NATURAL ENVIRONMENT RESEARCH COUNCIL

ISOTOPE GEOSCIENCES LABORATORY FACILITIES

ANNUAL REPORT

for the period

1ST APRIL 2003 to 31ST MARCH 2004

Prof R R Parrish, Head NIGL

March 31, 2004

NERC/IF/240

Contents

Annex 1 NIGL Mission Statement

NERC Scientific Services

NERC ISOTOPE GEOSCIENCES LABORATORY
MISSION STATEMENT

- To provide isotopic analysis and scientific support, through collaborative research endeavours, to scientists within the UK academic community in line with NERC's policy on improving quality of life and wealth creation;
- To provide isotopic analysis and scientific support to NERC institutes engaged in science budget or commissioned research and allied activities;
- To provide training in isotope analysis and interpretation techniques to postgraduate students at UK universities and other institutions of higher learning;
- To promote awareness of the application of appropriate isotope systems to the earth and environmental science community;
- Within a collaborative research environment, to make NIGL facilities and training in their use available to NERC institute staff and UK academics (including their research personnel), to undertake their own analytical work for their research programme;
- To undertake research and development into the application of isotopic analytical techniques to the earth and environmental sciences in order to provide state of the art methods and to meet evolving requirements of NERC user communities.

In order to achieve its objectives NIGL will:

- Monitor user satisfaction on a regular basis;
- Maintain its equipment and monitor its performance using Quality Assurance and Quality Control procedures;
- Work with HEI and NERC Institute colleagues to promote only the best science, through development of projects aimed at peer review via the NERC Isotope Geosciences Facilities Steering Committee;
- Maintain relevant technical and scientific documentation and make it available to visiting scientists;
- Maintain a high professional level of staff, including, when appropriate, the initiation of research by NIGL staff in the framework described above;
- Inform the users' community of development in methodologies and applications and maintain an awareness of the users' requirements;
- Disseminate such information to the scientific community via publications, conference presentations, seminars, etc.;
- Seek commissioned research to supplement the Science Budget allocation.

User Communities:

The NERC Isotope Geosciences Laboratory exists to provide specialised research facilities for earth and environmental scientists in NERC institutes and the UK Higher Education sector. The research of the facility is relevant to the pollution control and resource exploitation (water, minerals, energy) industries, the educational sector, and the wider governmental and industrial community concerned with the implications of climate change.

September 1996

Annex 2.1 NIGL Steering Committee Membership

NIGL STEERING COMMITTEE MEMBERSHIP

Chairman:	Prof N W B Harris	Department of Earth Sciences, Open University, Milton Keynes. Field of expertise: Igneous and metamorphic geology & geochemistry, isotope geochemistry
Members:	Dr J R Bacon	The Macaulay Institute, Aberdeen. Field of expertise: Pollution and environmental sciences
	Prof. J Davidson	Department of Geological Sciences, University of Durham, Durham. Field of expertise: Isotope geochemistry
	Prof. J Henderson	Department of Archaeology, University of Nottingham, Nottingham. Field of expertise: Archaeology
	Prof. S Metcalfe	School of Geography, University of Nottingham, Nottingham. Field of expertise: Palaeoenvironments, limnology
	Dr. T J Shepherd	Honorary Research Associate, British Geological Survey Field of expertise: Minerals resource and hydrothermal processes
	Dr. E Wolff	British Antarctic Survey, Cambridge. Field of expertise: Palaeoenvironments, isotopes in precipitation
Ex-officio:	Dr. P van Calsteren	Head of OUUSF, Dept. of Earth Sciences, Open University, Milton Keynes.
	Prof. A E Fallick	Director, Scottish Universities Environmental Research Centre, Kilbride.
	Dr. R L F Kay	Head Scientific Services Management Team, Natural Environment Research Council, Swindon.
	Prof. R R Parrish	Head, NERC Isotope Geosciences Laboratory, Keyworth.
	Prof. J A Plant	Chief Scientist, British Geological Survey, Keyworth.
Secretary:	Dr. M J Leng	Stable isotope Facility Manager, NERC Isotope Geosciences Laboratory, Keyworth.
Papers only:	Mr. D A Brown	Dept. of Science and Innovation Funding, Natural Environment Research Council, Swindon.

Annex 2.2 Remit and terms of reference for the NERC Isotope Geosciences Facilities Steering Committee

Remit

The NERC Isotope Geosciences Facilities Steering Committee exists to:

review applications for use of:
the NERC Isotope Geosciences Laboratory;
the Argon Isotope Facility at the SUERC;
the Isotope Community Support Facility at the SUERC; and
the Open University Uranium Series Facility

monitor outputs from these Facilities;

provide advice to the Director, Science and Innovation Funding on aspects of the operations of these Facilities.

The Director, Science and Innovation Funding, in turn, provides advice to the Science and Technology Board of Council on Services and Facilities relevant to their remit.

Terms of Reference

1. To review applications and to establish priorities for the Heads of these Facilities in the allocation of those of the Facilities' resources funded from the Science and Innovation Funding allocation, taking into account NERC Strategy and recommendations made through the NERC peer-review mechanisms.

2. To review the scientific quality of work undertaken by users utilising these Facilities, based on reports and publications.

3. To monitor the level of user-satisfaction with the Facilities, and to analyse the user-base.

4. To give guidance to the Heads of these Facilities on improvement of the Facilities' equipment and on their service function.

5. To advise the Director, Science and Innovation Funding on:

    a) the level and direction of the internal R & D programme for these Facilities;

    b) the anticipated levels of future demand and any consequential anticipated changes in resource requirements from these Facilities.

    c) on other matters, as appropriate and reasonable.

6. To receive annually a report from the Heads of these Facilities, and comment through the Chair on them before passing them to the Director, Science and Innovation Funding.

The NERC Isotope Geoscience Facilities Steering Committee exists to:

- review applications for use of the NERC Isotope Geosciences Laboratory, the Argon Isotope Facility at the SUERC, the Isotope Community Support Facility at the SUERC and the Open University Uranium Series Facility;
- monitor outputs from these Facilities;
- provide advice to the Director responsible for Science and Innovation Funding on aspects of the operations of these Facilities.

The Director responsible for Science and Innovation Funding, in turn, provides advice to the Science and Technology Boards of Council on Services and Facilities relevant to their remit.

Annex 3. Capital Equipment held by the NIGL laboratories

MASS SPECTROMETER, VG ELEMENTAL P54 MULTICOLLECTOR PLASMA IONIZATION, Asset Number 011248, Purchased 1997, Original Cost (P54+Axiom) £640,000.

MASS SPECTROMETER, VG ELEMENTAL AXIOM MULTICOLLECTOR PLASMA IONIZATION, Asset Number 011248, Purchased 1997, Purchased with P54.

MASS SPECTROMETER, MICROMASS 903, STABLE ISOTOPE RATIO, Purchased 1977, Original Cost £30,000

MASS SPECTROMETER, VG SIRA 10 STABLE ISOTOPE RATIO DH-HEAD, Asset Number 011230, Purchased 1987, Original Cost £100,000

MASS SPECTROMETER, OPTIMA STABLE ISOTOPE RATIO, VG, Asset Number 000750, Purchased 1993, Original Cost £136,770

MASS SPECTROMETER, OPTIMA STABLE ISOTOPE RATIO, VG, Asset Number 000751, Purchased 1993, Original Cost £162,495

MASS SPECTROMETER, ThermoFinnigan DELTA plus with ConFlo and FLASH EA and TC/EA, Asset Number 110760, Purchased 2001, Original Cost £107,891

MASS SPECTROMETER, GV Instruments dual inlet Isoprime with Multiprep and EuroPyrOH, Purchased 2002, Original Cost £172,725

MASS SPECTROMETER, TRITON THERMAL IONIZATION, Asset Number ???, Purchased 2003, Original cost £414,000.

MASS SPECTROMETER, TRITON THERMAL IONIZATION, ADDITIONAL SOURCE-LENS STACK AND SAMPLE TURRET, Asset Number 000392, Purchased 2003, Original cost £10,904.

