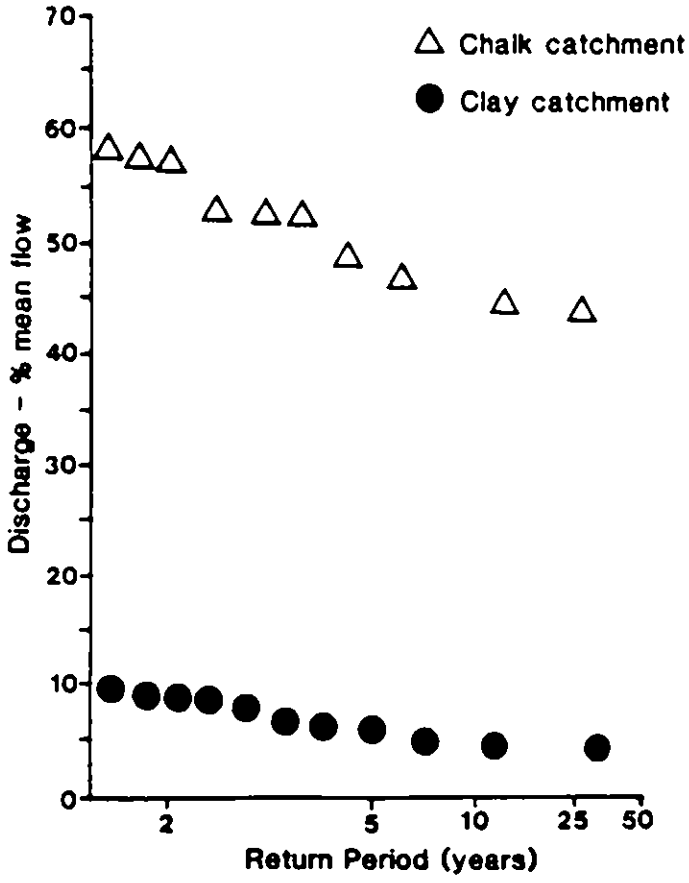
- the use of physically based models for studying land use change and water management problems.
- the systematic analysis and comparison of data from small European research basins.
- the regionalisation of flood and low flow behaviour of European rivers.

The main activity in the first year of the project has been to extend existing archives of mean daily and annual maximum discharge data to over 2000 catchments including an intensively monitored subset of 100 small research basins. Figure 2 shows some examples of initial data analysis from individual catchments and from pooling data in different regions.

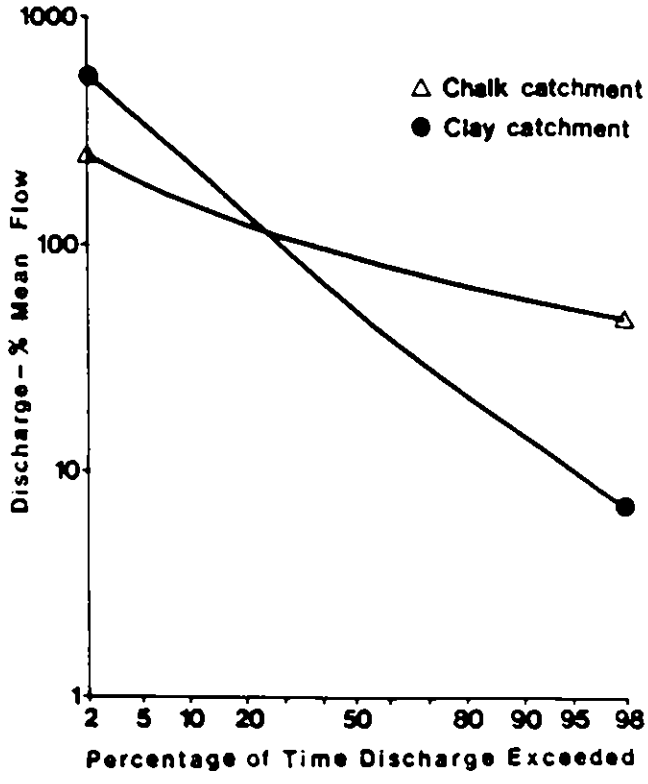
Comparing the hydrological response of catchments of different size and with different climates can be aided by standardising flow variables: in the case of low flows, by the mean discharge and in the example of flood frequency, by the mean annual flood. For example Figure 2a shows the annual minimum series for two catchments with discharge expressed as a percentage of the mean flow. The strong control of the geology of the catchment in influencing low flows can be clearly identified, with the groundwater discharge from the chalk aquifer sustaining low flows even in extreme droughts. In contrast, low flows from the impermeable clay catchment are at very low rates in every year of record. Figure 2b illustrates a similar contrast of regimes when comparing the flow duration curves derived from the entire series of the mean daily flows. When extending regional studies to larger areas, differences in climate are of increasing importance, and Figure 2c contrasts the monthly pattern of flows from a regime dominated by spring snowmelt in the Alps with that of the runoff from the Scottish Highlands.

Preliminary studies of annual maximum flood data from Norway have highlighted the importance of considering the dominant flood forming processes. Two major regimes have been identified, with mountainous catchments having a dominant snowmelt response and coastal areas experiencing higher floods from rainfall events. In areas with the same flood producing mechanism it is possible to 'pool' or average flood frequency curves to provide regional curves such as those shown in Figure 2d.

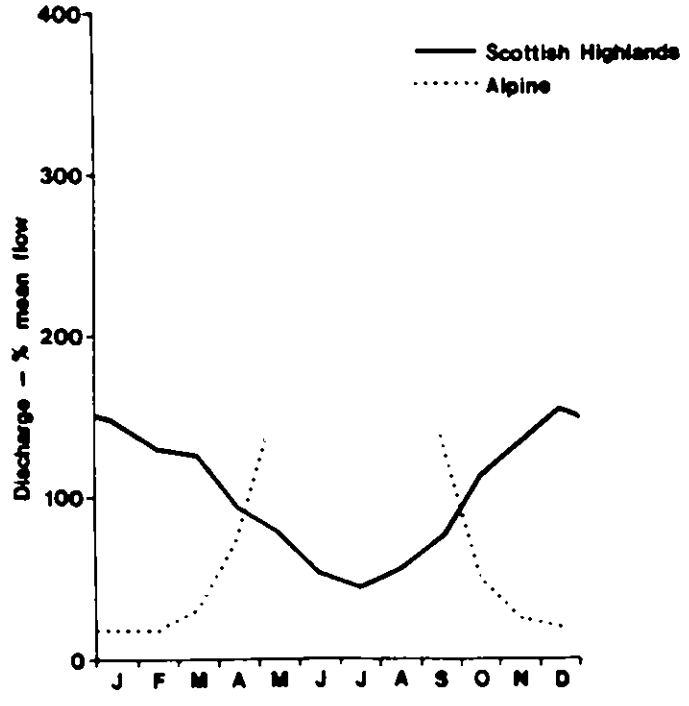
By providing techniques for deriving these summary statistics at ungauged sites, the results of the project will be of direct use for flood design and water resource planning. This regional approach will be complemented by using physically based catchment models to examine the effect of land use change on the frequency of low flows, using data from small research basins in Europe including the Institute's Plynlimon catchments.



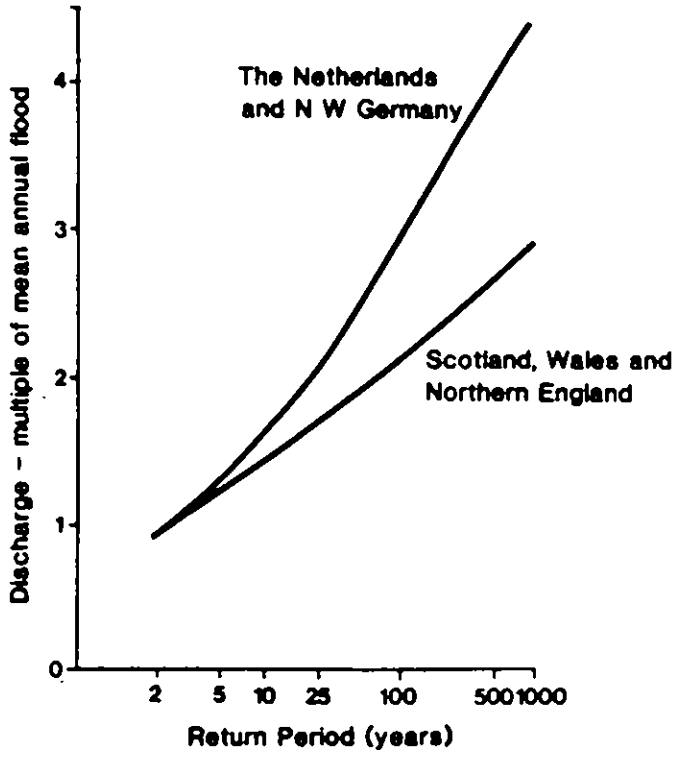
a) Annual Minimum Series



b) Flow Duration Curves



c) Monthly Flow Regimes



d) Flood Frequency Curves

Figure 2 Examples of analysis techniques used in Europe

Figure 4 The 'HYDRA', a new instrument developed at the Institute of Hydrology, U.K., which directly measures the total evaporation from dryland crops. The device works by making high frequency measurements of the amount of water vapour moving away from the crop

Evaporation from Sparse Dryland Crops

How much water moves out of the soil, up through vegetation and back into the atmosphere is a key question for plant physiologists interested in crop production, since crop water use is closely linked with yield. In arid parts of the world, where water is a major limiting factor in expanding agricultural productivity, finding the answer can be crucial.

The Institute of Hydrology has recently started a project to study the detailed processes of evaporation from sparse dryland crops, typical of those grown in many low rainfall areas of Africa and the Middle East. In this type of vegetation much of the rainfall is 'lost' as direct evaporation from the soil (e.g. Figure 3) and conventional methods of calculating crop water use are often very inaccurate. The principal aim of the study is to make detailed measurements of plant, soil and total evaporation, and to use these measurements to develop models which will give more accurate predictions of sparse crop evaporation.

The project is in Niger, West Africa, at the ICRISAT Sahelian Centre (International Crops Research Institute for the Semi-Arid Tropics) near Niamey, where experiments on crop productivity should benefit from the precise and frequent measurements of evaporation rate that the study can provide.

One of the main instruments used is the IH's new evaporation measuring device called the 'Hydra', (Figure 4). The instrument is composed of a sonic anemometer (a new electronic instrument that measures vertical wind speeds very rapidly) and an infra-red hygrometer, which measures humidity in the air with a beam of infra-red light. The third component, a thermocouple, gauges fluctuations in air temperature. These sensors are linked to a microprocessor to analyse the measurements as they are made. One feature which is very important for environmental research is the ability of the Hydra to run under battery power – very attractive for both hydrological and agricultural research applications.

Testing the Hydra's direct measurement of evaporation is only part of the joint study between ICRISAT and IH. A second goal is to predict evaporation. Weather data, recorded hourly using an automatic weather station, will be fed into an equation which breaks down evaporation into its components. Water loss from the plants and soil can then be predicted more exactly, since the equation includes a value for soil 'resistance' to evaporation and a value representing the degree to which plant stomata hamper evaporation. A model which quantifies the amounts of water used by the plants, and lost as soil evaporation, should be a useful tool in helping to assess different crop management practices which attempt to make more efficient use of the limited soil water supply.

To assist the interpretation of evaporation data in terms of crop production, a parallel programme of plant water relations and photosynthesis measurements was undertaken during the 1986 crop season. The objectives of this programme are to provide information on the ability and mechanisms used by the crop to tolerate dry soil conditions; factors which are closely linked with the plant's internal water status. Concurrent measurements of net photosynthesis, photo and dark respiration should help to assess the effects of soil water and environmental stresses on important growth limiting processes and to identify any particularly sensitive growth stages or gas exchange processes.

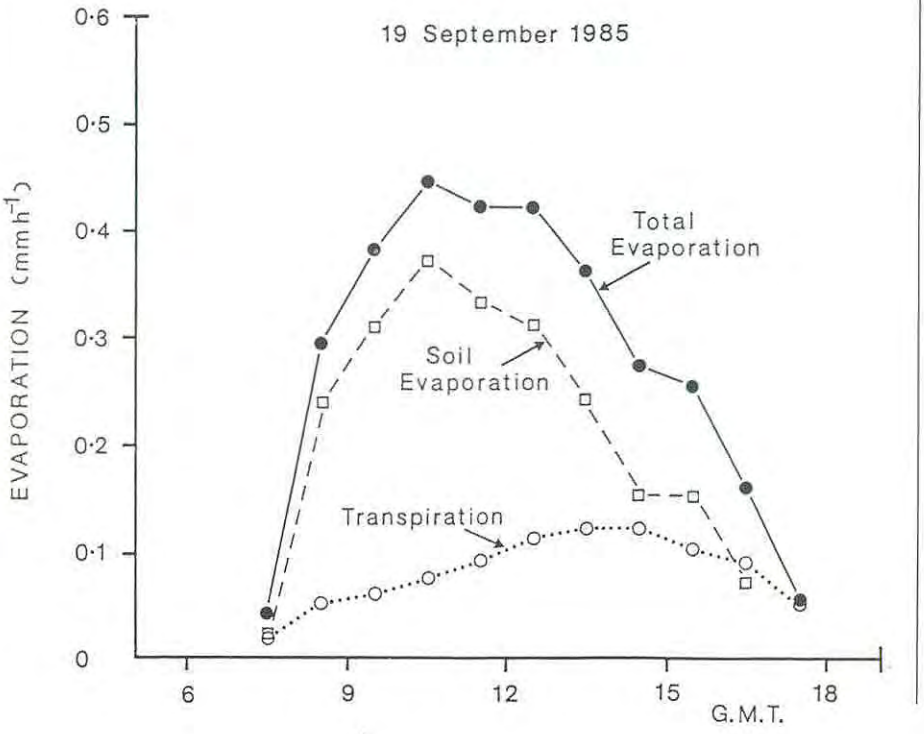


Figure 3 Diurnal trends in evaporation from a millet crop on a clear day showing that when the soil was wet, twice as much water was lost directly from the soil than was transpired by the plants

Radiation and Surface Energy Balance Studies

Studies of many aspects of the measurement and analysis of the radiation and soil heat flux components of the surface energy balance of vegetated and bare soil areas aid in the measurement and modelling of the available energy component of evaporation. Detailed investigations have been carried out at an experimental site at Wallingford where the radiation, soil flux and temperature components are monitored for bare soil and short and long grass areas throughout the year, for a very wide range of meteorological and soil moisture conditions. A variety of established and experimental sensors are being employed. Additional measurements are being made at other sites in the UK and overseas. The work is resulting in an improved understanding of the principles and errors associated with a wide variety of radiation and soil heat flux systems. The results are leading to better energy balance assessments both on the small and large scale in the UK and overseas.

Especially under bare soil and for sparser crops, the soil heat flux component is an important term in the energy balance used for evaporation measurement or modelling. The use of soil heat flux plates is being shown to be subject to considerable difficulties and errors. A method is being developed to calculate daily positive soil heat flux inputs from the diurnal range of soil temperature measured at 10cm depth. This approach has already been very successful for a variety of sites and is illustrated in Figure 5. The potential for the routine use of relatively easily measured soil temperatures to estimate soil heat flux in routine evaporation, energy balance and agroclimatological studies is being investigated.