MASS SPECTROMETER, VG 354 THERMAL IONIZATION, Asset Number 011237, Purchased 1982, Original Cost £300,000

MASS SPECTROMETER, FINNIGAN MAT262 THERMAL IONIZATION, Asset Number 000392, Purchased 1990, Original Cost £350,000

MASS SPECTROMETER, FINNIGAN MAT262 THERMAL IONIZATION, SPECTROMAT UPGRADE, Asset Number 000392, Purchased 2003, Original Cost £41,088

MULTICHANGE ANALYSER/OPTICAL SPECTROMETER, PRINCETOWN INSTRUMENTS, Asset Number 003477, Purchased 1995, Original Cost £60,362

MASS SPECTROMETER UPGRADE, PHOENIX 903, PROVAC, Purchased 1999, Original Cost £9,165

MASS SPECTROMETER UPGRADE, VG354, Asset Number 000387, Purchased 1990, Original Cost £135,688

MASS SPECTROMETER SOFTWARE AND PC UPGRADE, VG354, MICROMASS, Purchased 1998, Original Cost £30,000

ISOPREP 18 UPGRADE, VG, Asset Number 011226, Purchased 1989, Original Cost £80,000

MICROPROBE II 266 nm UV LASER SYSTEM, VG ELEMENTAL, Purchased 1999, Original Cost £91,538, Upgraded 2003, Cost £12,367

MCN 6000 DESOLVATING NEBULIZER SAMPLE INTRODUCTION SYSTEM, CETEC TECHNOLOGIES, Purchased 1997, Original Cost £20,232

ARIDUS DESOLVATING NEBULIZER SAMPLE INTRODUCTION SYSTEM, CETEC TECHNOLOGIES, Asset Number 107240, Purchased 2000, Original Cost £14,256
FLUORINATION EXTRACTION LINES FOR SILICATE OXYGEN, IN-HOUSE, Asset Number 007838, Purchased 1989, Original Cost £90,000
CARBONATE EXTRACTION SYSTEM, NIGL, Asset Number 011231, Purchased 1990, Original Cost £7,000
NITROGEN LINE EXTRACTION UNIT, NIGL, Asset Number 011233, Purchased 1990, Original Cost £10,000
FLUID INCLUSION NITROGEN EXTRACTION LINE, NIGL, Asset Number 011234, Purchased 1991, Original Cost £11,000
VACUUM OUTGASING EXTRACTION LINE, NIGL, Asset Number 011235, Purchased 1991, Original Cost £10,000
SPECTRON LASER SYSTEM, ND - YAG LASER 120, Asset Number 011238, Purchased 1992, Original Cost £20,000
SPECTRON LASER SYSTEM UPGRADE, ND - YAG LASER 120, New Wave Research, Asset Number 011464, Purchased 2003, Original Cost £11,759
CO2 LASER 10, SYNRAD, Asset Number 011239, Purchased 1994, Original Cost £10,000
LASER FLOURATION LINE, NIGL, Asset Number 011241, Purchased 1995, Original Cost £15,000
LASER BEAM DELIVERY SYSTEM, MERCHANTEK LASER BEAM SYSTEM, Asset Number 011464, Purchased 1997, Original Cost £4,113
LIQUID ARGON TANK, WESSINGTON CRYOGENICS, Asset Number xxxxx, Purchased 2003, Original Cost £5,657
MICROSCOPE/LASER DELIVERY SYSTEM, LEICA, Asset Number 007843, Purchased 1989, Original Cost £14,000
PETROGRAPHIC MICROSCOPE, LEICA, Asset Number 007840, Purchased 1990, Original Cost £5,000
PETROGRAPHIC MICROSCOPE AND DIGITAL CAMERA, NIKON ECLIPSE NOMARSKI DIC, Asset Number 111540, Purchased 2002, Original Cost £15,653
BINOCULAR MICROSCOPE, NIKON SMZ1500. Asset Number 111540, Purchased 2002, Original Cost £5000
BINOCULAR MICROSCOPE, NIKON SM210, Asset Number 000417, Purchased 1991, Original Cost £3,854
BINOCULAR MICROSCOPE, NIKON SMZ-U STEROMICROSCOPE, Asset Number 011723, Purchased 1997, Original Cost £5,463
BINOCULAR MICROSCOPE, NIKON SMZ-U STEROMICROSCOPE, Asset Number 012262, Purchased 1997, Original Cost £5,463
GAS CABINET AND MA, BOC, Asset Number 109782, Purchased 2001, Original Cost £6,078
CHILLER, CRYCOOL, Asset Number 011227, Purchased 1990, Original Cost £6,000
GDS STYLE PANEL, HAC TECHNICAL GAS, Purchased 2001, Original Cost £2,097
TURBO MOLECULAR PUMP, BALZERS, Asset Number 007722, Purchased 1995, Original Cost £5,251
TURBO MOLECULAR PUMP, EDWARDS, Asset Number 011379, Purchased 1997, Original Cost £7,467
TURBO MOLECULAR PUMP, EDWARDS EXT 250, Asset Number 011499, Purchased 1997, Original Cost £4,047
TURBO MOLECULAR PUMP, EDWARDS EXT 555H, Asset Number ______, Purchased 2002, Original Cost £5,953
TURBO MOLECULAR PUMP, EDWARDS EXT 255H, Asset Number ______, Purchased 2002, Original Cost £2,748
TURBO MOLECULAR PUMP, EDWARDS EXT 255H, Asset Number ______, Purchased 2002, Original Cost £2,882
TURBO MOLECULAR PUMP, PFEIFFER TMU 521P, Asset Number ______, Purchased 2003, Original Cost £5219
TURBO MOLECULAR PUMP, PFEIFFER TMU 521P, Asset Number ______, Purchased 2003, Original Cost £5060
DRY ROTARY PUMP, EDWARDS XDS-10C, Asset Number ______, Purchased 2002, Original Cost £2,141

DRY ROTARY PUMP, EDWARDS XDS-10C, Asset Number ______, Purchased 2002, Original Cost £2,141
DRY ROTARY PUMP, EDWARDS XDS-10C, Asset Number ______, Purchased 2002, Original Cost £2,141
DRY ROTARY PUMP, EDWARDS XDS-10C, Asset Number ______, Purchased 2002, Original Cost £2,141
MICROBALANCE, SARTORIOUS, Asset Number 000575, Purchased 1992, Original Cost £7,481
MICROBALANCE, PROGEN SCIENTIFIC, Asset Number 109420, Purchased 2001, Original Cost £7,667
MICROBALANCE WITH REMOTE WEIGH CHAMBER, CAHN INSTRUMENT CO, Asset Number 007841, Purchased 1992, Original Cost £8,500
FUME EXTRACTION, DISTRACTION LTD, Asset Number 111240, Purchased 2001, Original Cost £3,019
MEGAFUGE 1.0 HERAEUS CENTRIFUGE, HERAEUS, Asset Number 004474, Purchased 1995, Original Cost £3,917
LABORATORY SEPARATOR, INTERMAGNETICS CORP, Asset Number 007844, Purchased 1989, Original Cost £22,900
MAGNETIC SEPERATOR, FRANTZ, Asset Number 011242, Purchased 1989, Original Cost £3,500
JAW CRUSHER, FRITSCH, Asset Number 011243, Purchased 1989, Original Cost £3,00
JAW CRUSHER PULVERISSETTE MODEL II, FRITSCH, Asset Number 114763, Purchased 2004, Original Cost £8,762
DISK MILL, FRITSCH, Asset Number 011244, Purchased 1989, Original Cost £3,000
TUNGSTEN CARBIDE MORTAR, TORRINGTON PRECISSION, Asset Number 011340, Purchased 1997, Original Cost £3,895
GEMINI TABLE, GISCO, Asset Number 007845, Purchased 1991, Original Cost £4,400
INDUCTION GENERATOR, STANELCO, Asset Number 114427, Purchased 2003, Original Cost £13,037
STILL, PICOTRACE, Asset Number 114014, Purchased 2003, Original Cost £12,796
FREEZER MILL, SPEX, Asset Number 114015, Purchased 2003, Original Cost £11,883
COSTECH ZERO BLANK AUTOSTAPLER, PELICAN SCIENTIFIC, Asset Number 110760, Purchased 2003, Original Cost £5,630
ELIX WATER PRETREATMENT SYSTEM, MILLIPORE, Asset Number 114723, Purchased 2003, Original Cost £21,013

Note: Personal computers are not listed.

Annex 4.1 Projects Approved during 2003-2004

Summary of grades and RAE scores of applicant department

Global change

Ref. no.	Abreviated title	Project leader	Affiliation	RAE	Student	Grade
IP/774/0503	Belemnites	McArthur	University College London	5	n/a	α4
IP/777/0503	Lake Qarun	Holmes	University College London	5*	n/a	α3h
IP/779/0503	South Georgia lakes	Davies, S	University of Wales	4	n/a	α4
IP/783/0503	Lake Tana	Lamb, H	University of Wales	4	n/a	α3h
Pilot	Pakistan loess	Clarke, M	University of Nottingham	5	n/a	N/A
CASE	Diatoms in Lochnagar Scotland	Jones, V	University College London	5*	PhD	α4
IP/797/1103	Composition of Cretaceous ocean	Clarke	University of Wales Bangor	4	n/a	α4l
IP/800/1103	East African diatoms	Barker, P	Lancaster University	5	n/a	α4h

Igneous geochemistry and mantle dynamics

Ref. no.	Abreviated title	Project leader	Affiliation	RAE	Student	Grade
IP/781/0503	Sr isotope of plagioclase	Coogan	Leicester University	4	n/a	α4
IP/809/1103	Origin of S American adakites	Petford	Kingston University	3a	n/a	α4m

Polution and waste

Ref. no.	Abreviated title	Project leader	Affiliation	RAE	Student	Grade
IP/776/05/03	Nitrogen dynamics in the polar cryosphere	Hodson,A	University of Sheffield	5	n/a	α4
IP/778/0503	Cycling of dissolved organic N	Achterberg	University of Plymouth	4	PhD	α3h

Science based archaeology

Ref. no.	Abreviated title	Project leader	Affiliation	RAE	Student	Grade
IP/780/0503	Prehistoric shellfish	Thomas, K	University College London	5	n/a	α3h
IP/786/0503	Bone as palaeoclimate proxy	Hedges	University of Oxford	5*	PhD	α3m
IP/804/1103	Lewis population studies	Montgomery	Bradford University	5	n/a	α3h

Understanding the solid earth

Ref. no.	Abreviated title	Project leader	Affiliation	RAE	Student	Grade
CASE	North Himalayan Domes	Harris	Open University, Milton Keynes	5	PhD	α4
IP/796/1103	Dating the Main Central Thrust	Bickle	University of Cambridge	5*	PhD	α4m

Annex 4.2 Visitors, students and other collaboration

Students, visitors and post-doctoral researchers (2003-2004)

Aravinda, K.B.N. University of Nottingham.

Banks, Chris. University of Keele. NERC CASE PhD. Provenance of the Grampian Group, Scotland.

Bogaard, A. University of Nottingham.

Bonelli, Rossana. University of Siena / Italy.

Bourne, David. Pro-Vac Services, Crew.

Breeze, S. GV Instruments, Manchester.

Brewer, Tim (Dr.). Leicester University.

Caddick, Mark. Universirty of Cambridge. NERC Studentship PhD. The tectono-metamorphic evolution of the Central and Western Himalayas.

Chamberlain, Andrew. University of Sheffield.

Carmichael, Emma (Dr.). BAS, Cambridge.

Daly, Stephen (Dr.). University College Dublin.

Dean,Alison (Dr.). BAS, Cambridge.

El-Sayed, Badr. University of Plymouth.

Fisher, Jodie, University of Plymouth. Standard PhD. Chemostratigraphy and foraminiferal analysis of the Cenomanian - Turonian boundary (Upper Cretaceous) event.

Foster, Gavin (Dr). University of Bristol.

Gerdes, Axel (Dr). W Goethe Universität, Frankfurt am Main / Germany.

Hänsler, Thomas. Facts News Magazine, Basel / Switzerland.

Helps, Paul. Kingston University, London. Standard PhD. Scales of heterogeneities and equilibration volumes in granitoid magmas.

Henderson, Andrew. University College London. Standard PhD. Palaeolimnological evidence of recent environmental change in the Northeastern Tibet-Qinghai Plateau.

Henderson, Julian (Prof.). University of Nottingham.

Hughes, Susan (Dr). Durham University. NERC Post Doctoral Research Assistant. Direct evaluation of archaeological immigration.

Hunter, Morag (Dr.). BAS, Cambridge.

Jones, Matthew. University of Plymouth. Standard MSc. A Holocene molluscan $\delta^{18}O$ and $\delta^{13}C$ record from Gölhisar Gölü, Turkey.

Kislitsyn, Roman. University College Dublin.

King, Jessica. Open University, Milton Keynes. NERC CASE PhD. Cause and significance of crustal melting, Southern Tibet.

Lane, Ken. Scientific Glass Services, Keyworth.

Lee, Natasha. Leicester University. BSc Candidate.

Le Muray, Jon. University of Bradford.

Macpherson, Pamela. University of Sheffield. Standard PhD.

Manino, Marcello. University College London. Standard PhD. Monodonta lineata (Mollusca, Gastropoda) from Mesolithic shell middens as palaeoenvironmental indicators.

Mason, Andrew. Leicester University. Standard PhD. Proterozoic evolution of the Outer Hebrides.

Mather, T. University of Cambridge. NERC Standard PhD. Magma degassing and tropospheric volcanic plumes.

Ministry of Mines Delegation. Madagascar / Africa.

Montgomery, Janet (Dr.). University of Bradford.

Morley, David. University College London. Standard CASE PhD. Reconstructing past climate variability in continental Eurasia.

Moss, J. University of Newcastle.

Mwale, Simon. University of Nottingham.

Nagesh, A. B. University of Nottingham.

Patchett, Jon (Prof.). University of Arizona.

Parry, Steve. Aberdeen University. Standard PhD. The timing of end-Caledonian intrusion-related hydrothermal activity, East Grampians, Scotland.

Petras, Antonio. University of Nottingham.

Phillips, Richard. University of Oxford. NERC CASE PhD. Macro- and micro-structural evolution of the Karakoram Fault.

Ponting, Matt. 143 Main Street, Calverton, Nottingham.

Pyle, David (Dr.). University of Cambridge.

Reichow, Marc. University of Leicester. Standard PhD. The age and isotopic characteristics of syenites and granites, Transbaikalia, using TIMS and ICP-MS: implications for crustal growth and plume-related magmatism in Siberia.

Reynard, Linda. University of Oxford.

Richards, Andrew. Open University, Milton Keynes. NERC CASE PhD. Isotopic mapping of major Himalayan Structures.

Roberts, Steve. University of Edinburgh.

Schmidt, Robert. Spectromat, Bremen / Germany.

Stevens, R. University of Oxford. Standard PhD. Potential of isotopic analysis of bone as a palaeoclimatic proxy.

Swan, George. University College London. Standard PhD. Reconstructing Late Glacial - Holocene climate change in Lake Baikal using oxygen isotope analysis of endemic lacstrine diatoms.

Schwieters, Johannes (Dr.). Thermo Electron, Bremen / Germany. Principle design and development engineer.

Talma, A. S. Environtek, Pretoria / USA.

Teal, Riley (Dr.). BAS, Cambridge.

Thomas, Ken. University College London.

Thompson, Patricia (Dr.). University of Leicester. The significance of island arcs associated with oceanic plateaux.

Thow, Andrew. University of Oxford. NERC CASE PhD. Metamorphism and tectonics of the Karakoram Crust.

Trickett, Marc. Durham University. Standard PhD. Isotopic, osteogeological and historical studies of health and migration.

Tyler, Jonathan. University College London. NERC CASE PhD. Proxy climate signals in mountain lakes from $\delta^{18}O$ signals in diatom silica.

Vaughan, Alan (Dr.). BAS, Cambridge.

Vaughan, G.

Warren, Clare. University of Oxford. NERC CASE PhD. Emplacement dynamics of the Somail Ophiolite, Oman.

Wendall, N. BBC, London.

Wegener, Michael. Spectromat, Bremen / Germany.

Wilson, Graham. John Moores, Liverpool.

Winstanley, Ian. Thermo Electron (Finnigan), Hemel Hempstead.

Wynn, Peter. University of Sheffield. NERC CASE PhD. The provenance and fate of nitrogen in Arctic glacial meltwater.

Annex 4.3 Finance of the NIGL S&F Service

ANNUAL SPEND v INCOME

Income Category	**(£)**
Baseline Allocation from Services and Facilities	438,000
Other income, Science Budget, from Services and Facilities	
Minor Capital approved by Facilities and Services Swindon [includes: hotplates, autosampler, jaw crusher, laser upgrade, Milli-Q water system, turbo-pump, Triton mass spect source, Spectromat upgrade for MAT262, induction generator, freezer mill, HEPA workstations]	137,233
Down payment; MAT253 gas source IRMS	114,393
Partial payment (30%) Micromass gas source IRMS	53,182
Total Income	742,808
Expenses Relating to the NIGL Service	
Salaries including pension and NI payments	307,000
Capital – approved by Facilities and Services Swindon as above	304,808
Capital – paid from S&F allocation	14,400
Laboratory recurrent including T&S	116,600
Total expenses	742,808

Note:- These figures do not include additional commission/grants/administrative funding support that are outside of the funding envelope for NIGL, according to the revised funding algorithm.