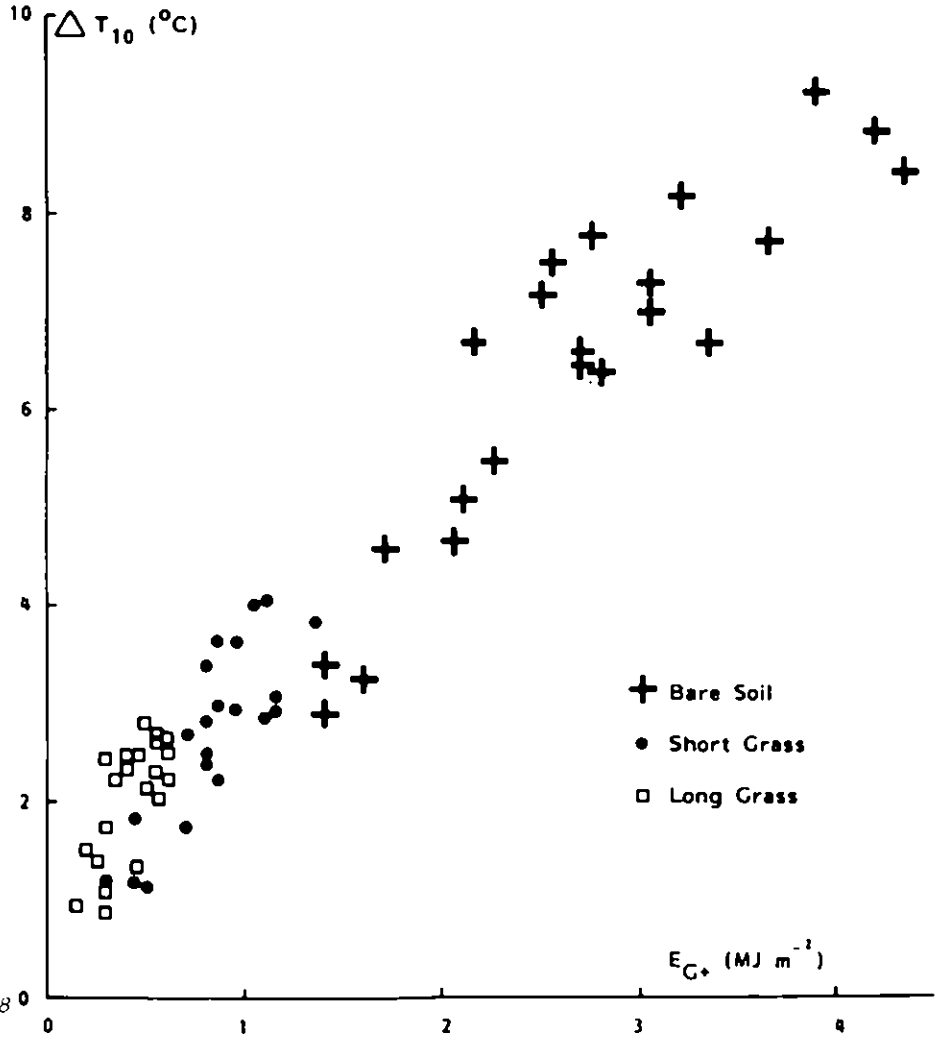


Figure 5 Graph showing the relationship between the daily positive heat flux into the soil (E_{G+}) and the rise in soil temperature at a depth of 10cm (ΔT_{10}) for three surface types measured at the energy balance research site at Wallingford in 1984

The effects of Afforestation on Water Yield in the Scottish Highlands: Process Studies

The physical processes governing evaporation from vegetation of the Scottish uplands, viz coniferous forest, heather and upland grass, have been studied through a series of experiments.

Relative transpiration rates have been determined from measurements using the neutron soil-moisture probe of the soil moisture content during drought periods beneath coniferous forest, heather, and grass at several Scottish sites. The results indicate that transpiration rates from heather are about half the rates from grass or coniferous forest

A conventional forest interception experiment at Knapdale Forest, on the Kintyre peninsula, gave total annual interception as 36% of the annual precipitation. A higher figure of 45% was measured at Queen's Forest, near Aviemore, for periods when there was no snow. These high interception figures are the result of high evaporation rates which reflect the efficiency of the turbulence-driven transport mechanisms associated with the aerodynamically-rough forest. Confirmation of the high interception rates has come from an experiment using the attenuation of gamma-rays as the means of measuring the amount of water held on a forest canopy (Figure 6). This experiment has also shown, in conjunction with a tree-weighing experiment, that spruce canopies can hold in excess of 28mm water equivalent of snow and that evaporation rates from snow-covered canopies can be as high as evaporation rates from rain-soaked canopies when the snow is melting.

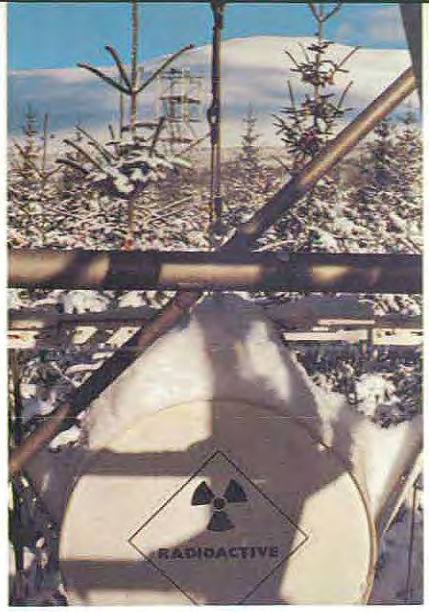


Figure 6 Gamma Ray alternation device for snow measurements

Although sublimation rates are lower than evaporation rates, sublimation is an important mechanism in snow interception from coniferous forest in upland Scotland, because of the large storages possible and the long periods of sub-zero temperatures during which the snow is available for sublimation. Interception losses of 80%–90% of the total snowfall have been observed for individual storms.

The rainfall interception characteristics of heather have been studied using a computer-controlled electronic balance to measure evaporation rates, while also making contemporaneous measurements of the prevailing weather. Whereas transpiration rates from heather are low these measurements have shown that heather is a very efficient interceptor of rain supporting high interception rates and having a relatively large storage capacity per unit area of foliage. The equipment was also used to determine the drainage function for heather.

The results of these studies have been incorporated into research models which in turn have yielded new information on the mechanisms controlling evaporation from upland vegetation. With these new insights it has been possible to develop seasonal models with a minimal data requirement suitable for predicting evaporation from catchments on time scales shorter than a year. Such a model applied to the Monachyle catchment at Balquhidder has given results in excellent agreement with observations.

The Water Use of Eucalypts in Southern India

Afforestation in Southern India using *Eucalyptus* species is the subject of much controversy with a key issue being the hydrological effects of afforestation: specifically whether large scale planting of eucalypts will deplete water resources. Interception loss in tropical climates from *Eucalyptus* is expected to be generally less than from other tree species but studies in Australia indicate that transpiration rates from certain *Eucalyptus* species may, if their roots are below the level of the water table, be very high. However, wide variation in water use, both interception and transpiration, is to be expected between species and climatic regimes. Before the hydrological implications of afforestation with eucalypts in Southern India can be assessed, work is needed to determine the comparative water use and the evaporative mechanisms of different species of trees, natural scrub vegetation and agricultural crops growing in different soils under different climatic regimes. To this end a method of measuring transpiration rates from eucalypts has been developed using deuterium as a tracer. This method has the advantage that it can be used where water tables are shallow and the neutron probe cannot be used. The method was tested on three year old *Eucalyptus teretecornis* trees growing in a plantation. Rates of 0.86mm d^{-1} were measured, well below estimates of the potential evaporation rates indicating considerable stomatal control.

Hintereisferner Project

The Institute has continued its studies of snowmelt processes and this year took part in a joint field experiment with the Universities of Innsbruck, Munich and Utrecht on the Hintereisferner Glacier in the Oetztal Alps. This glacier experiences high radiation and evaporation rates, in strong contrast to the sites in Norway and Scotland used for previous experiments. The aim of the project was to improve the energy balance method of predicting snowmelt and test the Institute's distributed model of mass and energy transfer within the snow. Figure 7 shows (from l. to r.) the IH meteorological instruments and neutron probe access tubes, the University of Munich wind and temperature profile mast and members of the University of Innsbruck measuring evaporation by a direct weighing method.

Figure 7 The Hintereisferner Project

Figure 8 The Allt á Mharcaidh in the Cairngorms

The Surface Water Acidification Programme

The Surface Water Acidification Programme is a major international collaborative effort to identify hydrological and chemical processes operating in catchments, which cause increased acidity in lakes and streams. Within this programme heavily acidified, pristine and intermediate catchments have been identified for study in the UK and Scandinavia. In the Cairngorm area of Scotland the Allt á Mharcaidh (Figure 8) has been selected as an intermediate catchment where background acidity is low but frequent and severe 'acid shocks' occur. Instrumentation in this catchment, to enable assessment of chemical and hydrological throughputs, has been installed in conjunction with the Macaulay Institute and DAFS.

The Allt á Mharcaidh is a c. 10km^2 catchment which drains an area on the western flank of the Cairngorm mountains into Glen Feshie. Precipitation totals c. 2000mm per annum of which up to half may be snowfall: snow lies over much of the catchment area for three months of the year, on average. The quantity and quality of the water input is assessed by a raingauge and bulk collector network and snow pit surveys are regularly undertaken in the winter months to characterise the composition of the snow pack and melt-water. Conductivity, pH, water temperature and stage are monitored automatically at the catchment outflow, as well as at two points within the catchment which delineate smaller sub-catchments, thereby enabling more detailed analysis of processes on a smaller scale within the overall framework of the whole basin. Regular sampling of the stream for chemical analyses is carried out at all three gauging stations throughout the year. Two automatic weather stations are located in the catchment to provide data describing wind, radiation and temperature variations enabling the calculation of lapse rates, evapotranspiration and energy balance.

One focus of the monitoring programme is the study of episodes: particular emphasis is placed on intensive sampling during rainfall and snowmelt events. To facilitate these studies, remote samplers capable of collecting water from the base of a snowpack and of collecting discrete rainfall samples during varying intensity storms have been designed and installed. Results to date indicate that acid pulses occur frequently and may be induced by rainfall and snowmelt events, the latter being more intense.

Snow Melt Sampler

An automatic snow melt sampler was required for acid rain studies in catchments in the Cairngorms, Scotland. The sampler must be buried during the establishment of the snow pack and some months before the onset of the melt phase.

The unit developed to meet the requirement has been perfected over recent winters and operated very successfully during the 1985/86 winter. It consists of two parts, the basic sampler and the control unit.

The basic sampler which is circular with diameter 60cm and height 42cm, is of robust construction to prevent damage from the weight of ice on top of the unit. It uses materials chosen to prevent contamination of the samples.

Figure 9 Snow melt sampler

The top is cone shaped to feed snow melt to a central funnel and transport tube that progressively rotates round an array of sample bottles (Figure 9).

The sampler is linked by cable to a control unit based on a C-MOS microprocessor system that enables the user to select the sampling interval. It carries out self checks on device operation and it records the times of sampling and finally switches off after 60 samples have been taken. The control unit also offers other modes of operation and enables data to be transferred via a standard RS-232 link.

Groundwater Information Processing System

The Institute of Hydrology has developed a microcomputer based software package for processing hydrogeological information based on extensive experience in groundwater resources investigation, particularly in developing countries. Low cost, reliability, flexibility and ease of use are important considerations which can be achieved by using microcomputers.

Output from the system can be a printed listing, a graph or a computer file for further analysis. The listings are designed for data verification, analysis or report presentation. Graphical output is either to a colour VDU or a hard copy plotter. Once the system has been set up to produce the first map, subsequent maps can be produced with minimal input from the user. The system runs on IBM-PC and Comart CP1502 computers.

Saline Intrusion Models

Groundwater resources management may need to take into account the intrusion of saline water in coastal aquifers. A field experiment has been undertaken at Studland Bay in Dorset, in conjunction with Imperial College, London, to collect detailed information on spatial and temporal variations in salinity and piezometry in beach sands. This information has been used to design and calibrate a numerical model which accurately simulates the observed variations in a one-dimensional plane by incorporating diffusion and dispersion processes.

Shallow Subsurface Sampling Techniques

A low-cost sampling technique, designed to obtain cores of saturated sands and gravels, has been applied to the heterogeneous alluvial deposits of the mid-Thames floodplain in order to study bias introduced by various sampling methods and to link aquifer permeability to grain-size statistical distribution parameters. This allows closer definition of parameter variations for 3-D models for environmental impact studies.

Real-Time Drought Management System for the Thames Basin

The management of a water resource system in times of drought is assisted if assessments can be made of the reliability of the system to supply water at specified dates in the future. Reliability in this context is defined in terms of the frequency with which restrictions of differing severity can be tolerated. If the acceptable frequency of restriction is forecast to be violated, then the water resource manager may seek alternative sources of supply or seek legal approval to relax statutory constraints on water use. In seeking legal sanction, the manager's case will be strengthened by an assessment of the change in risk to supply, as a consequence of relaxing a statutory constraint. A Real-Time Drought Management System has been designed and implemented by IH for Thames Water to provide reliability assessments of this kind.

Central to the reliability assessment procedure are simulation models of the water resource system which permit system behaviour to be evaluated under a range of operating and hydrological conditions. The Drought Management System incorporates two water resources models describing the Thames/Lea reservoir system supplying the London area, and the Farmoor reservoir system supplying the Oxford area. These reservoirs are of the pumped-storage type replenished by river abstractions, and together meet 58% of the water supply needs of the Thames Water Authority region.

The reservoir models are supplied with alternative forecasts of flow as input, each forecast sequence being regarded as equi-probable. Reservoir levels and demand restrictions imposed for each sequence are calculated within the water resource model. A statistical analysis of reservoir level on a given day of the forecast period then allows the level below which there is a specified risk of the storage falling to be calculated, together with confidence limits associated with the reliability assessment. An example of the output from the risk assessment procedure when applied to the Thames/Lea reservoir system during the 1976 drought is shown in Figure 10.

Provision of equi-probable flow forecasts is achieved through the use of a rainfall-runoff model and long historical records of rainfall dating back to 1890. A single rainfall sequence to be used as representative of rainfall over the forecast period is abstracted from the historical rainfall record, by taking for any year the same days of this forecast period; for example, if the forecast period is 1 August to 1 October 1986, then one sequence could be obtained by abstracting from the historical record the sequence 1 August to 1 October 1972. Clearly 96 sequences can be abstracted from a record spanning from 1 January 1890 to 1 August 1986. Each sequence is transformed using the rainfall-runoff model to an equi-probable flow sequence ready for use in the water resource models.

An important feature affecting the reliability of the two water resource systems is that recharge of aquifers in the preceding winter exerts a strong control of river flows in summer. The reservoir systems function primarily as buffer storage, their total storage capacity providing little more than three months supply. River abstractions are constrained by the need to maintain statutory minimum flows in the river and therefore the ability to abstract depends on flows being maintained above minimum levels during dry summers by contributions from groundwater. It is of paramount importance that the model-derived flow forecasts accurately reflect drainage from groundwater during dry summers

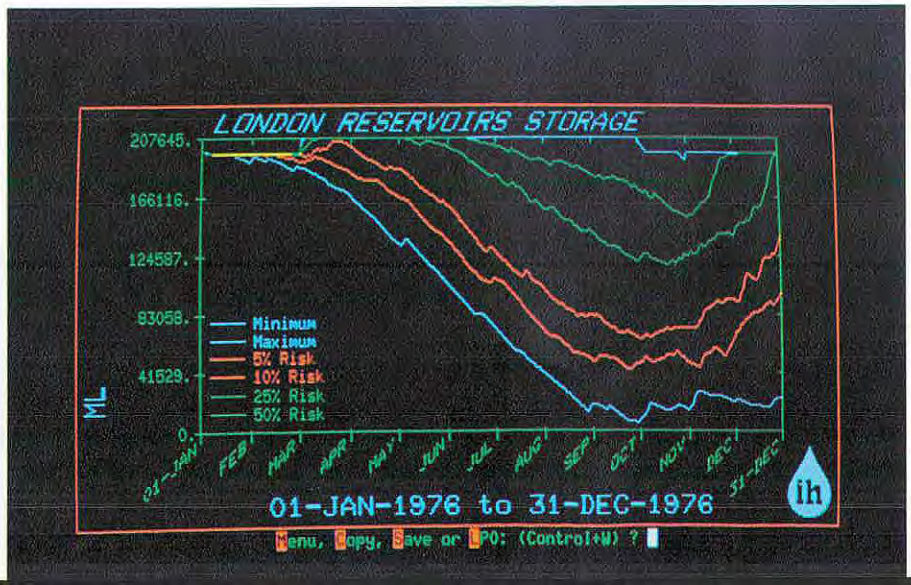


Figure 10 Risk assessment of the Thames/Lee system for the drought of 1976

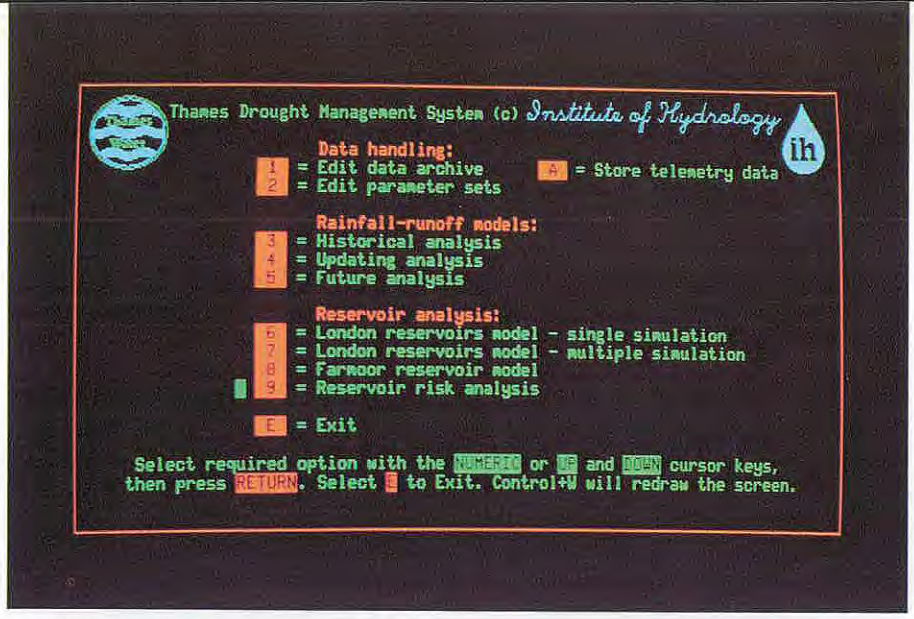


Figure 11 Drought management system control menu

if reliability assessments are to be credible. A method of forecast updating is incorporated in the Drought Management System to accommodate this fact. An empirical state updating procedure uses the error in model flow to adjust the water content of the conceptual model stores to achieve correspondence between measured and model flow. In this way the model is made to incorporate information on the current hydrological status of the basin.