Annex 4.4 NIGL Publications and completed PhD theses 2003-2004

Refereed publications 2003-2004

Global Change

Anderson, N, J. and Leng, M.J. 2004. Increased aridity during the early Holocene in West Greenland inferred from stable isotopes in laminated-lake sediments. Quaternary Science Reviews, v. 23, p.841-849.

Andrews, J. E., Coletta, P., Pentecost, A., Riding, R., Dennis, S., Dennis, P. F. and Spiro, B. 2004. Equilibrium and disequilibrium stable isotope effects in modern charophyte calcites: implications for palaeoenvironmental studies, Palaeoenvironment, v. 204, p. 101-114.

Casford, J.S.L., Rohling, e.J., Abu-Zied, R., Cooke, S., Fontanier, C., Leng, M.J. and Thomson, J.A. In Press. A method to optimise the confidence limits in radiocarbon-based chronostratigraphy. Marine Geology.

Casford, J.S.L., Rohling, E.J., Abu-Zied, R.H., Fontanier, C., Jorissen, F.J., Leng, M.J., Schmiedl, G. and Thomson, J. 2003. A dynamic concept for eastern Mediterranean circulation and oxygenation during sapropel formation. Palaeogeography Palaeoclimatology Palaeoecology, v. 190, p. 103-119.

Eastwood, W.J., Leng, M.J., Roberts, N, and Davies, B. In Press. Holocene climate change in the eastern Mediterranean region: a comparison of stable isotope and pollen data from a lake record in southwest Turkey. Journal of Quaternary Science.

Gagen, M, McCarroll, D. and Edouardo, J-L. In Press. The effect of site conditions on pine tree ring width, density and $\delta^{13}C$ series at a dry sub-Alpine site and the potential for extracting a palaeoclimatically useful signal from tree ring $\delta^{13}C$. Arctic, Antarctic and Alpine Research.

Hart, M.B., Feist, S.E., Price, G.D. and Leng, M.J. In Press. Re-appraisal of the K/T boundary succession at Stevns Klint, Denmark. Journal of Geological Society of London.

Henderson, A.C.G., Holmes, J.A., Zhang, J.W., Leng, M.J., and Carvalho, L.R. 2003. A carbon- and oxygen-isotope record of recent environmental change from Qinghai Lake, NE Tibetan Plateau. Chinese Science Bulletin, v. 48, p. 1463-1468.

Holmes, J.A. and Darbyshire, D.P.F. In Press. Preliminary trace-element and strontium isotope analysis of ostracod shells from the Slindon Silt Member. *In* Roberts M.B., Pope M.I. and Parfitt S.A. (eds) An early Middle Pleistocene hominid site at Eartham Quarry, West Sussex. Excavations 1990-1996. London; English Heritage Monograph Series Boxgrove Memoir.

Jones, V.J., Leng, M.J., Solovieva, N., Sloane, H.J., Tarasov, P. 2004. Holocene climate on the Kola Peninsula; evidence from the oxygen isotope record of diatom silica. Quaternary Science Reviews, v. 23, 833-839.

Lamb, A.L., Leng, M.J., Umer, M. and Lamb, H.F. 2004. The impact of Holocene climate change on the vegetation around Lake Tilo, Ethiopia, inferred by the concentration and composition (C/N & $\delta^{13}C$) of lacustrine organic matter. Quaternary Science Reviews, v. 23, p.881-891.

Lamb, A.L., Leng, M.J., Barker, P.A. and Morley, D. 2004. The potential of oxygen isotopes in diatoms as a palaeoclimatic indicator in lake sediments. Past Global Changes Newsletter. Spring 2004.

Large, D.J., Jones, T.F., Somerfield, C., Gorringe, M.C., Spiro, B., Macquaker, J.H.S. and Atkin, B.P. 2003. High-resolution terrestrial record of orbital climate forcing in coal. Geology, v. 31, p. 303-306.

Leng, M.J. 2003. Stable isotopes in lakes and lake sediment archives. *In*: Mackay, A, Battarbee, R., Birks, J. and Oldfield, F (eds). Global change in the Holocene. Arnold Publishers, London. p. 124-139.

Leng, M.J. and Anderson, N.J. 2003. Isotopic variation in modern lake waters from western Greenland. Holocene, v. 13, p. 605-611.

Leng, M.J. and Marshall, J.D. 2004. Palaeoclimate interpretation of stable isotope data from lake sediments. Quaternary Science Reviews, v. 23, 811-831.

Leng, M.J. 2004. Isotopes in Quaternary palaeoclimate research – editorial introduction. Quaternary Science Reviews, v. 23, p. 739-741.

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Annex 4.5 Projects worked on in 2003/2004

Stage reached: N = not started; 2 = field work done; 3 = sample prep. completed; 4 = analyses started; 5 = 50% analyses completed; 6 = analyses completed; 7 = completed
Costs are calculated using 2003/2004 time allocation reports.

Project Type/No.	Short Title	Project Leader	University/Institution	NERC Ref.	Stage Reached							Staff Time	Facility Time	Costs
					N	2	3	4	5	6	7			
Institute Project														
40133	U-Pb geochronology of the Charnian Supergroup	Carney	BGS	IP/564/0998	☑	☑	☑	☑	☑	☑	☒	10		£ 2,910.00
40155	Groundwater interactions in forested riparian zone	Shand P	BGS, Wallingford	IP/677/0900	☑	☑	☑	☑	☑	☑	☒	81		£ 23,571.00
40162	Provenancing of the Monian Supergroup, North Wales	Horak	National Museum & Gallery of Wales	IP/726/1001	☑	☑	☑	☑	☑	☑	☒	17		£ 4,947.00
40164	Polytomic and REE oxide interferences	Horstwood	NIGL	IP/715/1001	☑	☑	☑	☑	☑	☑	☒	6		£ 1,746.00
40165	Distribution & uptake of isotopes into biosphere	Evans	NIGL	IP/735/1001	☑	☑	☑	☑	☑	☑	☒	12		£ 3,492.00
40166	North Atlantic Oscillation in Swedish Lapland	Leng	NIGL	IP/736/1001	☑	☑	☑	☑	☑	☑	☑	40		£ 11,640.00
40167	Testing soil moisture extraction	Smith	BGS	Pilot	☑	☑	☑	☑	☑	☑	☑	2		£ 582.00
Total Institute Project												168	0	£ 48,888.00
In-house Research														
50050	Bhutan Geochronology	Parrish	NIGL	N/A	☑	☑	☑	☑	☑	☑	☑	12		£ 3,492.00
50057	Northern Hemisphere Glaciation	Parrish	NIGL	N/A	☑	☑	☑	☑	☑	☒	☒	18		£ 5,238.00
50058	U-Th-Pb Geochronology Textbook	Parrish	NIGL	N/A	☑	☒	☒	☒	☒	☒	☒	8		£ 2,328.00
Total In-house Research												38	0	£ 11,058.00

University Project

20157	Stable isotopes of ostacods, Morocco	Lamb, H	Aberystwyth	IP/401/0294	☑	☑	☑	☑	☑	☑	☑	5		£ 1,455.00
20164	Crop storage practices in Greek Bronze age	Jones G	Sheffield University	IP/418/0994	☑	☑	☑	☑	☑	☑	☒	29		£ 8,439.00
20186	Palaeoenvironmental reconstruction, Central Mexico	Entwistle	Kingston University	IP/468/0396	☑	☑	☑	☑	☑	☑	☑	12		£ 3,492.00
20213	Protcrozoic Evolution of Outer Hebrides	Parrish	Leicester University	N/A	☑	☑	☑	☑	☑	☑	☑	7	2	£ 2,183.00
20232	Hydro-climatic change - Eski Acigol, Turkey	Roberts	Loughborough University	IP/540/0498	☑	☑	☑	☑	☑	☑	☑	49		£ 14,259.00
20240	Hf-mantle dynamics subduction fluxes in SW Pacific	Pearce	Durham University	IP/559/0498	☑	☑	☑	☑	☑	☑	☑	6		£ 1,746.00
20242	Climate change in Ethiopia	Lamb	Aberystwyth	IP/539/0498	☑	☑	☑	☑	☑	☑	☑	29		£ 8,439.00
20243	Measurement of H/D ratios in collagen	Hedges	Oxford University	IP/560/0898	☑	☑	☑	☑	☑	☑	☑	10		£ 2,910.00
20247	Titanites from syenites and granites,Transbaikalia	Saunders	Leicester University	IP/566/0998	☑	☑	☑	☑	☑	☑	☑	1	2	£ 437.00
20260	Archaeological human dental tissues	Budd	Bradford University	IP/590/0499	☑	☑	☑	☑	☑	☑	☑	5		£ 1,455.00
20267	Application of Lu-Hf isotopic studies of crustal e	Downes	University of London	IP/601/0499	☑	☑	☑	☑	☑	☑	☒	2		£ 582.00
20277	Northeastern Tibet-Qinghai Plateau	Holmes	Kingston University	IP/623/0999	☑	☑	☑	☑	☑	☑	☒	4		£ 1,164.00
20279	Isotopic variability of Cd, Cu, An in soils	Thornton	Imperial College	CASE	☑	☑	☑	☑	☑	☑	☑	4		£ 1,164.00
20285	Significance of island arcs assoc.oceanic plateaux	Saunders	Leicester University	IP/634/0100	☑	☑	☑	☑	☑	☑	☑	52		£ 15,132.00
20286	Climate change in Lake Baikal	Mackay MacKay	University College London	IP/635/0300	☑	☑	☑	☑	☑	☑	☑	46	4	£ 13,678.00
20287	Holocene climate change in the eastern Med.	Eastwood	University of Birmingham	IP/636/0300	☑	☑	☑	☑	☑	☑	☑	1		£ 291.00
20290	Airborne particulate matter in London	Smith, S.	Kings College London	IP/645/0300	☑	☑	☑	☑	☑	☑	☒	5		£ 1,455.00
20292	Oxygen isotope fractonation - diatom silica & water	Battarbee	University College London	IP/648/0300	☑	☑	☑	☑	☑	☑	☑	15		£ 4,365.00
20298	Metamorphism and tectonics of the Karakoram Crust.	Searle	Oxford University	CASE	☑	☑	☑	☑	☑	☑	☑	23	66	£ 11,511.00

20299	Structural evolution of the Karakoram Fault	Searle	Oxford University	CASE	☑	☑	☑	☑	☑	☑	☑	13	10	£	4,513.00
20301	Silurian orogenic activity in the Caledonides	Strachan	Oxford Brookes University	IP/659/0900	☑	☑	☑	☑	☑	☑	☒	20		£	5,820.00
20302	Quantifying spreading rate of Troodos ophiolite	MacLeod	Cardiff University	IP/662/0900	☑	☑	☑	☑	☑	☑	☒	33		£	9,603.00
20303	Amazon River discharge over the last 85,000 years	Maslin	University College London	IP/660/0900	☑	☑	☑	☑	☑	☑	☒	5		£	1,455.00
20304	Studies of health and migration	Millard	University of Durham	IP/663/0900	☑	☑	☑	☑	☑	☑	☑	113.5	43	£	36,167.50
20306	Residential mobility in Anglo-Saxon Northumbria	Budd	University of Durham	IP/666/0900	☑	☑	☑	☑	☑	☒	☒	36		£	10,476.00
20307	Magmatic and tectonic evolution of Southern Tibet	Kelley	Open University, Milton Keynes	IP/667/0900	☑	☑	☑	☑	☑	☑	☑	2		£	582.00
20308	Holocene climatic change - eastern Mediterranean	Roberts	University of Plymouth	IP/669/0900	☑	☑	☑	☑	☑	☑	☑	1		£	291.00
20309	Investigating moisture - Central Mexico	Metcalfe	University of Edinburgh	IP/670/0900	☑	☑	☑	☑	☑	☑	☑	30		£	8,730.00
20310	Timescales of formation of rare-element pegmatites	Kelley	Open University, Milton Keynes	IP/675/0900	☑	☑	☑	☑	☑	☑	☑	4		£	1,164.00
20313	Environmental change - NE Tibet-Qinghai Plateau	Holmes	University College London	IP/679/1100	☑	☑	☑	☑	☑	☑	☒	37		£	10,767.00
20315	Provenance of Himalayan Formations	Harris	Open University, Milton Keynes	CASE	☑	☑	☑	☑	☑	☑	☒	41.5	94	£	18,938.50
20318	Oxygen isotopes from Chuna Lake sediments	Jones,V.L.	University College London	IP/681/0301	☑	☑	☑	☑	☑	☑	☑	5		£	1,455.00
20319	Palaeozoic terrane accretion in Western Mongolia	Cunningham	University of Leicester	IP/682/0301	☑	☑	☑	☑	☑	☑	☒	17.5		£	5,092.50
20320	Caledonian intrusion-related hydrothermal activity	Rice	University of Aberdenn	IP/683/0301	☑	☑	☑	☑	☑	☑	☒	41.5	108	£	19,960.50
20321	Constraining the petrogenesis of mafic pegmatites	Tarney	Leicester University	IP/685/0301	☑	☑	☑	☑	☑	☑	☒	20.5		£	5,965.50
20322	Events in the late Proterozoic to Ordovician rocks	Tanner	University of Glasgow	IP/686/0301	☑	☑	☑	☑	☑	☒	☒	74		£	21,534.00
20324	Diatom silica from a crater lake in Ethiopia	Lamb	John Moores University, Liverpool	IP/690/0301	☑	☑	☑	☑	☑	☑	☑	36		£	10,476.00
20330	Lake silica oxygen - east African climate	Maslin	University College London	IP/704/0901	☑	☑	☑	☑	☑	☑	☒	33		£	9,603.00
20331	Stable isotope biogeochemistry of methanogenesis	Hornibrook	University of Bristol	IP/706/0901	☑	☑	☑	☑	☑	☑	☒	6		£	1,746.00

20332	Climate and sea-level change in the Mersey Estuary	Lamb	John Moores University, Liverpool	IP/708/0901	☑	☑	☑	☑	☑	☑	☑	33		£	9,603.00
20334	Diatom silica - north-west Scotland	Flower	University College London	IP/717/1001	☑	☒	☒	☒	☒	☒	☒	4		£	1,164.00
20335	Lake Malawi drilling programme	Barker, P	University of Lancaster	IP/720/1001	☑	☑	☑	☑	☑	☑	☒	20		£	5,820.00
20336	High resolution relative sea-level changes	Shennan	University of Durham	IP/722/1001	☑	☑	☑	☑	☑	☑	☒	45		£	13,095.00
20337	Evolution of the Mogok belt	Searle	University of Oxford	IP/723/1001	☑	☑	☑	☑	☑	☒	☒	9		£	2,619.00
20338	Mortality, Morbidity and Population Diversity	O'Sullivan	Leicester University	IP/724/1001	☑	☑	☑	☑	☑	☑	☑	26		£	7,566.00
20340	Production & metrology of Roman coinage	Ponting	University of Nottingham	IP/728/1001	☑	☑	☑	☑	☑	☑	☑	4		£	1,164.00
20341	Evolution of the Kohistan arc and MMT zone	Waters,D	University of Oxford	IP/733/1001	☑	☑	☑	☑	☑	☑	☑	16		£	4,656.00
20342	Cross calibration.- 40Ar/39Ar & U/Pb isotopic dating	Fitton	University of Edinburgh	IP/734/1001	☑	☑	☑	☑	☑	☑	☑	2		£	582.00
20344	Fate of nitrogen in Arctic glacial meltwaters	Hodson,A	University of Sheffield	CASE	☑	☑	☑	☑	☑	☑	☑	61	72	£	23,007.00
20345	Past Climate Variability in Continental Eurasia	Mackay	University College London	CASE	☑	☑	☑	☑	☑	☑	☒	115		£	33,465.00
20346	Somail Ophiolite	Searle	University of Oxford	CASE	☑	☑	☑	☑	☑	☑	☑	41.5	92	£	18,792.50
20347	Holocene variation of the East Asian monsoon	Lloyd,J	Durham University	Pilot	☑	☑	☑	☑	☑	☑	☑	12		£	3,492.00
20349	Holocene Lake Sediments, Ireland.	Roberts	University of Plymouth	Pilot	☑	☑	☑	☑	☑	☑	☑	3		£	873.00
20351	Trans-European population movement - Roman empire	Henderson	University of Nottingham	IP/737/0302	☑	☑	☑	☑	☑	☑	☑	8		£	2,328.00
20352	Constraining the oil window - diagenetic proxies	Zalasiewicz, J	Leicester University	IP/738/0302	☑	☑	☑	☑	☒	☒	☒	23		£	6,693.00
20354	Assessing age of Central Highlands 'basement'	Prave	University of St. Andrews	IP/743/0302	☑	☑	☑	☑	☑	☒	☒	2		£	582.00
20356	Mid-Carboniferous C and O isotope stratigraphy	Tucker	University of Durham	IP/753/0302	☑	☑	☑	☑	☑	☑	☑	1		£	291.00
20357	Analysis of the Cenomanian - Turonian boundary	Price	University of Plymouth	IP/757/0302	☑	☑	☑	☑	☑	☑	☑	35		£	10,185.00
20358	Direct evaluation of archaeological immigration	Millard	University of Durham	IP/761/0302	☑	☑	☑	☑	☑	☑	☒	20		£	5,820.00
20359	Isotopes in glass	Henderson	University of Nottingham	Pilot	☑	☑	☑	☑	☑	☑	☑	30		£	8,730.00