Categorical monthly rainfall forecasts provided by the Meteorological Office each month may be incorporated in the risk assessment procedure. These forecasts give the probability of rainfall for the forthcoming month being 'above average', 'average', and 'below average'. The predictions are used as weights applied to each reservoir level scenario, in accordance with whether the rainfall sequence used to generate the scenario is above average, average, or below average for the first month.

The Drought Management System is implemented on a PDP-11/73 micro-computer. Extensive use is made of interactive menu and form facilities for driving the system and of colour graphics for displaying the results to the user. The control menu display is shown in Figure 11.

An archive of hydrometric data is kept up-to-date through real-time interrogation of a second computer, dedicated to real-time data acquisition of telemetry data. This allows the Real-Time Drought Management System to be used for a forecast period starting at the current date and extending for up to one year in the future. Monitoring the progress of a drought as it affects the future reliability of the water resource system is thereby made a quick and easy task.

Environmental Impact of Gravel Extraction Schemes

The alluvial floodplain environment is particularly susceptible to man's activities. Gravel extraction schemes can drastically alter the existing hydrological conditions in these environments.

A 2-D finite element model has been developed to evaluate and predict the consequences of gravel extraction and restoration schemes on groundwater flow patterns in the surrounding aquifer. The model has been designed to allow phased extraction, alternative infill materials or open water, partially or completely sealed pit boundaries as well as alternative pit configurations or size, and it can incorporate drainage channels, alternative boundary conditions and recharge.

The model has been applied to a 122ha area of the Thames floodplain west of Oxford to predict the likely consequences of a major gravel scheme on adjacent SSSI's.

Macrohydrology

Emerging problems of environmental change and of long range hydrological forecasting demand knowledge of the hydrological cycle at a global rather than a catchment scale. Studies at this scale require international and multidisciplinary collaboration between scientists specialising in the basic processes of surface hydrology on the one hand, and meteorologists and space scientists on the other. Scientists from IH are participating in several experiments which investigate the processes involved in global scale hydrology.

In collaboration with several national institutes in Brazil, research has been carried out on the water use of Amazonian rain forest, and its dependence on the controls in the atmosphere, the trees and the soil. Measurements were made of the radiant energy balance between the forest and the atmosphere at different wavelengths, and of the proportion of this energy used to support evaporation. In dry conditions water is lost by transpiration, and plant physiological techniques were used to supplement the micrometeorological measurement of total evaporation, by identifying contributions from leaves at different levels. The precipitation intercepted by the forest canopy in wet conditions re-evaporates, and detailed studies were made of the water lost in this way. The results indicate that this process is less important in the Amazon than in the maritime climate of the UK: in central Amazonia only 10% of rain water is lost by interception, (Figure 12). The unique data obtained in the course of this two year study have since been used to calibrate physical models of the

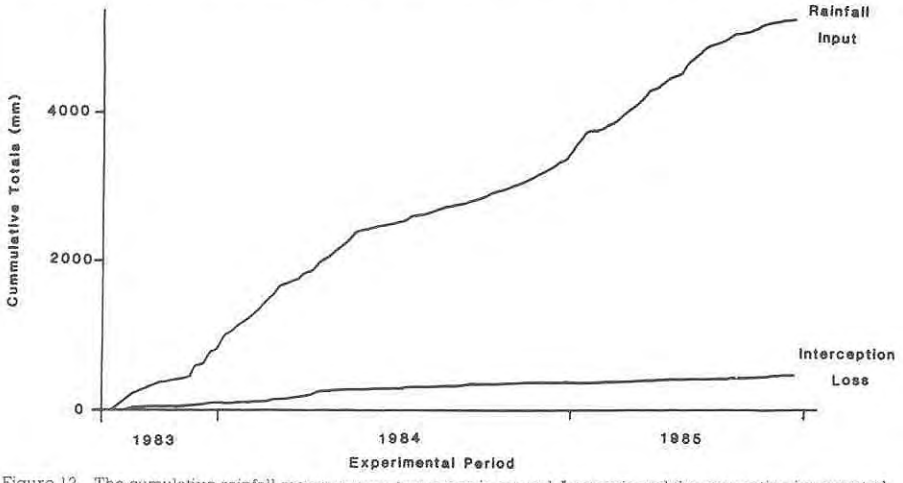


Figure 12 The cumulative rainfall measure over two years in central Amazonia and the proportion intercepted by the forest canopy

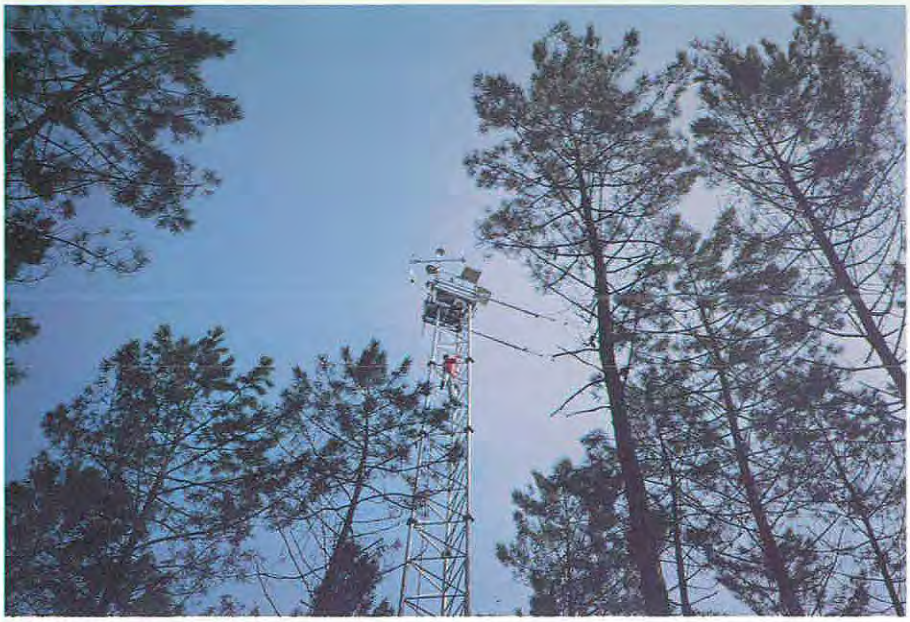


Figure 13 The micrometeorological tower in Les Landes forest in south west France, providing surface measurements in the HAPEX experiment.

evaporation from topical rain forest. At this site the average evaporation over the year is close to the potential rate; the monthly average exceeds the potential estimate by about 10% in wet months and falls below by about 10% in dry months. This extremely useful, simple result apparently contradicts previous data for forests in temperate climates, but is consistent with the same physical description: it is merely a consequence of the different frequency and duration of rainstorms at this location. Collaborative work is now in progress, in conjunction with scientists from the NASA Goddard Space Flight Center in the USA, to develop techniques to extrapolate this point calibration throughout the Amazon Basin using remote sensing techniques.

How changes in vegetation affect climate and how changes in climate affect vegetation are important and controversial problem which may be answered by a series of large scale hydrological experiments being planned under the World Climate Research Programme (WCRP). The first such experiment, HAPEX-MOBILHY (Hydrological Atmosphere Pilot EXperiment – MOdelisation du BILan HYdrique), is taking place during 1986 in south west France. The object is to measure evaporation from an area comparable in size to that of a grid used in models of the general circulation of the atmosphere. An area 100 km by 100 km is being studied: measurements include lysimetry, soil moisture, surface energy fluxes, spatially integrated fluxes (made with low flying aircraft) and remote sensing from the NASA C-130 aircraft and by earth satellite. IH is studying the evaporation from Les Landes pine forest which covers about one third of the area (Figure 14). The information obtained in this experiment will be used to develop an appropriate description of evaporation for mixed agricultural and forested land in models of global climate, and to provide 'ground truth' for extrapolating these model using remote sensing data.

Monitoring global scale changes of the land surface caused by climatic fluctuations, or by the activities of man himself, is arguably only possible on a continuous basis through satellite observations. Such monitoring has considerable potential value in furthering the science of climate and weather prediction by computer simulation, and in diagnosing, monitoring and predicting the impact of climatic variations on food and water resources. Unfortunately the techniques and algorithms for relating satellite data to land surface climatology are poorly defined. The International Satellite Land Surface Climatology Project (ISLSCP) is stimulating collaborative experiments at an international level to address this weakness. Scientist from IH have been selected as principal investigators in the First ISLSCP Field Experiment (FIFE), which is being managed by NASA, and which will begin in 1987 over a test site on the Konza prairie in central Kansas, USA. IH's experience in measuring and modelling evaporation is of value in studing the spatial variability of the controls on the evaporation over the FIFE site, and in the synthesis of areal average evaporation at a scale relevant to satellite observation.

Remote Sensing of Rainfall and Vegetation in the Sahel

For the last three years the EEC has been funding eight national teams to study the dynamics of desertification in West Africa using remote sensing techniques. The UK contribution, managed by IH, involves groups from ITE, Reading and Bristol Universities and Silsoe College who are developing methods of estimating rainfall and monitoring rangeland production in Niger. This project has extended existing work (funded by ODA) being carried out by Reading University to estimate rainfall and soil moisture from geostationary satellite data. A number of field trips have been made in the wet and dry seasons to obtain measurements on different vegetation species. Daily rainfall records have been obtained from 10 stations in Niger and from about 100 supplementary stations, including a dense network of 36 stations on a 2 km grid.

Using Meteosat infra-red imagery, with appropriate threshold temperatures, areas covered by clouds at low medium and high altitudes could be identified, as well

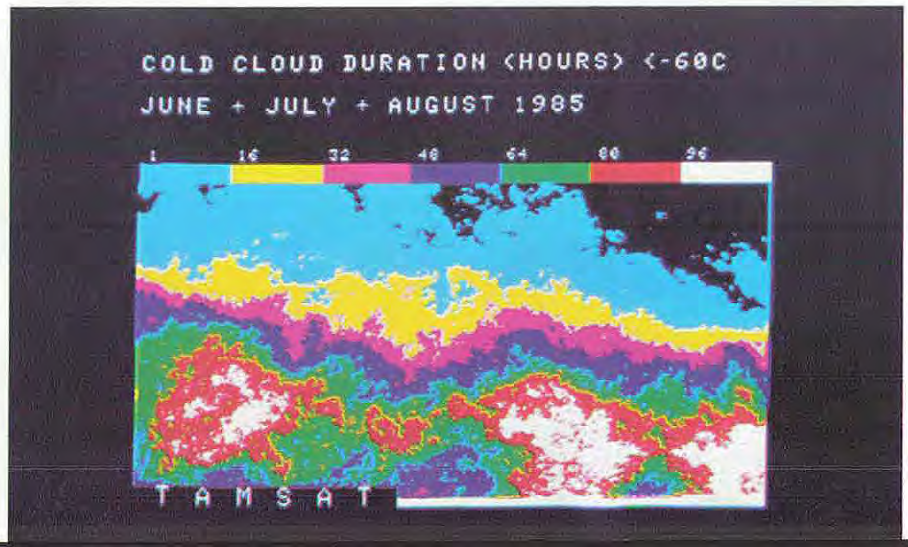


Figure 14 The duration in hours of cold, therefore, high, cloud during three months of the wet season over an area of the Sahel, between 9° and 20°N and 14°E and 7°W.

Figure 15 The rainfall totals in mm for the months of June, July and August obtained with a dense network of 36 raingauges distributed over an area of 10 × 10km located near Tahoua, Niger.

as the cloud-free areas. In the Sahel region of West Africa, the rainfall comes from large convective storms which can be readily identified from thermal infra-red imagery. Areas of cloud which are producing the most intense rainfall have been shown to have sharp gradients of temperature and increasing area – both indicative of a developing rather than a declining storm system.

For periods of 10 and 30 days completely automatic methods of analysis of infra-red imagery were developed to give duration of clouds extending to high altitudes (Figure 15). Maps of the total duration of high cloud indicate the distribution of rainfall and methods have been developed to convert these values of duration of high cloud into rainfall totals over the period. The methods require either 4, 8 or 21 images per day and, in addition, some methods require rainfall measurements from the main hydro-meteorological stations. Using these methods, maps of the rainfall distribution over the Republic of Niger have been prepared for the months of the 1985 wet season.

Results from the dense network of 36 raingauges demonstrated the great variability in the spatial distribution of rainfall in these regions (Figure 16). If the only rainfall measurement available in this 10 × 10km area had been located where the minimum rainfall was measured, then it would have indicated a wet season with only 70% of average rainfall. Whereas if the only rainfall measurement had been located at the maximum, it would have indicated 140% of the average rainfall. This spatial variability creates problems when using ground based measurements of rainfall to calibrate or check satellite estimates. In addition, it suggests that satellite estimates of *areal* rainfall over 10 day or longer periods should be a much better indicator of possible drought conditions, than point measurements of rainfall made by raingauges.

A model was developed for estimating the mean soil moisture in the first 10–20cm of soil over extended areas. This model could be used to indicate the length of the growing season and any periods during the wet season when there was insufficient soil moisture to maintain vegetation growth.

Two vegetation indices, NDVI and PVI were investigated as a means of estimating biomass from remotely-sensed data. Field vegetation data were used to calibrate these indices. The PVI was found to be more sensitive than the NDVI in conditions of low biomass. The PVI was found to correlate well with measured herbaceous biomass (Figure 16). The correlation was successfully checked using field measurements of biomass made by independent observers.

The feasibility of an operational vegetation monitoring system, based on NOAA polar orbiting satellite data was established in principle, although it will necessary to test these assumptions using actual NOAA imagery and, with further season's field data to confirm the proposals in practice.

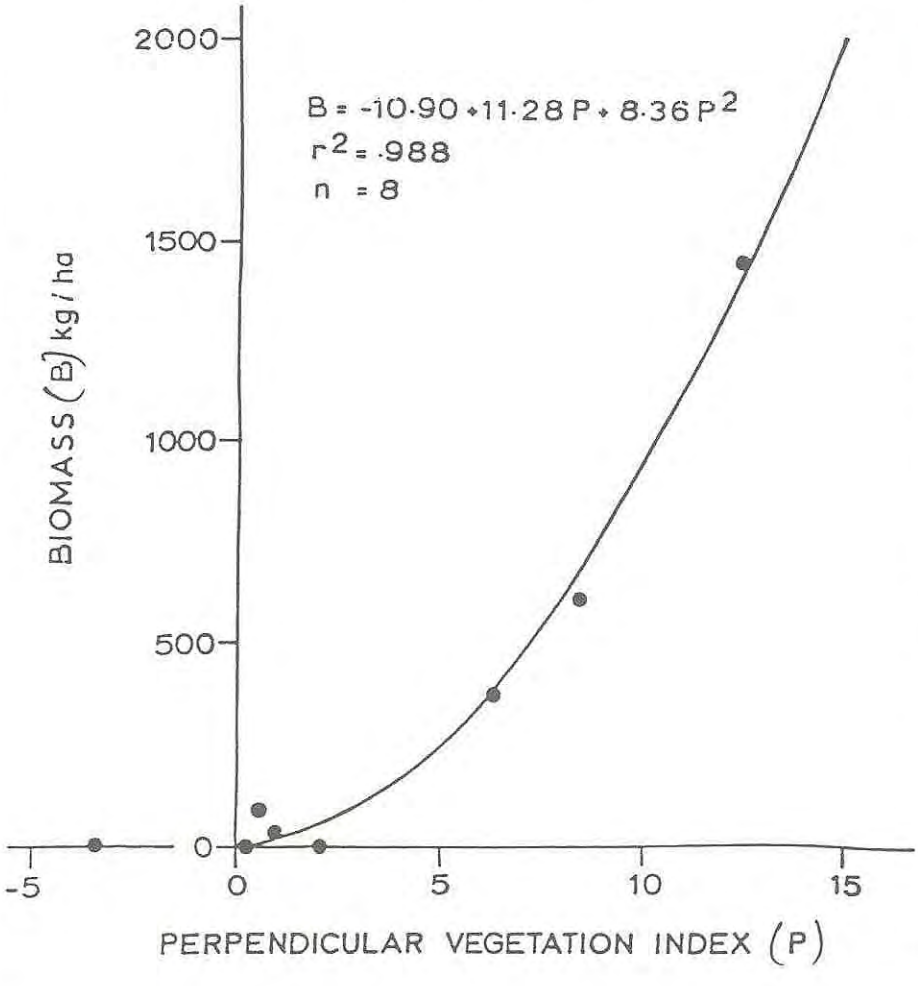


Figure 16 The relationship between the Perpendicular Vegetation Index (P) and biomass (B) expressed as dry weight used to calibrate satellite measurements.

Figure 17 Satellite dish at Wallingford receiving data from out-stations via Meteosat.

Data Transmission via Meteosat

Some 18 months ago the Institute of Hydrology installed a satellite receiving station at Wallingford for the reception of data transmitted from Data Collection Platforms (DCP) (Figure 18). Since then, ten DCPs have been installed at various sites within the UK, telemetering data on river level, rainfall and from an automatic weather station. Two types of DCP are in use, the simpler accepting several channels of analogue data, in much the same way as a data logger. The more adaptable of the DCPs accepts serial digital data (RS 232C) and for these an intelligent interface, which also doubles as a multi-channel solid state logger, is in its final stages of development, enabling a variety of sensors to be connected to the DCP.

While most of the out-stations are still being used experimentally, to evaluate system reliability and to develop the electronic interfacing, rain data from a remote site in upland Wales are now being used operationally (Figure 19). In addition a DCP is currently en-route to Antarctica where it will be installed in a joint IH/BAS project to transmit data from the Institute of Hydrology's experimental cold regions automatic weather station (Figure 20).

Software have been developed to enable the incoming data from the satellite to be stored on floppy disc on a PC for subsequent processing and transfer to a mainframe computer.

The transmission of data via satellite will assume increasing importance during the next decade. By taking the steps which it has, the Institute of Hydrology is now the second largest user of DCPs in the UK, second only to the Meteorological Office. It is intended to continue, and to expand, these developments in the coming years, enabling data from remote UK, and overseas, sites to be collected. Costing little more than in-situ data logging, while also including the latter, the method has the advantage of near real-time operation. This is important in any project involving forecasting, but it also provides an early warning of equipment failure in situations where only historic records are required.

Figure 18 Out-station telemetering rainfall data from a remote upland site in Wales via Meteosat.

Figure 19 Cold regions automatic weather station on test in the Cairngorm mountians.

Annex 1

Publications

April–December 1985

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Annex 2

Staff List

Director

Grade 5 McCulloch J S G, Dr

Scientific

Grade 6 Rodda J C, Dr
Smith D B
Debney A G P

PSO Bell J P
Beran M A
Blackie J R
Calder I R,Dr
Dean T J, Dr
Farquharson F A K
Gilman K
Gustard A, Dr
Lowing M J, Dr
Moore R J
Moore R V
Morris E M, Dr
Neal C, Dr
Roberts J M, Dr
Shuttleworth W J, Dr
Stewart J B, Dr
Strangeways I C, Dr
Templeman R F, Dr
Whitehead P G, Dr

SSO Batchelor C H
Bathurst J C, Dr
Biggin D S
Blyth K
Boorman D B
Bradford R B
Bromley J, Dr
Calver A, Dr
Cooper D M, Dr
Cooper J D
Eeles C W O
Finch J W, Dr
Gash J H C, Dr
Green C S, Dr
Hall R L, Dr
Harding R J, Dr
Hosking J R M, Dr
Jones D A, Dr
Kirby C, Mrs
Lees M L
Marsh T J
Moore C J, Dr
Oliver H R, Dr
Packman J C
Parks Y P, Mrs
Piper B S
Reed D W, Dr
Roberts G, Dr
Robinson M
Smith C J
Wallace J S, Dr

SPTO Brunsdon G P
Turner M, Mrs

HSO Acreman M C
Arnell N W, Dr
Barr A G, Dr
Black K B
Boyle S A
Dixon A J
Gardner C M K, Dr
Hodnett M G
Hudson J A
Johnson R C
Leeks G J
Lloyd C R
Marshall D C W
McNeil D D
Meigh J R
Morris D G
Roberts A M, Mrs
Williams R J
Wright I R

SO Bayliss A C
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Dales M Y, Miss
Field E, Miss
Gross R, Miss
Hill P J
Jenkins A, Dr
Lardner A J
Morris S E, Mrs
Musgrove T
Neale R
Ridler B J, Miss
Rosier P T W
Tucker J M, Mrs
Walls J

ASO Altay T
Billingham P W
Bronsdon V J, Mrs
Bryant S J, Miss
Clayton M C, Mrs
Cannon B, Mrs
Hill S, Mrs
Matthews A, Mrs
Peckham J, Miss
Snow E A, Mrs
Whitcombe A, Miss

SDP Powis J, Mrs

PTO Andrews P D R
Edwards S J
Forbes S K
Fraser J R
Stroud M R
Walker M E
Wyatt R G

Administrative

PGSE	*Hughes W A*
CRAFT	*Drewett R G*
	Standbridge I R
	Warwick A C
	White J P
STKPR3	*Jones J H*
BAND 12	*Sibley C F A*
BAND 8	*Jones H V R*
HEO	*Marsters M W*
LIB 3	*Wharton S B, Mrs*
EO	*Howarth M, Mrs*
	Kisby P J, Mrs
	Parker J R
PS	*Beresford S, Mrs*
	Champkin J A, Mrs
	Davies A M, Mrs
CO	*Baghurst P M, Mrs*
	Cattell L, Mrs
	Fenton S A, Mrs
CA	*Black S, Mrs*
	Dolton D S, Mrs
	Howard V, Mrs
	Stevens M E, Mrs
S/TYP	*Hebbert M E, Mrs*
	Hornsby J, Mrs
	Smith S, Mrs
TYP	*Fish P A, Mrs*
	West V C M, Mrs
TEL OP	*Younghusband E, Mrs*

ERRATA

Appendix 3
Standing Committees

Services and Facilities Committee

Council Members	Mr F G Larminie OBE (Chairman) Professor I G Gass Lord Cranbrook Professor R M Cormack Dr K A Browning FRS Professor R Wilson CBE, FRS
Sub Committee Chairmen	Professor M Wells Professor E H Brown Professor J King
Senior NERC Staff	Mr H Fish CBE Dr J C Bowman CBE Mr B J Hinde Professor J C Briden Dr P B H Tinker Dr J D Woods Dr L M Skinner Mr H J Down
Assessors	Mr J W Ramster (MAFF) Dr T W Hegarty (DAFS) Mr M H A Smith (MOD) Mr J D Thomas (DTI)
Mr J Plevin (Secretary)	

Appendix 12
Staff List

Page xxiv Headquarters Staff: 169 not 189

Appendix 1
Staff Matters

Senior Staff Changes
April 1985 November 1986

NERC Headquarters

Dr J McGinnety
(Grade 5), returned from secondment with DES on 18 September 1985 to become Director Policy, Planning and External Affairs.

Institute of Terrestrial Ecology

Professor J N R Jeffers
(Grade 4), retired on 30 September 1986.

Professor F T Last
(Grade 5) of ITE Bush, retired on 5 June 1986.

British Geological Survey

Dr R Gallois
of BGS Edinburgh, promoted to Grade 5 on 6 January 1986

Mr D A Gray
(Grade 5), of BGS Keyworth, retired 6 September 1985.

Terrestrial and Freshwater Sciences

Dr P B H Tinker
was appointed as Director (Grade 3) on 2 December 1985.

Marine Sciences

Professor J D Woods
was appointed as Director (Grade 3) on 1 March 1986

Earth Sciences

Professor J C Briden
was appointed as Director (Grade 3) on 1 March 1986

NERC Scientific Services

Mr B J Hinde
was promoted to Grade 5 on 30 September 1985

Mr B F Rule
(Grade 5), resigned 4 August 1985

Individual Merit Promotions

with effect from 1 July 1986

Dr J D Gage
of SMBA, promoted to IMP Grade 6 for his study of the deep sea benthos.

Dr W N Edmunds
of BGS, promoted to IMP Grade 6 for his studies related to the origin of ground waters

Dr P F Entwistle
of IOV promoted to IMP Grade 6 for his studies into the use of baculoviruses of insects.

Dr R J Pankhurst
of BAS, promoted to IMP Grade 6 for his work within the BGS Isotope Research Group on the setting up of methods for the isotopic analysis of the ageing of rocks

Mr M L Somers
of IOS, promoted to IMP Grade 6 for his work in the development of the GLORIA long range side scan sonar system for rapid reconnaissance mapping of the ocean floor.

Dr J G Jones
of FBA, promoted to IMP Grade 6 for his work concerned with the quantitative ecology of freshwater systems employing a number of isolation procedures to elucidate problems related to mineralisation

IMP Promotions

with effect from 1 July 1985

Dr J M S Blaxter
of SMBA, promoted to IMP Grade 5 for his work on the physiology of clupeoids with particular reference to herrings

Dr J P Croxall
of BAS, promoted to IMP Grade 6 for his work on the assessment of the role of seabirds and sea mammals in the antarctic ecosystem.

Dr C S Reynolds
of FBA, promoted to IMP Grade 6 for his work on the factors which determine the quantitative growth, succession and decay of algal species in lakes and bodies of freshwater.

Honours

Birthday Honours 1985

Professor Malcolm G Brown
then Director BGS, received a knighthood

Mrs M A Hogg
then recently retired from FBA, received the British Empire Medal

Birthday Honours 1986

Dr J C Bowman
Secretary to Council, awarded the CBE

Mr T E Dugdale
lately of IOS Bidston, received the MBE

Appendix 2
Headquarters Publications

The NERC Headquarters has published the following reports and reviews during the year under review. Most of these issues and a full list of NERC publications, are available from Headquarters Public Relations. This summary does not take into account the wide range of publications produced by NERC's component and grant aided research Institutes.

Research Contracts Awarded to Universities and Polytechnics by the Natural Environment Research Council, Series D No 27

NERC Newsjournal March 1986

NERC Newsjournal June 1986

NERC Newsjournal September 1986

NERC Newsjournal December 1986

The 1986 NERC Corporate Plan

Appendix 3
Standing Committees

Earth Sciences Committee

Council Members	Professor M J O'Hara (Chairman) Mr P Ackers Professor G Eglinton Professor I G Gass Mr H Fish CBE Mr F G Larminie Dr M F Ridd
Grants Committee Chairmen	Professor M Brooks Professor A J Smith
Independent Members	Dr C M Bristow Dr P Ibbotson Professor J Nye Professor R K O'Nions
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Assessors	Mr J R V Brooks (DEn) Mr T Pike (ODA) Mr G L Milward (DTI) Mr W G B Phillips (DOE)
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Professor P S Liss	University of East Anglia
Dr J G Lockwood	University of Leeds
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Dr R T Pollard	Institute of Oceanographic Sciences
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Dr J Grace	University of Edinburgh
Dr P Grubb	University of Cambridge
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Dr A Lance	RSPB
Professor J H Lawton	University of York
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Professor R W Nesbit	University of Southampton
Professor I Parsons	University of Aberdeen
Professor J-P Poirier	Institut de Physique du Globe de Paris
Dr E G Purdy	Esso Exploration
Mr J Rose	Birkbeck College
Dr R C Searle	Institute of Oceanographic Sciences
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Mr M H A Smith	Ministry of Defence
Mr J D Thomas	Department of Trade and Industry
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Professor D Q Bowen	University of London
Professor J B Thornes	University of Bristol
Professor D J Blundell	University of London
Professor A N Hunter	
Professor C D Curtis	University of Sheffield

Appendix 4
Research Grants

Number of Research Grants and Special Topic Grants current and sum of payments made during financial year 1 April 1985 - 31 March 1986

Research Grants

Grant Holders	Universities	Aquatic and Atmospheric Physical Sciences	Aquatic Life Sciences	Geological Sciences	Terrestrial Life Sciences	Total Expenditure £ 1985/86
	Aberdeen		5	5	11	175,543
	Aston	-	2	-	-	6,127
	Bath	1	-		1	25,220
	Belfast	-	3	-	-	28,664
	Birmingham	2	1	4	2	36,420
	Bristol	4	5	3	5	175,586
	Cambridge	11	-	32	8	705,281
	Dundee	-	7	-	-	56,208
	Durham	-	-	6	3	79,263
	East Anglia	4	-	1	2	92,850
	Edinburgh	6	1	6	9	204,885
	Essex	1	-	2	-	35,548
	Exeter	3	-	1	4	68,231
	Glasgow	-	6	4	6	229,630
	Heriot-Watt		1	-	-	7,850
	Hull		2	2	-	15,590
	Keele	-	-	-	1	13,313
	Lancaster	1	3	-	2	72,214
	Leeds	1	-	7	3	134,493
	Leicester	-	2	9	2	121,443
	Liverpool	1	2	6	1	44,717
London	*Birkbeck College*	-	-	1	1	12,112
	Chelsea College	-	1	-	-	6,024
	Goldsmiths' College	-	1	1	-	23,167
	Imperial College	3	1	8	4	173,769
	King's College	-	2	2	1	29,688
	Queen Mary College		3	-	1	25,889
	Royal Holloway and Bedford New College		2	1	-	32,710
	University College	1	-	5	2	54,366
	Loughborough	1	2	-	-	27,534
	Manchester	3	-	6		60,121
	Manchester Institute of Science & Technology	5	-	-	-	48,529
	Newcastle	-	2	6	4	99,679
	Nottingham	1	1	2	2	45,607
	Open	-	-	7	-	66,284
	Oxford	6	2	8	5	154,916
	Reading	3	1	1	3	71,519
	Sheffield	-	-	4	2	41,037
	Southampton	5	5	1	3	72,468
	St Andrews	-	6	1	1	74,531
	Stirling	2	1	-	2	52,696
	Strathclyde	1	1	-	1	20,312
	SURRC	-	-	3	-	187,420
	Sussex	-	1	-	-	1,948
University of Wales	*Aberystwyth*	-	2	2	2	30,224
	Bangor	2	9	2	2	106,342
	Cardiff	1	3	5	5	147,512
	Swansea	2	7	-	1	107,169
	Institute of Science & Technology		2		1	20,369
	Warwick		1		-	8,693
	York		-	-	2	33,563
	Sub-total	**72**	**96**	**154**	**106**	**4,165,274**

Institution	Aquatic and Atmospheric Physical Sciences	Aquatic Life Sciences	Geological Sciences	Terrestrial Life Sciences	Total Expenditure £ 1985/86
Polytechnics					
Huddersfield	1				1,110
Lanchester	1				8,445
Leicester	1				14,633
Liverpool	-	-			3,425
Plymouth	2	2			10,645
Portsmouth	-	3		-	12,664
Preston	-	-		2	3,940
Sub-total	**5**	**5**	**-**	**3**	**54,862**
Others					
Cranfield Institute of Technology					200
Game Conservancy					14,203
London Middlesex Hospital					7,096
London Zoological Society				1	11,879
Sub-total	**1**	**-**	**1**	**2**	**33,378**
Non Grant Holders					
Atomic Weapons Research Establishment					9,343
Sub-total					**9,343**
Total Research Grants	**78**	**101**	**155**	**111**	**4,262,857**

Special Topic Grants

Institution	Number of Grants	Total Expenditure £ 1985/86
		£
Aberdeen	2	25,495
Birmingham	2	45,366
Bristol	1	8,020
Cambridge	3	50,319
Darlington Trust	1	2,122
Dundee	2	24,681
Durham	1	9,111
East Anglia	1	14,963
Essex	1	10,804
Glasgow	1	13,957
Royal Botanic Gardens	2	13,574
London *Birkbeck College*	1	5,661
Liverpool	2	24,425
Nottingham	2	2,935
Open	2	18,098
Oxford	3	30,741
Reading	1	14,091
Southampton	4	23,430
UCNW	4	31,392
UMIST	1	2,653
***Total Special Topic Grants**	**37**	**371,838**
Grand Total of Expenditure Research Grants and Special Topics		**4,634,695**

* **FOOTNOTE:** Total Special Topic funding for 1985-86 = £896,000. Other funding for Special Topics is £448,000 in Universities classified under "Centrally Funded Projects" (see Appendix 9) and £76,000 in Institutes and Associations.