20360	Magma degassing and tropospheric volcanic plumes	Pyle	University of Cambridge	IP/762/0802	☑	☑	☑	☑	☑	☑	☒	6	18	£	3,060.00
20361	Origin of the North Himalayan granites	Harris	Open University, Milton Keynes	IP/763/0902	☑	☑	☑	☑	☑	☑	☒	44		£	12,804.00
20362	Oxygen isotope compositions of phytolites	Jones,MK	University of Cambridge	IP/766/0902	☑	☑	☑	☑	☒	☒	☒	1		£	291.00
20363	Ancient Islamic al-Raqqa glass, Syria	Henderson	University of Nottingham	IP/767/0902	☑	☑	☑	☑	☑	☑	☑	1		£	291.00
20364	Strontium-isotope stratigraphy - deep sea cores	Clarke	University of Wales: Bangor	IP/769/0902	☑	☑	☑	☑	☑	☑	☒	43		£	12,513.00
20366	Snaefellsnes Peninsula	Fitton	University of Edinburgh	IP/771/0902	☑	☑	☑	☑	☑	☑	☒	42		£	12,222.00
20367	Equilibration volumes in granitoid magmas	Clemens	Kingston University	IP/772/0902	☑	☑	☑	☑	☑	☑	☒	59	46	£	20,527.00
20368	Social implications of Anglo-Saxon childhood diet	Chamberlain	University of Sheffield	IP/775/0902	☑	☑	☑	☑	☑	☑	☑	52.5	27	£	17,248.50
20370	Tracking the Siberian Plume	Saunders	Leicester University	IP/777/0902	☑	☒	☒	☒	☒	☒	☒	45		£	13,095.00
20371	Stable sulphur isotopes in seagrasses	Kennedy	University of Wales-Bangor	IP/778/0902	☑	☑	☑	☑	☑	☑	☒	31		£	9,021.00
20373	Immigration & lead exposure from cremated remains	Millard	University of Durham	IP/781/0902	☑	☑	☑	☑	☑	☑	☒	14		£	4,074.00
20374	Immigration and lead exposure of Vikings	Millard	University of Durham	IP/782/0902	☑	☑	☑	☑	☑	☑	☒	1		£	291.00
20375	Migration and lead exposure of early Anglo-Saxons	Millard	University of Durham	IP/783/0902	☑	☑	☑	☑	☑	☑	☒	64	20	£	20,084.00
20376	Climatic variability in Peru over 2000 years	Frogley	University of Sussex	IP/785/0902	☑	☑	☑	☑	☑	☑	☑	62		£	18,042.00
20377	Stalagmite record of Ethiopian climate	Baker	University of Newcastle	IP/786/0902	☑	☑	☑	☑	☑	☑	☑	26	6	£	8,004.00
20378	Fate of immobile elements in subduction systems.	Downes	University of London, Birkbeck	IP/789/0902	☑	☒	☒	☒	☒	☒	☒	75.5		£	21,970.50
20379	Belemnites	McArthur	University College London	IP/774/0503	☑	☑	☑	☑	☑	☑	☒	15		£	4,365.00
20380	Nitrogen dynamics in the polar cryosphere	Hodson,A	University of Sheffield	IP/776/05/0 3	☑	☑	☑	☒	☒	☒	☒	20		£	5,820.00
20381	Lake Qarun	Holmes	University College London	IP/777/0503	☑	☑	☑	☒	☒	☒	☒	14	2	£	4,220.00
20382	Cycling of dissolved organic N	Achterberg	University of Plymouth	IP/778/0503	☑	☑	☒	☒	☒	☒	☒	2		£	582.00
20383	South Georgia lakes	Davies, S	University of Wales	IP/779/0503	☑	☑	☑	☑	☑	☑	☒	38		£	11,058.00
20384	Prehistoric Shellfish	Thomas, K	University College London	IP/780/0503	☑	☑	☑	☑	☑	☑	☒	47	6	£	14,115.00
20386	Lake Tana	Lamb, H	University of Wales	IP/783/0503	☑	☑	☒	☒	☒	☒	☒	5		£	1,455.00

20387	Bone as palaeoclimate proxy	Hedges	University of Oxford	IP/786/0503	☑	☑	☑	☑	☑	☑	☑	14	10	£ 4,804.00
20388	Grampian Provenance	Winchester	Keele University	CASE	☑	☑	☑	☑	☑	☑	☒	41	39	£ 14,778.00
20389	North Himalayan Domes	Harris	Open University, Milton Keynes	CASE	☑	☑	☑	☒	☒	☒	☒	15		£ 4,365.00
20390	Pakistan loess	Clarke, M	University of Nottingham	Pilot	☑	☑	☑	☑	☑	☑	☒	16		£ 4,656.00
20391	Lochnagar	Jones, V	University College London	CASE	☑	☒	☒	☒	☒	☒	☒	5		£ 1,455.00
20392	Dating the main castrol thrust	Bickle	University of Cambridge	IP/796/1103	☑	☑	☑	☑	☑	☑	☒	2	6	£ 1,020.00
20396	Adakites	Petford, N	Kingston University	IP/809/1103	☑	☑	☑	☑	☑	☑	☑	10		£ 2,910.00
20398	Ethiopean Neoproterozoic limestones	Jenkin	Leicester University	Pilot	☑	☑	☑	☑	☑	☑	☒	4		£ 1,164.00
Total University projects												**2200**	**673**	**£ 689,329.00**
Total												**2406**	**673**	**£ 749,275.00**

Please note: Does not include NIGL projects: Method development/innovation

Annex 5. Description and Reports of the NIGL Analytical Facilities

Notes on the running of facilities, analytical output, and notable developmental work is listed below. Some scientific highlights arising from work in the facilities is outlined in Annex 7.

5.1 CARBON-HYDROGEN-OXYGEN FACILITY

This facility includes a VG Optima dual inlet mass spectrometer plus Isocarb for automated $^{13}C/^{12}C$ and $^{18}O/^{16}O$ on micro-carbonates. This is shared with the CAL facility and the mass spectrometer is also connected to a Carlo Erba NA1500 elemental analyser with VG triple cryogenic trap for organic $^{13}C/^{12}C$ and C/N analysis. In addition there is a VG SIRA dual inlet mass spectrometer with 48 port Isoprep 18 and Multiport Manifold for $^{2}H/^{1}H$ and $^{18}O/^{16}O$ analysis of waters. A rebuilt Micromass 903 dual inlet mass spectrometer with manifold for $^{18}O/^{16}O$ is used for the off-line extracted diatom silica (original 1977 instrument, will be replaced in August 2004). The new BAS and NERC funded water facility, which consists of the Micromass Isoprime dual inlet mass spectrometer with Multiprep and EuroPyrOH with continuous flow option, for high precision $^{2}H/^{1}H$ and $^{18}O/^{16}O$ analysis of waters, was installed during August 2003. The hydrogen facility is now fully operational.

Studies directed towards understanding past climate variability are continuing to be a major part of NERC-funded research into the potential impacts of future climate change. Within NIGL much of this work continues to be centered on $^{13}C/^{12}C$ + $^{18}O/^{16}O$ analysis of carbonates, $^{18}O/^{16}O$ + D/H analysis of ice cores and contemporary waters, $^{13}C/^{12}C$ and C/N analysis of organics and $^{18}O/^{16}O$ analysis of diatom silicate. These isotope techniques continue to be major tools in palaeoclimate research, and demand for such studies is continuing to increase. NIGL is the only UK laboratory with this range of capability. In the coming year we plan to set up the technique for the analysis of silicon isotopes, in particular from diatom silica which will help assess palaeo-productivity in both lake and marine sediments.