Appendix 5
Research Studentships

Awarded 1 October 1985
Tenure three years

Institution	Aquatic and Atmospheric Physical Sciences	Aquatic Life Sciences	Geological Sciences	Terrestrial Life Sciences
University/Polytechnic				
Aberdeen		3		
Aston	-	2		
Belfast	–	1	1	-
Birmingham	5	2	3	2
Bristol	4	3	5	1
Brunel	–	1		-
Cambridge	4	1	11	4
Dundee		4	-	1
Durham	–	1	4	3
East Anglia	5	1	2	2
Edinburgh	2	1	7	2
Essex	–	1	–	1
Exeter	1	–	1	1
Glasgow	1	2	3	1
Hull			2	1
Keele			1	1
Kent	-			1
Lancaster	2	2	1	1
Leeds	1		6	1
Leicester	-	–	5	–
Liverpool	1	1	6	5
Liverpool Polytechnic				1
London *Birkbeck College*			1	–
Goldsmiths' College			2	
Imperial College			7	3
King's College (KQC)			2	
London School of Economics			1	
Queen Mary College			1	
Royal Holloway & Bedford New College			2	
UMBS Millport	-		–	
University College	2	-	3	
Manchester	2	2	3	
Manchester Institute of Science & Technology	2		–	
Newcastle	1		6	-
Nottingham	2		5	2
Open	-		2	–
Oxford	3		7	5
Portsmouth Polytechnic	–			1
Plymouth Polytechnic	–			–
Reading	3		3	2
St Andrews	1	2	3	2
Sheffield	1	1	4	2
Southampton	4	1	4	–
Stirling	1	1	-	1
Strathclyde			1	–
Sunderland Polytechnic			–	1
Sussex			1	
University of Wales				
Aberystwyth			2	1
Bangor	2	3	–	2
Cardiff	–	1	7	2
Swansea		4	1	2
Institute of Science & Technology		–		1
Warwick		2		1
York	-	–		2
Total	**56**	**49**	**131**	**67**

Appendix 6

Advanced Course Studentships

Awarded 1 October 1985
Tenure one year

Institution	Aquatic and Atmospheric Physical Sciences		Aquatic Life Sciences	Geological Sciences	Terrestrial Life Sciences
University/Polytechnic					
Aberdeen	–		3		
Birmingham	13		6	–	
Camborne School of Mines	–		4	–	
Cranfield Institute of Technology			–	2	
Durham			10	3	
Edinburgh			–	4	
Hull			4	–	
Leeds			14		
Leicester			2		
Liverpool	1		–	–	
London *Imperial College*	5	–	26	6	
King's College (KQC)	–	4	–	–	
Queen Mary College	–	–	2	–	
University College	5		12	3	
Wye College	–		–	5	
Napier College	–	2	–		
Newcastle Upon Tyne	6		7		
Oxford	–		–		
Plymouth Polytechnic	–	5	–		
Reading	9	–	3		
Sheffield	–		4		
Southampton	6	–	–		
Stirling	–	4			
University of Wales					
Aberystwyth			4		
Bangor			3		
Institute of Science & Technology	–	5	–	–	
Total	**49**	**22**	**104**	**33**	

In addition, 5 awards were made to the Remote Sensing Course jointly run by University College and Imperial College

Appendix 7
Research Fellowships

Research Fellowships awarded 1985
Tenure two years

	Name	Institution	Topic
Aquatic and Atmospheric Physical Sciences	M R Dawson	UCW Aberystwyth	The development of riffles and bars in gravel bedded rivers.
Aquatic Life Sciences	S R L Bolt	Southampton University	Environmental effects on behaviour and osmore-regulation in selected amphipods
	S Morris	Calgary University	An investigation of the ecophysiological significance of modulators of haemocyanin oxygen affinity.
Geological Sciences	P Doyle	British Museum (Natural History)	Palaeobiogeography of the Mesozoic Belemnoids
	S M Wickham	Cambridge	Fluid transport in the Continental shelf.
	D J W Cooper	Leicester	Sedimentology of the northern continental margin of the Indian plate in Ladakh-Zanskar, Himalayas.
	P M Trayner	UC Cardiff	Three dimensional volume balancing and its application to the geometry of faults.
Terrestrial Life Sciences	j L B Mallet	University College, London	Natural selection for warning colouration in hybrid zones of *Heliconius* butterflies
	D P Whitfield	Cambridge University	Polyandry and mate desertion in Red-Necked Phalarope.

Appendix 8
Account for the year

Account for the year ended 31 March 1986

1984/85	**Receipts**	*1985/86*
£		£
65,303,000	**Parliamentry Grant-in-Aid**	67,880,000
	Commissioned Research from Government Departments	
2,352,545	Department of Trade and Industry	2,215,401
8,253,442	Department of Energy	7,788,192
4,910,163	Department of the Environment	5,061,651
2,142,900	Ministry of Agriculture, Fisheries & Food	2,187,646
215,283	Nature Conservancy Council	364,078
2,688,996	Overseas Development Administration	3,925,798
385,142	Others	463,680
625,956	**European Communities**	950,009
3,382,763	**Fees and charges to outside bodies**	4,821,639
2,872,004	**Miscellaneous Receipts**	4,255,977*
93,132,194	**Total Receipts**	99,924,071**
303,889	**Balance brought forward 1 April**	462,350
93,436,083		**100,386,421**

1984/85	**Payments**	*1985/86*
£		£
	Administration	
1,859,372	Salaries and Wages	2,009,146
1,026,443	Recurrent Expenses	1,242,205
	Central Expenses	
3,630,923	Superannuation	5,215,578
99,845	Training	93,714
70,560	Advertising	-#
46,348	Other Expenses	65,339
	Component Institutes of the Council	
30,949,973	Salaries and Wages	30,587,259
29,221,609	Recurrent Expenses	29,270,531
4,470,191	Capital Equipment	6,692,612
5,089,143	New Building and Research Vessels	5,503,947
	Grant-Aided Laboratories and Units	
3,837,072	Salaries and Wages	4,043,785
1,415,517	Recurrent Expenses	1,494,587
234,927	Capital Equipment	281,429
9,458	New Building and Research Vessels	52,658
4,199,167	**Grants for Research in Universities etc**	4,634,695
5,714,461	**Postgraduate Training Awards & Fellowships etc**	6,021,409
1,098,724	**Other Expenditure on Research**	2,940,380
92,973,733	**Total Expenditure**	100,149,274
462,350	**Balance carried forward 31 March**	237,147
93,436,083		**100,386,421**

* Includes £325,000 capital receipt (Sale of Taunton site).
** Includes £447,600 relating to Association local receipts
# Responsibility for Advertising costs has been transferred to the Institutes/Associations.

Appendix 9
Summary of Payment

Summary of Payments and Receipts for year ended 31 March 1986

	General Expenses £	*Capital Expenses* £	*Commissioned Receipts* £	*Ordinary Receipts* £	*Net Total* £
Component Institutes					
British Geological Survey	22,229,269	2,423,437	17,510,382	355,235	6,789,089
Institute of Oceanographic Sciences	6,621,250	799,068	4,717,639	423,137	2,275,542
Institute for Marine Environmental Research	1,751,832	229,888	752,611	11,079	1,218,030
Institute of Marine Biochemistry	564,856	36,182	164,700	6,662	429,676
Institute of Hydrology	2,749,283	143,283	1,680,643	31,927	1,179,996
Institute of Terrestrial Ecology	5,351,155	466,607	1,328,930	106,488	4,390,344
Institute of Virology	1,068,397	24,290	17,843	131,773	943,071
British Antarctic Survey	9,820,325	2,872,536	-	444,964	12,247,897
Sea Mammal Research Unit	412,581	3,362	207,506	6,480	201,957
NERC Scientific Services	4,240,199	3,667,047	-	85,910	7,821,336
	54,809,147	**10,663,700**	**26,372,254**	**1,603,655**	**37,496,938**
Grant-Aided Laboratories and Units					
Marine Biological Association	1,715,358	64,049	338,286	99,493	1,341,628
Scottish Marine Biological Association	1,651,861	127,252	479,026	44,449	1,255,638
Freshwater Biological Association	2,171,153	142,786	598,528	140,503	1,574,908
	5,538,372	**334,087**	**1,415,840**	**284,445**	**4,172,174**
Headquarters and Other Expenditure					
Headquarters	3,251,351	-		1,235,830	2,015,521
Research Grants	3,960,952	673,733		-	4,634,695
Training Awards and Fellowships	6,021,409	-	-		6,021,409
Headquarters Directed Units					
Research Vessel Services	5,048,643	1,532,859		176,289	6,405,213
Outside Research					
Centrally Funded Projects	800,891				800,891
International Phase of Ocean Drilling	1,840,493	-			1,840,493
Unit of Comparative Plant Ecology – Sheffield	257,766	41,230	-		298,996
Other Centrally Administered Items					
Relocation Costs	65,339				65,339
Superannuation	5,215,578			955,758	4,259,820
Training	93,714				93,714
	5,374,631	-	-	**955,758**	**4,418,873**
Grand Total	**86,903,665**	**13,245,609**	**27,788,094**	**4,255,977**	**68,105,203**

Appendix 10

Main Field Budget 1985/86

The NERC Main Field Budget shown in the following tables conveys the main features of the NERC scientific programme classified into subdivisions of the five major divisions of the Earth, Seas, Inland Waters, Terrestrial Environment and Atmosphere.

The criteria used to define a Main Field are primarily scientific, but also take into account operational and other practical considerations. Within a single Main Field the research nearly always covers a range of scientific disciplines, which reflects the fact that the Main Fields condense what in reality are many thousand individual research projects in progress at 14 institutes and most universities. There is inevitably a good deal of subjective judgement in deciding where to draw the boundaries between Main Fields. In many cases what is being identified is better described as a 'centre of gravity' of a field of scientific activity which intergrades at its periphery with several adjacent fields.

Since this is also an expenditure budget for a particular financial year the whole of the NERC expenditure for that year, including support of research and training at universities and commissioned research, is allocated to one or other of the Main Fields. Overheads, such as expenditure on central administrative functions at institutes and Council Headquarters, are assigned pro-rata. Running costs of large facilities such as research vessels are assigned in proportion to how they have been deployed over the various Main Fields. Major capital expenditure in the year in question, eg on buildings, is also assigned according to their anticipated use.

In the Table which follows, total expenditure is shown, net of incidental receipts, with the commissioned research shown separately. This may differ from the actual spend on commissioned research projects in 1985/86 (see Appendix 11) due to adjustments in respect of opening and closing balances, and methods of funding.

		Total Expenditure A	Commissioned Research B	Column A as a percentage of Total Expenditure
	The Solid Earth	**£k**	**£k**	**%**
1	Geological survey of UK landmass and associated studies including deep geology	7,713	2,687	8.0
2	Geological surveys and associated studies on overseas land masses, including geomorphology and quaternary studies overseas (solid geology and hydrogeology)	5,499	3,670	
3	Structure and composition of the NW European continental shelf and margin	7,150	6,598	7.5
4	Minerals resources and reconnaissance in UK and world mineral data compilations	3,047	2,488	3.2
5	Geochemical research excluding support	1,413	87	1
6	Mineralogy and petrology	74	12	0.1
7	Geophysics, excluding support surveys	3,458	720	3.6
8	Engineering geology	128	14	0.1
9	Marine geology and geophysics (other than NW European shelf and margin)	5,217	2,145	5.4
10	Palaeontological and palaeoenvironmental research	415	177	0.4
11	Hydrogeology	1,845	1,358	1.9
12	Glaciology	1,880		2.0
13	Extra-terrestrial studies	18	–	
14	Information	1,552	26	1.6
15	Remote sensing	134		0.1
16	Computing	40		0.1
17	Major capital	2,993		3.1
18	Research grants/training awards/ Fellowships	4,263		4.5
	Total	**46,839**	**19,982**	**48.8**

	The Seas	Total Expenditure A £k	Commissioned Research B £k	Column A as a percentage of Total Expenditure %
1	Ocean circulation and fluid mechanics	3,138	1,155	3.2
2	Tides and surges	1,615	459	1.7
3	Marine chemistry	1,155	268	1.2
4	Sedimentology (including sedimentation)	289	71	0.3
5	Information services (marine)	77	36	0.1
6	Scientific services and methods (marine)	638		0.7
7	Studies of deep ocean ecosystems	3,759	530	3.9
8	Studies of shelf sea ecosystems	1,793	362	1.8
9	Studies of coastal waters and estuarine ecosystems	1,388	384	1.4
10	Experimental studies of environmental and ecological processes	810	146	0.8
11	Functional and behavioural responses of marine organisms to their environment	1,542	200	1.6
12	Pollutants in the marine environment	919	244	1.0
13	Studies related to culture of bivalves and fish	459	135	0.5
14	Marine mammals	920	207	1.0
15	Basic biology of marine organisms	833	20	0.9
16	Major capital	1,013		1.1
17	Research grants/training awards/ Fellowships	1,918		2.0
	Total	**22,266**	**4,138**	**23.2**

	Inland Waters	Total Expenditure A £k	Commissioned Research B £k	Column A as a percentage of Total Expenditure %
1	Hydrology – systems studies	959	375	1.0
2	Hydrology – process studies	1,516	385	1.6
3	Hydrology – applied studies	1,231	788	1.3
4	Hydrology – service activities	579	132	0.6
5	Rivers, canals, streams etc	1,074	368	1.1
6	Lakes, ponds, reservoirs etc	1,705	143	1.8
7	Basic biology (non-habitat orientated)	579	74	0.6
8	Scientific services, methods and information	256	75	0.3
9	Major capital	77		0.1
10	Research grants/training awards/ Fellowships	1,385		1.4
	Total	**9,361**	**2,340**	**9.8**

	The Terrestrial Environment	Total Expenditure A £k	Commissioned Research B £k	Column A as a percentage of Total Expenditure %
1	Vertebrates	2,074	236	2.2
2	Invertebrates	1,299	101	1.3
3	Plants	2,332	403	2.4
4	Micro-organisms and microbiology	1,379	39	1.4
5	Soil	1,406	384	1.5
6	Habitats	929	106	1.0
7	Scientific services, methods and information	534	9	0.6
8	Major capital	408		0.4
9	Research grants/training awards/ Fellowships	2,664		2.8
	Total	**13,025**	**1,278**	**13.6**

	The Atmosphere	Total Expenditure A £k	Commissioned Research B £k	Column A as a percentage of Total Expenditure %
1	Dynamical meteorology and climatology	1,057	25	1.1
2	Physical meteorology	703	25	0.7
3	Ionosphere and magnetosphere	1,842		2.0
4	Major capital	374		0.4
5	Research grants/training awards/ Fellowships	426		0.4
	Total	**4,402**	**50**	**4.6**
	Grand Total	**95,893**	**27,788**	**100.0**

Appendix 11

Source of Funds for Commissioned Research

Source of Funds for Commissioned Research in 1985/86
(Actual Spend: Full Economic Cost)

A detailed breakdown of expenditure on commissioned research is displayed in the following tables. These itemise the spend on commissions funded by the original customer departments and by other customers in both the public and private sectors. These expenditure figures represent actual charges to customers and not necessarily amounts received in the financial year in question, which are shown in Appendices 8 and 10; for example, due to financial year variations, actual receipts from the European Communities (Table G below) in 1985/86 were £960k.

The information is provisional, dependent in some cases on continuing discussions with customers, and is presented in the following order:

		Total Funds £k
Table A	Department of Trade and Industry	2,224 4
Table B	Department of Energy	7,816 6
Table C	Department of Environment	5,064.5
Table D	Ministry of Agriculture, Fisheries and Food	2,262 5
Table E	Nature Conservancy Council	356 2
Table F	Overseas Development Administration	3,861.5
Table G	European Communities	899.7
Table H	Other organisations	5,266.5
	Grand Total	**27,751.9**

Table A: Research Commissioned by Department of Trade and Industry – 1985/86

Commission	*Institute*	Actual Expenditure £k *Customer Share*	*NERC Share*	*Other Sources*	*Total*
Geological land survey of Gt Britain	BGS	237.5	237 4		474.9
Regional geochemical reconnaissance	BGS	644 6	-		644.6
Mineral intelligence, statistics and economics	BGS	498.6			498.6
Fiscal incentives	BGS	49.0			49.0
Mineral reconnaissance programme	BGS	473.0			473.0
Strategic minerals	BGS	194 0			194.0
Exploration criteria for buried mineral deposits based on new metallogenic models	BGS	62 2			62.2
Geochemical recognition of hidden granites and associated tungsten mineralisation	BGS	22 0			22:0
Sub-total		**2,180.9**			
The effects of long term preservation on the viability and stability of micro organisms	ITE	43 5	43 5		87.0
Sub-total		**43.5**			
Total		**2,224.4**			

Table B: Research Commissioned by Department of Energy - 1985/86

Commission	Institute	Customer Share	NERC Share	Other Sources	Total
				Actual Expenditure £k	
Offshore geology (main programme)	BGS	6,100 0	899 6	565 0	7,564.6
Geothermal energy: Larne borehole	BGS	1 3	-	-	1 3
Geothermal background: Hot dry rock programme	BGS	662 9			662 9
Geothermal background: Low enthalpy programme	BGS	223.3			223.3
Deep source gases and hydrocarbons within the UK crust	BGS	28.8	33.5		62 3
Seismic monitoring in SW England - Phase II	BGS	7: 4	-		7: 4
Sub-total		**7,087.7**			
Continental Margins	IOS	24 0			24 0
Wave climate studies	IOS	161 1			161.1
Advice to the Department	IOS	10 0			10.0
Guidance Notes	IOS	45 0			45.0
Investigation of near surface current profiles	IOS	84 0			84.0
Directional wave measurements in the Southern North Sea	IOS	59 2			59 2
Wave climate measurements around the UK (ship borne wave recorder measurements)	IOS	76.4	4 6		81 0
Wave measurements for statistical research west of the Scilly Isles	IOS	23 0	1.4		24.4
Analysis of residual currents in deeper waters north and west of Scotland	IOS	10.0			10 0
Non-UKOOA data banking	IOS	22 4			22 4
Sub-total		**515.1**			
Near surface current measurements	SMBA	198.8	0.3		199.1
Residual current statistics	SMBA	15 0	-		15.0
Sub-total		**213.8**			
Total		**7,816.6**			

Table C: Research Commissioned by Department of the Environment - 1985/86

Commission	Institute	Customer Share	NERC Share	Other Sources	Total
				Actual Expenditure £k	
Geological planning for development/Land use/Resource planning	BGS	,,191 6	250 4		1 442.0
Hydrogeology in Scotland - Phase II	BGS	38 9	-		38 9
Trace element concentrations in British aquifers	BGS	71.6		-	71 6
Nitrate pollution in groundwater	BGS	64 7		41 3	106 0
Study of limestone workings in the West Midlands	BGS	187 4			187 4
Behaviour of wastes in landfill sites	BGS	119.8		-	119 8
Radioactive waste research	BGS	474.9	7 7	70 8	553 4
Sub-total		**2,148.9**			
Regional and site specific investigation of biological processes at the Great Meteor East location	IOS	121.8	82.5		204 3
Site characterisation studies	IOS	372.4	8 5		380 9
Studies of large and local scale advection and dispersion relevant to Great Meteor East location	IOS	119 6	90.9		210 6
Studies of sediment movement in the Irish Sea	IOS	14.9			14.9
Diffusion of natural radionuclides in sediments	IOS	11.2	2.6		13.8
Development of instrumentation for use with low frequency penetrator transponder	IOS	19 4	2.1		21 5
Site assessment studies	IOS	789 0	47 9		836 9
Particulate matter in the water column in relation to the disposal of RAW	IOS	47 4	0 4		47.8
Sub-total		**1,495.7**			

Commission	Institute	Actual Expenditure £k			
		Customer Share	*NERC Share*	*Other Sources*	*Total*
Environmental quality in estuaries – an integrated study	IMER	158.1	10 0		168.1
Estuarine chemistry of metals	IMER	82.1	6 7		88.8
The origin, composition & distribution of 'Hot particles' derived from the nuclear industry and dispersed in the environment	IMER	41.5	3.1		44.6
Evaluation of techniques for detecting pollution effects on benthic communities	IMER	8.2	0.9		9.1
Estuarine sediment bioturbation metal distribution	IMER	36 4	2.8		39.2
Sub-total		**326.3**			
Effects of upland afforestation on water resources	IH	28.0	107.7	38.5	174 2
Effects of upland use on water quality	IH	24.2	44.1	9.3	77.6
Pesticide pollution in catchments	IH	22.6	8.9	-	31.5
North Sea Water balance	IH	6.0	1.0		7.0
Residual flows	IH	4.5	5.5		10.0
Hydrological analysis representative basins	IH	34.3	28 9		63.2
Regional flood and storm hazard over reservoired catchments	IH	34.5	22 1		56.6
Improved methods of reservoir flood estimation	IH	2 7			2 7
Sub-total		**156.8**			
Chemicals in the terrestrial environment	ITE	60 0	1 5		61 5
Effects of acidic deposition on plants and soil	ITE	173 5	186.9		360.4
Sheep grazing studies	ITE	14 0	7.3		21.3
Distribution and Dynamics of radionuclides in the terrestrial environment	ITE	75 0			75.0
Effects of afforestation and land management of acidity in 5 catchment areas in Wales	ITE	15.1	26 6		41 7
Effect of altitude and occult precipitation on acid deposition at Great Dun Fell, Cumbria	ITE	66.0	0 8		66 8
Effects of acid rain on fresh water ecosystems in North West England	ITE	10.2	26.1		36 3
Upland management and water quality – Phase II	ITE	17 8	211.2		238 2
Wash birds and invertebrates	ITE	50.0	12.6		62.6
Monitoring of nitrogen oxides and ozone in Scotland and analysis of past UK data	ITE	22 7	3 3		26.0
Radionuclide concentrations in bird tissues, their foods and feeding areas near Ravenglass	ITE	18.6	5.1		23.7
Sub-total		**522.9**			
Effects of flow regime on recruitment of salmonid fish – Phase II	FBA	20.0	34 1	43.5	97 6
Upland management and water quality – Phase II	FBA	26.1	19 0		45.1
Automatic identification and enumeration of algae	FBA	7.0	15 5	-	22.5
Analysis of natural river communities	FBA	83 7	67.2	24 3	175.2
Nitrates in surface water, inputs and seasonality	FBA	31.5	2.2		33 7
Acidification of lakes and reservoirs. Diatom studies - Cumbria	FBA	36.8	38 2		75 0
Nitrates – Loss processes in raw water	FBA	16 3	5 8		22 1
Validation of Biotic Score	FBA	36 8	–		36 8
Sub-total		**258.2**			
Perflurocarbon tracers for marine studies	MBA	50 0			50.0
Effects of heavy metals on estuarine benthic organisms	MBA	70 4	26 9	43.6	140.9
Surface complexation model to determine Kd values	MBA	35 3			35 3
Sub-total		**155.7**			
Total		**5,064.5**			

Table D: Research Commissioned by Ministry of Agriculture, Fisheries and Food - 1985/86 *Commission*	*Institute*	Actual Expenditure £k *Customer Share*	*NERC Share*	*Other Sources*	*Total*
Movement of material on the seabed under the combined action of waves and tides – Phase II	IOS	27.7			27.7
Wave current interaction	IOS	60.5			60.5
Modernisation of class A tide gauge network and the modernisation of STW's	IOS	25.0			25.0
2D numerical models of the seas around Britain	IOS	137.6			137.6
Statistical prediction of extreme sea levels	IOS	48.3			48.3
Trends in mean sea levels	IOS	13.1			13.1
Data banking for class A network	IOS	57.2			57.2
Class A tide gauge network	IOS	135.6			135.6
Improvements of tidal prediction for flood protection	IOS	66.3			66.3
Effects of wave set up	IOS	79.0			79.0
Probability of extreme waves and sea levels offshore	IOS	18.6			18.6
High wave studies	IOS	7.2			7.2
Ocean circulation modelling	IOS	16.6			16.6
Sub-total		**692.7**			
CPR programme	IMER	241.3	488.3		729.6
Sub-total		**241.3**			
Plankton production in the Western English Channel	MBA	133.1	280.5		413.6
Sub-total		**133.1**			
Nutritional requirements and feeding behaviour of fish	IMB	135.1	76.6		211.7
Bait attraction and acceptance in long lining	IMB	3.3	-		3.3
Relationships between lipids in phytoplankton, zooplankton and herring larvae	IMB	26.3			26.3
Sub-total		**164.7**			
The physiology of stress responses in freshwater fish	FBA	35.0	41.7		76.7
Salmonid/coarse fish interactions in chalk streams	FBA	48.9			48.9
Effects of flow regime on salmonid recruitment	FBA	21.8	34.1	41.7	97.6
Sub-total		**105.7**			
Fish biology	SMBA	29.1	182.6		211.7
Hydrography of the NW Approaches	SMBA	101.9	1.7		103.6
Phytoplankton in relations to mariculture	SMBA	18.7	2.3		21.0
Organic degradation	SMBA	66.6	297.7		364.3
Sub-total		**216.3**			
Wetland review	IH				23.8
Distributed catchment models	IH				55.3
Forecasting Flood Flows	IH				60.5
Archive of rainfall and run off data	IH				89.3
Flood hydrograph estimation procedures	IH				58.7
Effects of urbanisation on catchment hydrology	IH				22.0
Effects of artificial drainage on catchment hydrology	IH	551.4			24.4
Catchment response and the flood frequency curve	IH				36.7
Review flood studies statistical procedures	IH				143.7
Risk-based criteria for economic analysis of flood protection works	IH				6.3
Hydrological behaviour of flat agricultural catchments	IH				44.7
Leaching of nitrates	IH				6.0
Sub-total		**551.4**			

Commission	Institute	Actual Expenditure £k Customer Share	NERC Share	Other Sources	Total
Sheep grazing studies	ITE	20.0	0.4		20.4
Sub-total		**20.0**			
Whale research	SMRU	64.5	65.1		129.6
Seal research	SMRU	72.8	222.9		295.7
Sub-total		**137.3**			
Total		**2,262.5**			

Table E: Research Commissioned by Nature Conservancy Council – 1985/86

Commission	Institute	Actual Expenditure £k Customer Share	NERC Share	Other Sources	Total
BRC-recording of data	ITE	61.3	140.6	-	201.9
Population ecology of bats	ITE	9.7	53.1		62.8
Butterfly monitoring scheme	ITE	12.0	63.3		75.3
Birds of prey and pollutants	ITE	51.0	49.8		100.8
Creating attractive grasslands	ITE	30.0	30.9		60.9
Impact of land drainage on wildlife	ITE	30.7	16.6		47.3
Ecological of woodland fritillary	ITE	16.0	14.4		30.4
Acidification effects on freshwater plants and invertebrates	ITE	12.0	-		12.0
Effects of fluoride on lichens	ITE	20.0	107.5		127.5
Sand dune grazing	ITE	20.0	10.5		30.5
Butterflies management in woodlands	ITE	30.5	8.8		39.3
Effects of nitrogen on species diversity	ITE	4.2	0.4		4.6
Changes in lowland grassland	ITE	5.0	-	-	5.0
Loch Leven phosphorous loading	ITE	11.5	3.9	18.7	34.1
Sub-total		**313.9**			
Assessment of the nutrient status and associated algae productivity of Malham Tarn	FBA	28.0			28.0
Sub-total		**28.0**			
Advice and services	IH	14.3			14.3
Sub-total		**14.3**			
Total		**356.2**			

Table F: Research Commissioned by Overseas Development Administration – 1985/86

Commission	Institute	Actual Expenditure £k Customer Share	NERC Share	Other Sources	Total
Mineral/geological/hydrogeological surveys	BGS	3,507.0		-	3,507.0
Hydrological surveys	IH	354.5		-	354.5
Total		**3,861.5**			

Table G: Research Commissioned by European Communities – 1985/86

Commission	*Institute*	Actual Expenditure £k *Customer Share*	*NERC Share*	*Other Sources*	*Total*
CREST programme	BGS	313.7	310.2	–	623.9
Groundwater nitrate pollution	BGS	41.3	–	64.7	106.0
Variations of acid deposition in groundwater in British geological environments	BGS	9.8			9.8
Experimental studies of the acid buffer capacities of British soils and rocks	BGS	6.3			12.6
RAW Phase II					
In-situ nuclide migration studies at a shallow land burial site	BGS	18.4			19.5
Cement grouts as borehole and shaft seals for repositories in argillaceous rocks	BGS	16.0			16.0
Coupling geochemical models based on thermodynamical equilibrium with models of solute transport	BGS	0.9			1.1
The vertical hydraulic conductivity of rock adjacent to single exploratory boreholes	BGS	10.4			10.4
Investigations of the populations of introduced and resident micro-organisms in deep repositories	BGS	5.0		0.7	5.7
Natural long term (10^1 - 10^4y) elemental migration in saturated clays and sediments	BGS	8.2		0.4	8.6
Co-operative projects with Atomic Energy of Canada Ltd (AECL) in the fields of hydrology and geochemistry	BGS	3.3			3.3
Geotechnical laboratory modelling of a repository for heat emitting RAW	BGS	8.6	6.0		14.6
Sub-total		**441.9**			
Seasat scatterometer data in relation to enclosed, semi-enclosed seas and coastal waters	IOS	1.6			1.6
Sub-total		**1.6**			
The role of surfaces in the transport of radionuclides in the marine environment	IMER	21.5	48.4		69.9
Sub-total		**21.5**			
Strategies for managing nitrates and heavy metals in the river system	IH	30.6	18.1	6.5	55.2
Predicting the effects of acid rain on water quality	IH	22.0	3.5		25.5
Sub-total		**52.6**			
West and Central African Hardwoods	ITE	11.0	3.6		14.6
Effects of canopies of different tree species on chemistry of throughfall and stemflow	ITE	21.6	40.7		62.3
Effects of acid precipitation on fish and other biota in freshwater in Scotland	ITE	13.4	18.7		32.1
Atmosphere surface exchange of oxides of nitrogen ozone and ammonia	ITE	18.9	18.9		37.8
Acid mist and tree injury	ITE	28.5	28.5		57.0
The fate and effect of pollutant fluoride in the terrestrial ecosystem	ITE	14.0	50.5		64.5
EC information system on the state of the environment Bitopes	ITE	61.0	–		61.0
Acid deposition on groundwater	ITE	14.4	14.4		28.8
Effects of acidification of natural waters upon amphibia	ITE	6.5	16.9		23.4
Selection of conifer genotypes able to produce high density wood when trees are growing rapidly	ITE	11.2	16.8		28.0
Sub-total		**200.5**			
Population biology of the Mediterranean Monk Seal in Greece	SMRU	34.3	37.2		71.5
Sub-total		**34.3**			

Commission	Institute	Customer Share	NERC Share	Other Sources	Total
				Actual Expenditure £k	
Survey of effect of important chemicals on freshwater environment (ECDIN)	FBA	20.0			20.0
Bacterial production of nitrate in aquatic systems	FBA	32.7	32.7		65.4
Acidification problems of freshwater Al + 3 specification and trophic relationships	FBA	45.1	18.0	27.1	90.2
Sub-total		**97.8**			
Biological availability of heavy metals on estuarine bethnic organisms	MBA	43.6	26.9	70.4	140.9
Volatile organic sulphur compounds	MBA	5.9	-	-	5.9
Sub-total		**49.5**			
Total		**899.7**			

Table H: Research Commissioned by Other Organisations – 1985/86

Commission	Institute	Customer Share	NERC Share	Other Sources	Total
				Actual Expenditure £k	
Welsh Office					
Hydrogeological mapping in Wales	BGS	10.0			10.0
Admiralty Marine Technology Establishment					
Underwater explosion analysis	BGS	18.3			18.3
DED					
N Ireland survey	BGS	409.6			409.6
Public bodies					
Various commissions	BGS	597.9	46.0		643.9
Private sector					
Various commissions	BGS	1,107.9			1,107.9
Sub-total		**2,143.7**			
Ministry of Defence					
Studies in the Upper Ocean	IOS	29.1			29.1
Sea level prediction at Barrow-in-Furness	IOS	27.7			27.7
Ships of opportunity programme to collect XBT observations in the North Atlantic	IOS	3.5			3.5
ERS Data Centre product support team	IOS	29.8			29.8
United States Geological Survey					
GLORIA operations	IOS	1,109.1			1,109.1
GLORIA construction	IOS	700.0			700.0
Marconi Underwater Systems Ltd					
Technology transfer	IOS	18.6			18.6
North West Water Authority					
H F radar development at Cumbria	IOS	12.8			12.8
EXXON					
Storm surge current simulation and wave investigation	IOS	27.8			27.8
Investigation and simulation of storm current events	IOS	13.0			13.0
ESTEC					
Study of ERS I radar altimeter data processing requirements	IOS	18.0			18.0
UKOOA					
Data banking	IOS	5.0			5.0
Sub-total		**1,994.4**			