Summary of analytical output (1 April, 2003 to 31 March, 2004)

Type of analysis	No. of analyses	Approx. % standards, blanks, tests, duplicates etc.
Water D/H	700	35
Water $^{18}O/^{16}O$	3200	25
Silicate $^{18}O/^{16}O$	665	30
Bulk carbonate $^{13}C/^{12}C$, $^{18}O/^{16}O$	2900	20
Micro-carbonate $^{13}C/^{12}C$, $^{18}O/^{16}O$	2200	25

5.2 COMBUSTION ANALYSIS & LASER FACILITY

The facility includes two automated on-line combustion systems (elemental analysers) linked to Finnigan Delta+XL continuous-flow and VG Optima dual-inlet mass spectrometers, and off-line combustion and laser fluorination systems served by a second VG Optima dual-inlet mass spectrometers. The two VG Optimas are shared with the 'CHO' facility. The systems allow analysis of: $^{34}S/^{32}S$ and $^{15}N/^{14}N$ ratios in a wide variety of substrates; D/H and $^{13}C/^{12}C$ ratios of bulk organic matter; and $^{18}O/^{16}O$ ratios of sulphates, nitrates, and bone/tooth phosphate. The sulphur and nitrogen work is largely focussed on studies of the interaction of atmospheric pollutants with terrestrial ecosystems, and of processes in surface and groundwaters. Analyses of organic matter and phosphate form an important part of the Laboratory's programme of palaeoclimate and archaeological studies.
From early 2003 all of the laboratory's $^{15}N/^{14}N$ and $^{34}S/^{32}S$ isotope analyses, traditionally done off-line, has been undertaken on the ThermoFinnigan 'continuous-flow' system. $^{18}O/^{16}O$ analysis of nitrates and sulphates, which can provide valuable additional information on these environmentally important species, has now been added as a routine new capability. During 2003 the methodology for producing silver phosphate from tooth and bone was established, with the result that most phosphate $^{18}O/^{16}O$ work can also being undertaken by combustion techniques, rather than by use of the laser.

The facility maintained high analytical output throughout the year (below).

Summary of analytical output (1 April, 2003 to 31 March, 2004)

Type of analysis	No. of analyses	Approx. % standards, blanks, tests, duplicates etc.
$^{13}C/^{12}C$ + C/N (organic)	6120	25
$^{15}N/^{14}N$	1370	40
$^{18}O/^{16}O$ (phosphate, sulphate, nitrate)	3260	40
$^{34}S/^{32}S$	1050	40

5.3 PLASMA IONISATION MULTI-COLLECTOR MASS SPECTROMETRY (PIMMS) - TRACER FACILITY

The PIMMS-Tracer facility comprises dedicated Sr, Sm-Nd, Lu-Hf and common-Pb clean chemical laboratories, and a portion of the VG Microprobe II UV laser ablation (LA) system, the VG Elemental Axiom and P54 mass spectrometers, and the Finnigan-Mat 262 and ThermoFinnigan Triton mass spectrometers. The facility generates high precision isotope data for a wide range of tracer isotope studies, covering pollution/environmental, solid earth geochemistry and archaeological science. The particular strength of the facility is the capability of the P54 and Axiom to provide high precision data for elements that are beyond the normal scope of traditional TIMS, and for laser ablation in situ analysis.

This year has seen Vanessa Pashley, the PIMMS Facility Support Scientist, take six months maternity leave and Marcello Di-Bonito trained to cover her absence. Now returned, both Vanessa and Marcello are providing support in moving the Facility forward by implementing improvements.

The output summaries for both TIMS and PIMMS reflect a disappointing year for the Facility that can be directly attributed to the lack of service support for the three obsolete models of mass spectrometers that underpin the Facility. The P54 (electronics), Axiom (magnet power supply) and

Finnigan-Mat 262 (software) have all experienced considerable downtime due to problems that have disabled or severely restricted their use, with little or no service support possible. Thankfully, the efforts of NIGL support staff and scientists are bearing fruit at this time with at least one plasma instrument working reliably again and the 262 beginning to reach its previous good performance levels obtained several years ago.

A new mass spectrometer, the ThermoFinnigan Triton, has been added to the PIMMS-Tracer Facility for ultra-high precision Sr and Nd isotope work. This instrument is shared with the Uranium-Thorium-Lead Facility, its primary user. Plans to replace the aging technology of the P54 with a modern PIMMS instrument have been brought forward due to the deteriorisation in the P54 and it is expected that the next year will benefit from its installation and reliable operation as illustrated by comparing our experiences with the productivity and efficiency of the Triton and Finnigan-MAT 262 (see table below).

The addition of a new generation PIMMS instrument will enhance and further build on the excellent record for plasma analysis within the Facility, which currently documents:

- 52 of 211 NIGFSC projects over the last 5 yrs
- nearly 20,000 analyses
- >50 peer-reviewed publications in the last 4 yrs
- support for 13 PhD students, 9 postdoctoral researchers and 4 visiting scientists over the last 4 yrs

Highlights from the last year include peer-reviewed publication of work emphasised in previous reports including the:

- LA-PIMMS technique pioneered by NIGL (Horstwood et al, 2003)
- Capability development for high-precision Zn isotope measurement (Mason et al, 2004a; Mason et al, 2004b)
- Ability for LA-Sr isotope data to enhance models of Global Change through erosion studies of the Himalayas (Oliver et al, 2003).
- Fingerprinting of Roman mints through LA-Pb isotope studies of coins (Ponting et al, 2003), and
- Investigation of terrane reconstruction in Scotland through LA detrital zircon studies (Philips et al, 2003)

This year, the PIMMS-Tracer Facility has also completed a number of major commissions including a large project with the British Geological Survey to provide Sr, Nd and Hf isotope data as well as LA and TIMS U-Pb geochronology on a suite of samples from Southern Mauritania, as well as a smaller geochronology project on samples from Northern Mauritania. As a world leader in high-precision and accurate U isotope analysis, the PIMMS-Tracer Facility has been one of only three laboratories to take part in a pilot study for the Ministry of Defence, and the only one able to provide consistent high-precision results on the difficult determination of ^{236}U in human urine samples. This world leading expertise and the ability to attract and complete these major commissions, now allows the PIMMS-Tracer Facility to move itself forward in helping to finance a replacement for one of the more troublesome instruments. It is expected that this will increase capability and capacity through decreased downtime and increased reliability and the Facility looks forward to the next 5 years being even more productive.

Summary of analytical output for PIMMS (1st April 2003 to 31st March 2004)

Type of analysis	No. of analyses	Approx. % standards, blanks, tests, duplicates etc.
Common Pb (including laser ablation)	1301	73.3[1]
Hf (including laser ablation)	1315	81.8[1]
U	130	51.5

Summary of analytical output for TIMS (1st April 2003 to 31st March 2004)

Type of analysis	No. of analyses	Approx. % standards, blanks, tests, duplicates etc.
Sr - 262	236	74.6[1]
- Triton	***1053***	***20.1***
Nd - 262	235	71.9[1]
- Triton	***365***	***16.7***
Sm - 262	322	10.6
Pb - 262	162	29.6

[1] *An increased number of standards were run to troubleshoot instrument problems.*

5.4 URANIUM-THORIUM-LEAD FACILITY

High precision and high spatial resolution U-Th-Pb geochronology are crucial tools used to understand tectonic and metamorphic processes. NIGL's U-Th-Pb geochronology facility is the only UK laboratory that produces high precision U-Th-Pb ages coupled with low analytical blanks (routinely <10 pg Pb), which permits the routine analysis of single crystals or single domains within complex crystals. The facility comprises a dedicated clean chemical laboratory and VG 354 mass spectrometer, access to the 266 nm UV laser system and the PIMMS instruments (Axiom and P54), and a microscopy lab with binocular and petrographic - differential interference contrast microscopes and a networked digital camera system, and in 2004-2005 ~80-90% of available time on a ThermoElectron Triton mass spectrometer.

The facility has a full-time mass spectrometrist, Mr. Neil Boulton, who supervises day to day activities on the VG 354 and Triton, including student training, running samples and maintenance activities required by the high precision U-Th-Pb technique. Dr. Quentin Crowley is scientist in charge of the day-to-day running of the U-Pb clean laboratory and training and supervision of students and visitors. Dr. Matt Horstwood supported by ICP technicians Ms. Vanessa Pashley and Mr. Marcello Di Bonito supervises laser ablation ICP geochronology activities.