Commission	Institute	Actual Expenditure £k: Customer Share	NERC Share	Other Sources	Total
Water Research Centre					
Studies on sewage and sewage sludge disposal to sea (1)	IMER	42.9	1.0		43.9
Studies on sewage and sewage sludge disposal to sea (2)	IMER	16.1	0.3		16.4
Installation of service unit, and rental on IMER premises	IMER	29.4			29.4
Population simulation model for bivalves in coastal waters	IMER	10.5	0.4		10.9
Modelling contaminants in the North Sea	IMER	8.5	0.7		9.2
SOTEAG					
Environmental monitoring at Sullom Voe, Shetland	IMER	30.6			30.6
Environmental Protection Agency					
Mussel eggs as integrators of chromosal damage induced by environmental mutagens	IMER	36.7			36.7
Sub-total		**174.7**			
Scottish Development Department					
Base flow estimation in Scotland	IH	1.8			1.8
Thames Water Authority					
Real time drought management	IH	17.9			17.9
Welsh Office					
Effects of upland use on water quality	IH	9.3	44.1	24.2	77.6
Royal Society					
Surface water acidification programme	IH	96.2	20.7		116.9
Public bodies					
Various commissions	IH	113.5			113.5
Private sector					
Various commissions	IH	216.7			216.7
Sub-total		**455.4**			
MOD					
Gruinard Island	ITE	3.1	0.4		3.5
Welsh Office					
Upland management and water quality	ITE	9.2	211.2	17.8	238.2
Acid rain in Wales	ITE	10.0	37.2	-	47.2
Scottish Development Department					
Loch Leven phosphorous loading	ITE	7.0	3.9	23.2	34.1
Tayside Regional Council					
Loch Leven phosphorous loading	ITE	6.7	3.9	23.5	34.1
Department of Agriculture and Fisheries for Scotland					
Loch Leven phosphorous loading	ITE	[illegible]	[illegible]	25.2	34.1
Forestry Commission					
Conservation survey project. Newborough Forest	ITE	7.0			7.0
Countryside Commission					
Assessment of amenity tree planting scheme	ITE	32.0			32.0
Countryside implications of changes on the common agriculture policy	ITE	9.2			9.2
Central Electricity Generating Board					
Ecological studies at Winfrith Heath	ITE	16.3			16.3
Ecological survey at Hinckley Point	ITE	21.4			21.4
Public bodies					
Various commissions	ITE	48.7			48.7
Private sector					
Various commissions	ITE	62.2			62.2
Sub-total		**237.8**			

Commission	Institute	Actual Expenditure £k			
		Customer Share	NERC Share	Other Sources	Total
Welsh Office					
Analysis of natural river communities in GB	FBA	9.3	67.2	98.7	175.2
Effects of Flow Regime on young stages of salmonid fish	FBA	9.2	34.1	54.3	97.6
Scottish Development Department					
Analysis of natural river communities in GB	FBA	15.0	67.2	93.0	175.2
The Royal Society - surface waters acidification programme					
Measurement of ph in freshwaters	FBA	38.5	5.2		43.7
Chemical speciation of aluminium in natural waters	FBA	22.9	7.8	10.0	40.7
Trophic relationships and effects of acid waters on stream invertebrates	FBA	4.2	38.4	35.1	77.7
Analysis of sediments of selected lakes	FBA	4.0	-	-	4.0
Public bodies					
Various commissions	FBA	44.3			44.3
Private sector					
Various commissions	FBA	26.1			26.1
Sub-total		**173.5**			
UNEP					
Satellite observations on free-living seals	SMRU	23.1			23.1
Sub-total		**23.1**			
Public bodies					
Various commissions	SMBA	57.4			57.4
Private sector					
Various commissions	SMBA	6.5			6.5
Sub-total		**63.9**			
Total		**5,266.5**			

Appendix 12
Staff List

Headquarters

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Director — Mr B J Hinde

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Ships' crews — 104

The NERC Scientific Services (NSS) provides central scientific and technical services in support of the Council's research activities. The three units described below come with NSS.

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Head of Service — Mr H J Down

The NERC Computing Service was formally constituted on 1 October 1979 to provide specialist advice and services on computing and associated activities to the NERC Institutes. The NCS is dispersed between a Headquarters at Swindon, two major installations at Keyworth and Wallingford and other NERC sites.

Southern Area Centre — c/o IH
Maclean Building
Crowmarsh Gifford
Wallingford
Oxon OX10 8BB
Telephone 0491 38800

Northern Area Centre — c/o BGS
Nicker Hill
Keyworth
Nottingham NG12 5GG
Telephone 06077 611

Technology Division — Polaris House
North Star Avenue
Swindon
Wilts SN2 1EU
Telephone 0793 40101

Head of Division — Vacant

Technology Division was formed in March 1984 with responsibility for radiocarbon dating, equipment and analytical services, remote sensing planning and coordination, marine planning, technology audit, administrative computing and office automation.

Research Vessel Services — No 1 Dock
Barry
South Glamorgan
Telephone 0446 737451

Head of Service — Dr L M Skinner

The Research Vessel Services was formed on 1 June 1978 to operate and maintain the NERC research ships, and to provide the shipborne instrumentation, data acquisition and computing facilities necessary to implement the marine research programmes of both NERC component institutes and university departments. The facilities provided by RVS include four research ships, two of which have a world-wide capability, a large equipment pool of modern oceanographic instrumentation and a number of computer based data acquisition systems. The RVS also provides the scientific and technical support to operate these systems at sea.

In addition NSS is responsible for the operation of a newly formed research unit.

NERC Unit for Thematic Information Systems — University of Reading
Department of Geography
Whiteknights
PO Box 227
Reading RE6 2AB
Telephone 0734 875123

Director — Dr J R G Townshend

Staff — 6 from NERC and
7 from the University

The NERC Unit for Thematic Information Systems was formed on 1 October 1985 with special responsibility for developing techniques for the management, analysis and display of remotely sensed and digital map data.

Science Directorates

Provide scientific support for Council and administer the NERC institutes. Grant-aided associations also fall under their aegis.

Earth Sciences	Director
British Geological Survey.	Professor J C Briden
Marine Sciences	Dr J D Woods

Institute for Marine Environmental Research, Institute of Oceanographic Sciences, Marine Biological Association of the UK, Scottish Marine Biological Association, Sea Mammal Research Unit.

Terrestrial and Freshwater Sciences	Dr P B H Tinker

Institute of Hydrology, Institute of Terrestrial Ecology, Institute of Virology, Freshwater Biological Association.

Component and Grant-Aided Institutes

The work carried out by each Institute is described briefly in this appendix. Most Institutes publish annual or periodic reports which describe work both completed and in progress in much more detail. These may usually be obtained on application to the Director

Normally, general enquiries should be addressed to the Director at the Headquarters of the Institute. However, it may be apparent than an outstation of the Institute may deal more readily with an enquiry and in this case enquiries may be directed to the named person at that location.

The non Science Group staff includes a wide variety of support grades such as Professional and Technology Officers, ships officers and crew cartographic draughtsmen, librarians, data processors, as well as administrative grades

British Geological Survey	Keyworth Nottingham NG12 5GG Telephone (06077) 6111 Telex 378173
Director	Professor Sir G M Brown FRS (1)
Deputy Director	Mr G I Lumsden (1)
Total Staff	760
Science Group	520

Formed in 1965 by amalgamation of the Geological Survey of Great Britain (founded in 1835), Geological Survey of Northern Ireland, Overseas Geological Surveys (founded in 1947 as Directorate of Colonial Geological Surveys) and the Geological Museum. The name was changed from Institute of Geological Sciences on 1 January 1984. Research is centred on modern geological sciences surveying of the UK landmass and continental shelf, the production of general and specialist maps and reports, and the maintenance of national archives of geological data and specimens Field and laboratory teams embrace projects in geology, geophysics, geochemistry, hydrogeology, engineering geology and economic mineralogy. Large contracts with Government Departments include Continental Shelf geology, geophysics and oil/gas assessment; mineral resources assessment; regional geochemical surveys; waste-disposal feasibility studies; deep geological structures of sedimentary basins, geothermal energy sources; natural hazards assessment; and overseas surveys in developing nations. Advisory services are provided on a wide range of economic and environmental topics.

The Museum* and Library are open to the public and provide a major national reference centre for geological sciences information.

The Survey is administered through the Directorates listed opposite. The numbers in brackets refer to the BGS office locations listed on page xxvi.

Programmes Directorate A	Director: Dr R W Gallois (2)

Chiefly Regional Geological Surveys and associated field-orientated studies of Scotland and England north of Ribble-Tees line.

Programmes Directorate B	Director: Mr E G Smith (1) (also Chief Geologist)

Chiefly Regional Geological Surveys, primary surveys, resurveys, and associated field orientated studies of England south of a Ribble-Tees line, and of Wales.

Programmes Directorate C	Director: Mr J H Hull (1)

Chiefly Department of Energy projects on the UK Continental Shelf and research developments in comparable environments elsewhere

Programmes Directorate D	Director: Dr D K Bloomfield (1)

Primarily concerned with all programmes overseas funded by Overseas Development Administration, local governments and EEC. Also the maintenance of a global information system on minerals for Department of Trade and Industry.

Geochemistry Directorate	Chief Geochemist: Mr P J Moore (4)

Mostly concerned with basic research in geochemistry, mineralogy and petrology Also special Surveys concerned with mineral and geochemical reconnaissance with supportive specialist laboratories.

Geology Directorate	Chief Geologist: Mr E G Smith (1)

Include basic research in engineering and structural geology, hydrogeology, stratigraphy, sedimentology, and palaeontology, and the maintenance of standards of science and expertise in these fields for the various Programmes throughout the Survey

Geophysics Directorate	Chief Geophysicist: Dr R T Haworth (1)

Includes basic research in siesmology, geomagnetism, gravity, deep geology, engineering geophysics and various aspects of applied geophysics together with the maintenance and development of specialist laboratories.

Information and Central Services Directorate	Head: Dr B Kelk (1)

Development of BGS Information Systems, liaisons with the other seven Directorates in all matters concerning Information Processing and Dissemination and marketing Development. Responsibility for the Library, Drawing Office, Photographic Section and Editorial and Publication Section.

Addresses of BGS Offices

Keyworth
Nottingham NG12 5GG
Telephone
Plumtree (06077) 6111
Telex 378173

2. Murchison House
West Mains Road
Edinburgh EH9 3LA
Telephone 031-667 1000
Telex 727343

3. 154 Clerkenwell Road
London EC1R 5DU
Telephone 01-278 3281

4. 64 Gray's Inn Road
London WC1X 8NG
Telephone 01-242 4531

5. 19 Grange Terrace
Edinburgh EH9 2LF
Telephone 031-667 1000
Telex 727343

6. Bryn Eithyn Hall
Llanfarian
Aberystwyth
Dyfed
Telephone
Aberystwyth (0970) 611038

7. St Just
Pennsylvania Road
Exeter EX4 4HE
Telephone
Exeter (0392) 78312/3

8. 20 College Gardens
Belfast BT9 6BS
Telephone Belfast (0232) 666595

9. Institute of Hydrology
Maclean Building
Crowmarsh Gifford
Wallingford
Oxfordshire OX10 8BB
Telephone Wallingford (0491)
38800
Telex 849365

10. *Eskdalemuir Geophysical
Observatory
Langholm
Dumfries & Galloway DG13 0QW
Telephone Langholm (05416) 283

11. *Magnetic Observatory
Hartland
Bideford
Devon EX39 6BH
Telephone Hartland (02374) 364

12. *Meteorological Officer
The Observatory
Lerwick
Shetland ZE1 0RR
Telephone Lerwick (0595) 22349
Telex 75171

13. Windsor Court
Windsor Terrace
Newcastle-upon-Tyne
NE2 4HE
Telephone (0632) 817088

*to be automated February 1987

Institute of Hydrology

Maclean Building
Crowmarsh Gifford
Wallingford
Oxfordshire OX10 8BB
Telephone
Wallingford (0491) 38800
Telex 849365

Director: Dr J S G McCulloch

Total Staff: 129
Scientific Staff: 95

The Institute, a component body of NERC since its formation in 1965, carries out fundamental studies of the behaviour of water in its main phases in the hydrological cycle and of the manner of its movement between these phases. For part of its work the Institute is exploring hydrological systems within complete catchment areas by studies of the influence of geomorphology and geology and of land use on the response to rainfall. Another part of the Institute's research programme consists of studies of the component processes of the hydrological cycle, such as the evaporation of water intercepted by vegetation and infiltration of water into the soil. The Institute also undertakes commissions for applied studies in the UK and overseas. These studies range from ad hoc advice on local flooding to water resources surveys or operational studies on larger river basins

***Institute of Marine Biochemistry**

St Fittricks Road
Aberdeen AB1 3RA
Telephone
Aberdeen (0224) 875695

Acting Director: Dr C B Cowey

Total Staff: 21
Scientific Staff: 16

The Institute became a component body of NERC in October 1971 and evolved from the former Fisheries Biochemical Research Unit of the University of Aberdeen. Research is centred on achieving an understanding of those basic biochemical principals of marine organisms that appear to be of particular importance in their adaptations to the marine environment and to their role and survival in the ecosystem. Much of the work has applications to fisheries research. Close contact is maintained with the University of Aberdeen and students may work in the Institute for postgraduate degrees under supervision of the staff

Institute for Marine Environmental Research

Prospect Place
The Hoe
Plymouth PL1 3DH
Telephone
Plymouth (0752) 21371

Director: Dr B L Bayne

Total Staff: 87
Scientific Staff: 69

The Institute was formed in 1970 with the general aim of conducting concerted multidisciplinary studies of marine and estuarine ecosystems and their component parts with an emphasis on the study of the mechanisms of natural variability, among other things as the basis for development of techniques for predicting the effects of pollutants and other man-made intervention. The principal programmes are concerned with estuarine ecology, the plankton of the open sea and the effects of changes in water quality on the performance of estuarine and coastal ecosystems. The IMER building, opened in 1977, has facilities for research in biology, physics, chemistry, physiology, biochemistry, histology, simulation modelling and the design of instrumentation for marine ecology

*to close in August 1987

Institute of Oceanographic Sciences

Brook Road
Wormley
Godalming GU8 5UB
Telephone
Wormley (042879) 4141
Telex 858833

Director: Dr A S Laughton FRS

Total Staff: 285
Scientific Staff: 182

The Institute of Oceanographic Sciences was established on 1 June 1973 by combining the National Institute of Oceanography, the Institution of Coastal Oceanography and Tides, and the Unit of coastal Sedimentation. This brought together those research activities of Council whose primary aim is the study of the oceans and shallow seas, and their interactions with the atmosphere, the seabed and the shore. The work of the Institute is divided between three laboratories as follows:

Wormley
Marine Physics (ocean circulation and fluid mechanisms), Marine biology, Marine geology, Marine geophysics, Marine chemistry, Marine Information and Advisory Service, Applied Physics, Ocean Engineering, Central Administration and Main Library.

Bidston
Sedimentation Tides and Shelf Sea Dynamics; Tidal Computations; Tidal Instrumentation and Engineering; Marine Information and Advisory Service.

Bidston Observatory: Bidston
Birkenhead
Merseyside L43 7RA
Telephone (051) 653 8633

Assistant Director: Dr D E Cartwright, FRS

Institute of Terrestrial Ecology

Edinburgh Research Station
Bush Estate
Penicuik
Midlothian EH26 0QB
Telephone
031-445 4343
Telex 72579

Director Terrestrial Ecology North:
Dr O W Heal
(from early 1987)
Monks Wood Experimental Station
Abbots Ripton
Huntingdon
Cambridgeshire PE17 2LS
Telephone
Abbots Ripton (04873) 381/8
Telex 32416

Director Terrestrial Ecology South: Dr J P Dempster

Total Staff: 265
Scientific Staff: 206

The Institute of Terrestrial Ecology (ITE) was established in 1973 to study the factors determining the structure, composition and processes of land and freshwater systems, and of individual plant and animal species. It is developing a sounder scientific basis for predicting and modelling environmental trends arising from natural or man-made change. The results of this research are available to those responsible for the protection, management and wise use of our natural resources. A significant portion of ITE's work is research commissioned by customers, such as the Nature Conservancy Council who require information for wildlife conservation, the European Communities, and the Department of the Environment. The remainder is fundamental research supported by NERC, often in close collaboration with universities. ITE's expertise is widely used by international organisations in overseas projects and programmes of research.

Terrestrial Ecology North: Edinburgh Research Station
Bush Estate
Penicuik
Midlothian EH26 0QB
Telephone
031-445 4343/6
Telex 72579

Head of Station: Dr M H Unsworth

Banchory Research Station
Hill of Brathens
Glassel
Banchory
Kincardineshire AB3 4BY
Telephone
Banchory (03302) 3434
Telex 739396

Acting Head of Station: Dr B Staines

Merlewood Research Station
Grange-over Sands
Cumbria LA11 6JU
Telephone
Grange-over-Sands
(04484) 2264/6
Telex 65102

Head of Station: Dr O W Heal

Terrestrial Ecology South: Monks Wood Experimental Station
Abbots Ripton
Huntingdon
Cambridgeshire PE17 2LS
Telephone
Abbots Ripton (04873) 381/8
Telex 32416

Head of Station: Dr M D Hooper

Bangor Research Station
Penhros Road
Bangor
Gwynedd LL57 2LQ
Telephone
Bangor (0248) 364001/5
Telex 61224

Head of Station: Dr C Milner

Furzebrook Research Station
Wareham
Dorset BH20 5AS
Telephone
Corfe Castle (0929) 51518/9
Telex 418326

Head of Station: Dr M G Morris

The British Antarctic Survey

High Cross
Madingley Road
Cambridge CB3 0ET
Telephone
Cambridge (0223) 61188
Telex 817725

Director: Dr R M Laws, CBE FRS
Deputy Director: Mr W N Bonner

Total Staff: 161
Scientific Staff: 90

The British Antarctic Survey, started under naval auspices in 1943, was controlled by the Colonial Office and Foreign and Commonwealth Office for over 20 years until it was transferred to NERC in April 1967. The Survey initiates and carries through scientific work in Antarctica particularly in the Falklands Islands Dependencies and the British Antarctic Territory in which it maintains five stations. It is also fully responsible for managing and operating two ships and two aircraft.

There are three scientific divisions covering Atmospheric Sciences, Earth Sciences and Life Sciences. These, together with the administrative division, are centred at Cambridge. Mapping is undertaken by The Directorate of Overseas Surveys and The Hydrographic Department of the Ministry of Defence and close contact is also maintained with many university departments. The majority of BAS work in the Antarctic is carried out by short-term contract staff who are first trained in the UK and then supervised by permanent staff in the UK.

The results of the Survey's work are published either in British Antarctic Survey Scientific Reports or in the British Antarctic Survey Bulletin and papers also appear in the appropriate scientific and technical journals.

Head of Atmospheric Sciences: Dr M J Rycroft
Head of Earth Sciences: Dr C W M Swithinbank
Head of Life Sciences: Mr W N Bonner

Institute of Virology

Mansfield Road
Oxford OX1 3SR
Telephone
Oxford (0865) 512361
Telex 83147

Director: Dr D H L Bishop
Deputy Director: Mr J S Robertson

Total Staff: 42
Scientific Staff: 28

The Unit of Invertebrate Virology developed from the Insect Pathology Unit of the University of Oxford and became a component body of NERC in 1971. The wider interests made it necessary to change the name in 1980 to the NERC Institute of Virology. Its central theme is research on the viruses and virus diseases of insects, notably those of important pest species from both UK and overseas. The Institute has recently developed interests in viruses associated with wild birds in association with the Institute of Terrestrial Ecology and in viruses of trees and wild grasses. Studies on the basic physical and biochemical properties of insect viruses provided data necessary for their identification and for the understanding of the infection process. The Institute also studies the ecological importance of viruses both as regulators of natural populations in ecosystems and as potential controllers of pest species. The Institute maintains close links with the University of Oxford and teaches undergraduates and graduate students.

Freshwater Biological Association

The Ferry House
Far Sawrey
Ambleside
Cumbria LA22 0LP
Telephone
Windermere (09662) 2468/9
Telex 8950511
G REF 16173001

Director: Dr R T Clarke

Total Staff: 106
Scientific Staff: 78

The Freshwater Biological Association was founded in 1929 to promote fundamental research into the biology and ecology of all kinds of freshwaters. Basic chemical and physical studies comprise an increasing part of the research programme. Biological studies include, for example, taxonomy, community structure, feeding behaviour, population ecology and physiology and their relations with environmental variables both natural and man induced. These researches are carried out on algae, higher plants, bacteria, protozoa, a wide range of invertebrates and fish. Some studies are predominantly field orientated and observational, but increasingly the research programme is becoming experimental in nature. Processes of element cycling and energy transfer are growing areas of interest. Field researches are carried out all over Britain and occasionally abroad, with a concentration of effort on the Cumbrian Lakes and upland rivers (from the Windermere Laboratory) and on chalk streams and lowland rivers (from the River Laboratory).

The FBA receives about 2% of its income from its 2,000 members who include private individuals, universities, scientific societies, fishery organisations and the water industry, the bulk of its funds are provided by NERC as a grant-in-aid or repayment for commissioned work.

Visiting workers and research students play an important part in the overall research activities and joint projects with other institutes and various universities are actively pursued.

Windermere Laboratory: as above
Assistant Director: Dr D J J Kinsman

River Laboratory:
East Stoke
Wareham
Dorset BH20 6BB
Telephone
Bindon Abbey (0929)
462314
Telex 8950511
G REF 16174001

Officer-in-charge: Dr A D Berrie

Marine Biological Association of The United Kingdom

The Laboratory
Citadel Hill
Plymouth PL1 2PB
Telephone
Plymouth (0752) 21761

Director	Professor E J Denton CBE FRS
Deputy Director	Dr E D Corner
Total Staff	85
Scientific Staff	57

The Association was founded in 1884 on the initiative of leading scientists of the day within universities and national institutions.

The Laboratory at Citadel Hill opened in 1888 and since 1965 the Association has been supported largely by a grant-in-aid from NERC: its research has always covered a wide range of biological, chemical and physical problems.

In recent years special emphasis has been given to work on productivity in the fronts and thermoclines of the waters around Britain and on biological and chemical processses in estuaries; both these programmes have been greatly aided by successes in laboratory studies of animals and plants and by numerical modelling. Another important area of research concerns the properties of nervous systems and makes use of particularly favourable preparations, the most notable of which are the giant nerve fibres and synapses of the squid, in this work a leading role is played by scientists from the universities.

Among the MBA's library services is a current awareness and bibliographic information service on aspects of marine pollution. The laboratory regularly provides research facilities for a large number of visitors from other institutes and universities both in the UK and overseas.

Scottish Marine Biological Association

Dunstaffnage Marine
Research Laboratory
PO Box No 3
Oban
Argyll PA34 4AD
Telephone
Oban (0631) 62244
Telex 776216

Director	Professor R I Currie CBE
Deputy Director	Professor J B L Matthews
Total Staff	74
Scientific Staff	50

The Scottish Marine Biological Association evolved from other bodies, the first of which was set up by the Scottish Meteorological Society in 1884 with funds from the Edinburgh Fisheries Exhibition of 1882. Its objects are to promote the study of marine science through research and education. The main support for the work of SMBA is now provided by NERC through a grant-in-aid. Research is mainly concerned with understanding the processes which control the marine ecosystem, particularly in Scottish coastal waters but also in the adjacent part of the North Atlantic Ocean. The emphasis is on an experimental approach, but a certain amount of survey work is also conducted and some projects are concerned with studying the effects of the marine environment of industrial developments on the coast, and with fish farming in Scottish waters. Research workers from universities make an important contribution to the programme and formal agreements with several Scottish universities facilitate this and the involvement of staff in university affairs.

Sea Mammal Research Unit

c/o British Antarctic Survey
High Cross
Madingley Road
Cambridge CB3 0ET
Telephone
Cambridge (0223) 311354
Telex 817725

Director	Dr R M Laws CBE, FRS
Officer in charge	Dr J Harwood
Total Staff	15
Scientific Staff	12

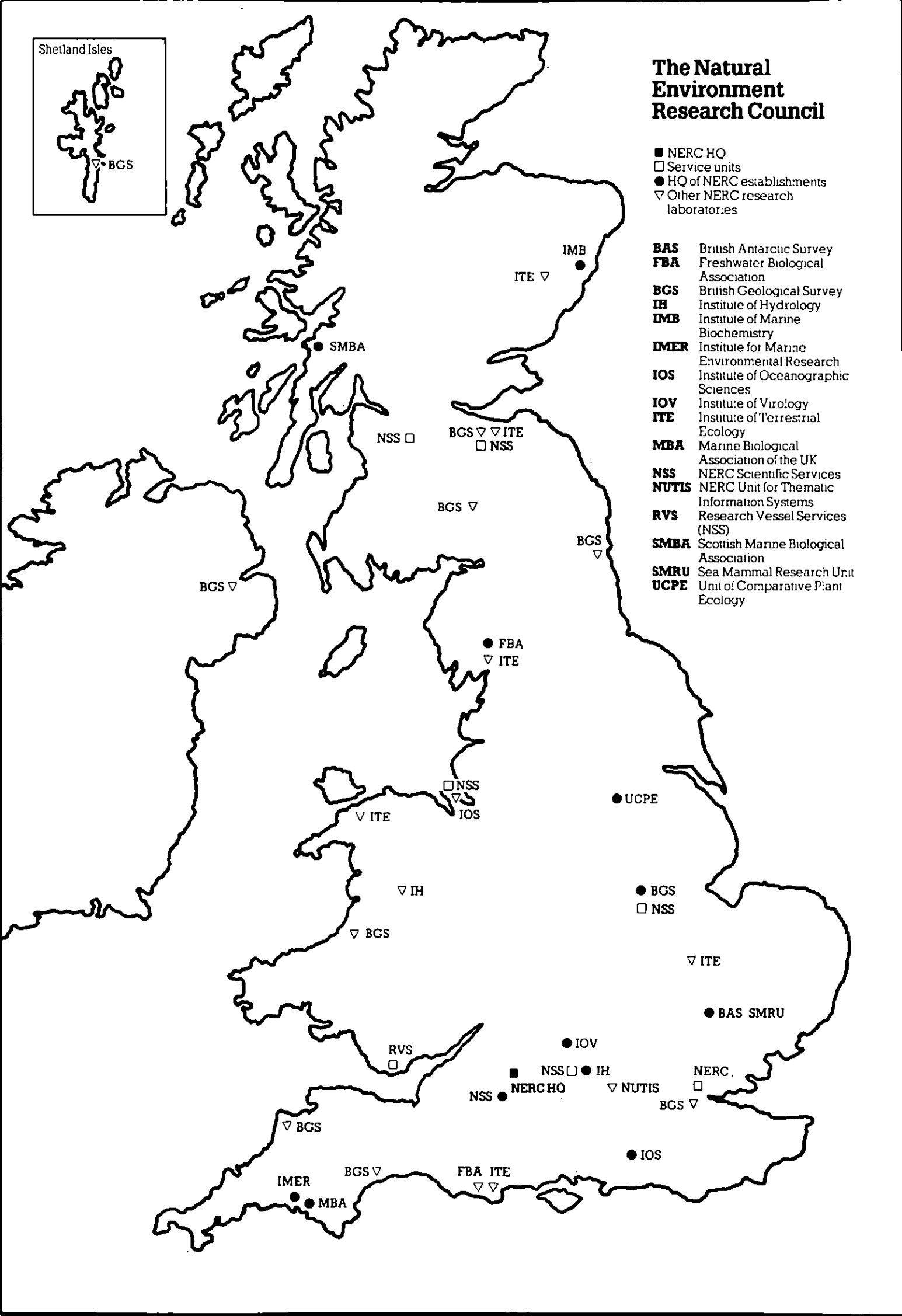
The Unit was created in December 1977 when the IMER Seals Research Division was amalgamated with the Whale Research Unit, formerly of IOS. It is responsible for providing scientific information to Council for advice to Government Departments on issues relating to sea mammals; in the case of British seals this responsibility is statutory under the Conservation of Seals Act 1970. The work of the Unit is designed to investigate the role of seals and whale in the marine ecosystem, and in particular the effects of management of their population dynamics.

Unit of Comparative Plant Ecology

Department of Botany
Sheffield University
Sheffield S10 2TN
Telephone
Sheffield (0742) 78555
Ext 4315
Telex 54348

Director	Professor I H Ronson
Deputy Director	Professor P G Grim
Total Staff	14
Scientific Staff	6

The Unit of Comparative Plant Ecology, based at the Department of Botany, Sheffield University, developed from the Grassland Research Unit funded since 1961 by the former Nature Conservancy. Since 1973 it has been supported directly by NERC and changed its name early in 1974. The Unit is making a fundamental study of the interaction of plants with their environment and in particular of the mechanisms controlling plant distribution and vegetation structure; formulating predictive approaches to plant competition and distribution; and gaining understanding of the tolerance of species and ecotypes to a range of environments. It is also concerned with transmitting information based on its research to applied scientists and non-biologists dealing with vegetation management and habitat reconstruction. The staff contribute to the training of post-graduate students and to the formal teaching programme of the Department of Botany.


Shetland Isles
BGS
The Natural Environment Research Council
■ NERC HQ
□ Service units
● HQ of NERC establishments
▽ Other NERC research laboratories
BAS British Antarctic Survey
FBA Freshwater Biological Association
BGS British Geological Survey
IH Institute of Hydrology
IMB Institute of Marine Biochemistry
IMER Institute for Marine Environmental Research
IOS Institute of Oceanographic Sciences
IOV Institute of Virology
ITE Institute of Terrestrial Ecology
MBA Marine Biological Association of the UK
NSS NERC Scientific Services
NUTIS NERC Unit for Thematic Information Systems
RVS Research Vessel Services (NSS)
SMBA Scottish Marine Biological Association
SMRU Sea Mammal Research Unit
UCPE Unit of Comparative Plant Ecology
IMB
ITE ▽
SMBA
NSS □
BGS ▽ ▽ ITE
□ NSS
BGS ▽
BGS ▽
BGS ▽
● FBA
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▽ NUTIS
NERC □
BGS ▽
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● IOS
IMER
● MBA
BGS ▽
FBA ITE
▽ ▽

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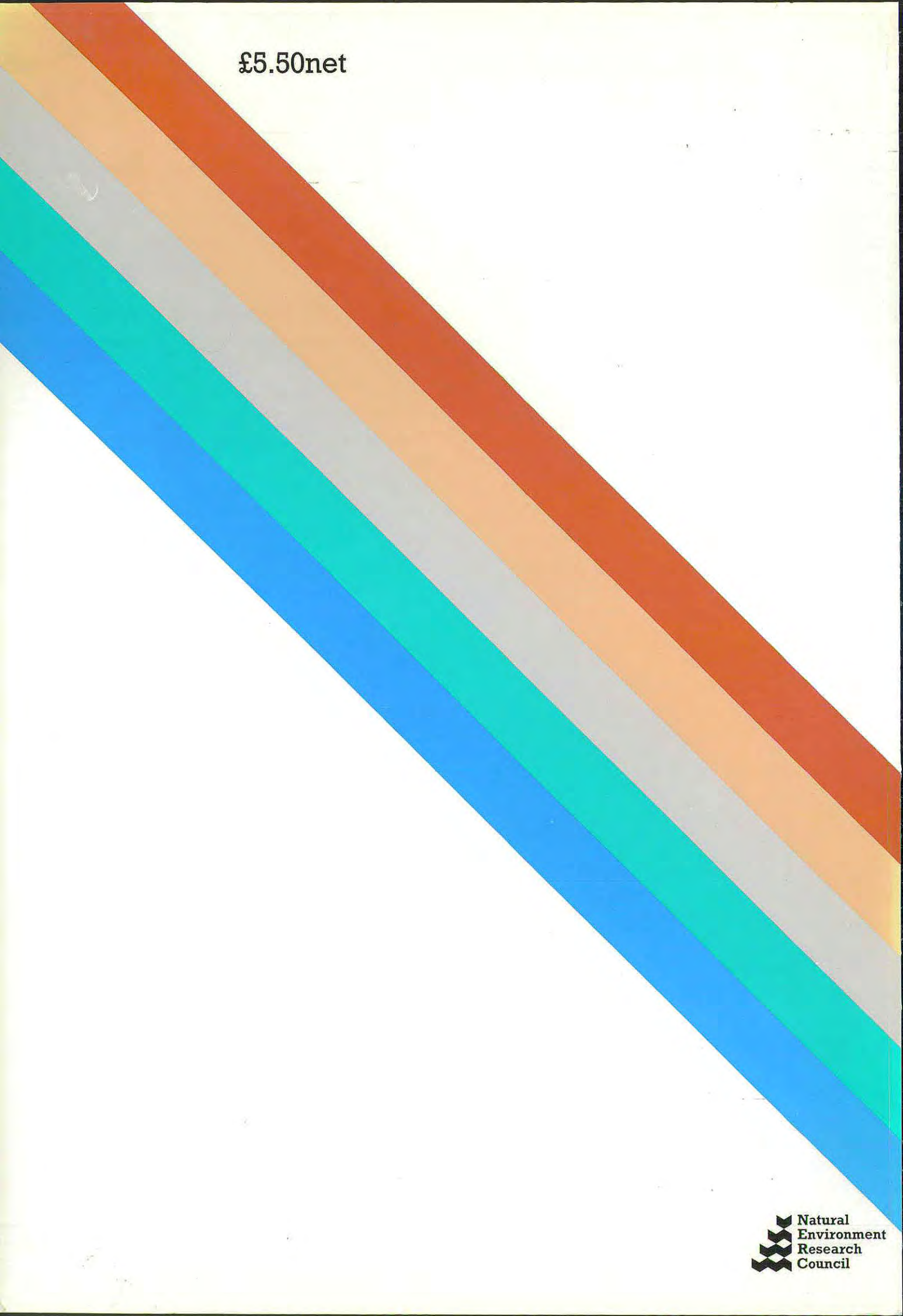

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