The geoscience community's demand for U-Th-Pb analytical support continues to exceed the facility's available capacity but progress continues to be made in improving the infrastructure. The Triton TIMS instrument, fitted with 9 Faraday collectors, and RPQ and ion counting SEM was installed and tested in May-June 2003. The Triton will be upgraded in early April 2004 with an additional multiple ion counter array to permit analysis of extremely small Pb samples. During FY 2003-2004 the VG 354 was operated almost continuously, while the Triton saw only limited duty, mainly because the bulk of the instrument time was spent on Sr and Nd to backfill a capacity shortfall created by extended MAT 262 downtime. It is envisaged that the Triton will progressively take over from the 22-year-old VG354 as primary U-Pb instrument in 2004-2005.

One of the long-term aims of the facility is to achieve reliable dating of samples with <50 pg Pb to further facilitate high precision timescale research, which requires the highest performance levels available, both in chemistry and mass spectrometry. Good data have been obtained on the VG354 at levels as low as 7 pg total Pb (with sub pg common Pb) but reliable, routine <1 pg Pb blanks are required. New water purification and closed-system ultra-pure acid distillation systems have just been installed in the clean chemistry lab and are being tested. Based on the experience of other laboratories, NIGL should be able to achieve 0.05-0.1 pg/ml Pb reagent blanks, facilitating <<1 pg total blanks within 2 years. With regards to mass spectrometry, we have significantly lowered our background organic levels in the TIMS instruments and tests in 2004 on the Triton show it to be significantly more sensitive than other TIMS instruments, allowing better precision levels per pictogram Pb to be achieved.

The laser ablation U-Pb capability of the U-Th-Pb Facility also goes from strength to strength (see highlight, Annex 7). Recent studies have demonstrated the ability of the technique in measuring extremely small ion signals in young and/or low U minerals, and yet still achieve high quality data with or without a correction for any common-Pb which may have been incorporated into the mineral at the time of crystallization. Over the last year, this capability has been exploited in a number of major commercial research as well as direct scientific projects with exceptional results.

Summary of analytical output (1 April, 2003 to 31 March, 2004)

Type of analysis	No. of analyses	Approx. % standards, blanks, tests, duplicates etc.
TIMS U-Pb analyses	591	26
Laser-PIMMS analyses	706	51.2

Annex 6 Staff during 2003-2004 year

University of Leicester employee (not supported by S&F allocation)

Prof R R Parrish, Professor of Isotope Geology & Head of NIGL (80% secondment via contract between NERC/BGS and University of Leicester to manage NIGL and conduct collaborative project research)

Administrative support (not supported by S&F allocation)

Mrs B I Bullock-von Moos, PA to Prof. R R Parrish and NIGL Administrator (joined 2003)

Open-ended employees of NERC (British Geological Survey) – supported in part by S&F allocation

Ms C Arrowsmith, SO, Stable Isotope Scientist

Mr N Boulton, SO, Mass Spectrometry Technician

Mrs C Chenery, HSO, Laser assisted Stable Isotope Scientist

Dr Q G Crowley, HSO, Radiogenic Isotope Scientist

Mrs D P F Darbyshire, Grade 7, Deputy Head of NIGL, igneous petrogenesis, mineral deposits, Sr-Nd isotopes, BGS liaison

Dr J A Evans, Grade 7, Research Scientist, U-Pb dating, Sr-Nd evolution of sedimentary basins

Ms J Green, ASO, Stable Isotope Technician

Dr T H E Heaton, Grade 7, Sulphur-Nitrogen-Oxygen Facility Manager, life sciences and palaeoenvironment

Dr M S A Horstwood, SSO, PIMMS Facility Manager, plasma source mass spectrometry, laser ablationapplication, U-Pb geochronology

Dr P D Kempton, Grade 7, Research Scientist, igneous petrogenesis, Nd-Sr-Pb-Hf isotopes (transferred to NERC, Swindon, 2004)

Dr M J Leng, Grade 7, Carbon-Hydrogen-Oxygen Facility Manager, stable isotopes in palaeoenvironment

Dr S R Noble, Grade 7, Uranium-Thorium-Lead Chronology Facility Manager, U-Pb geochronology, radiogenic isotope mass spectrometry

Ms V H Pashley, SO, PIMMS Facility Support Officer (maternity leave 6 months during year)

Ms H J Sloane, HSO, Isotope Geochemist

Mr A B Sumner, Tech Grade 1, Laboratory Technician

Mr A K Wood, ASO, p/t Mineral Separation Technician

Other isotope staff at NIGL (not supported by S&F allocation)

Dr T L Barry, HSO Post-doctoral Researcher (3 year 2002-2005) BAS/U Cardiff

Dr L M Chambers, HSO Post-doctoral Researcher (2 year 2002-2004) BGS

Dr M J Flowerdew, HSO Post-doctoral Researcher (3 year 2002-2005) BAS

Mr M Di Bonito, SO, PIMMS Facility Support Scientist (joined 2003, casual)

Dr A Gerdes, HSO, German Science Foundation. Granites and granulites of Central Europe (transferred to W Goethe University, Frankfurt (M) / Germany 2003)

Mr A Mason, SO, Support Scientist (joined 2003, casual)

Affiliated BAS/BGS isotope staff (not supported by S&F allocation)

Dr I L Millar, SSO, Research Scientist, British Antarctic Survey

Dr R J Pankhurst, Individual Merit Research Scientist (IMP6), British Antarctic Survey (retired 2002; Honorary Research Associate of NIGL/BGS 2002-2005)

Dr T Shepherd, Individual Merit Research Scientist (IMP6), British Geological Survey (retired 2003; Honorary Research Associate of BGS 2003-2006)

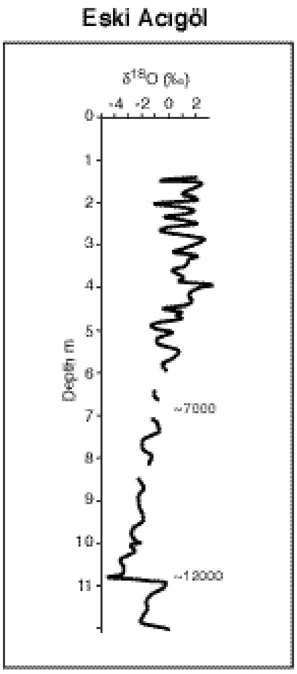
Annex 7. Selected NIGL scientific highlights for the period 2003-2004.

Global Change

The last deglacial transition: an East Mediterranean crater lake record

Establishing if past environmental changes have been synchronous between regions is important for understanding the dynamics of the Earth's climate system, especially during periods of rapid climate change such as the last deglacial transition. For this, laminated lake sediment 'archives' such as Eski Acıgöl are essential. Within Eski Acıgöl, 12m of laminated sediment covers the period from >15 000 to *ca.* 6500 Cal. BP. $\delta^{18}O$ and $\delta^{13}C$ values from authigenic carbonate, sediment lithology, and other proxies (e.g. diatoms, mineralogy) indicate major climatically-induced switches in hydrological conditions during the deglacial climatic transition. Regional changes in the precipitation-evaporation balance appear to have exerted the primary control over lake state. Limnological switches occurred abruptly (<100 varve years) and match closely the sequence of Late-Glacial changes recorded in N. Europe and the Greenland Summit ice cores.

(With Neil Roberts, University of Plymouth).



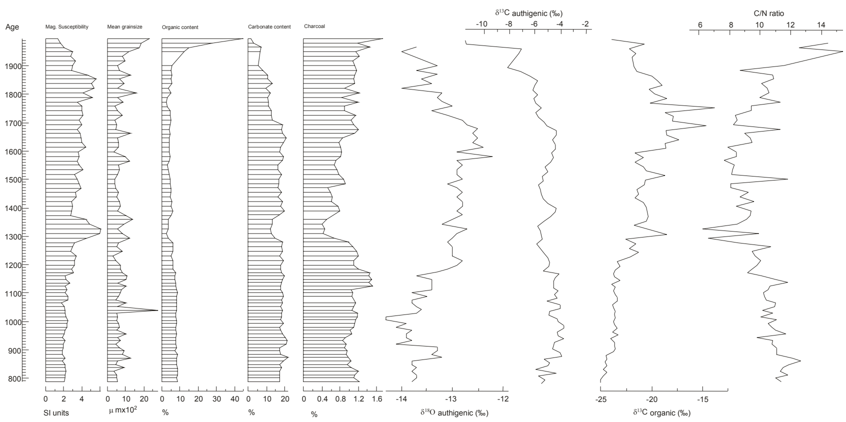
A clear hydro-climatic reversal is evident in the stable isotope record from Eski Acıgöl immediately prior to the start of the Holocene, apparently coeval with the Younger Dryas stage, and indicating a period of dry and cold conditions. A fine-resolution stable isotope analysis involving continuous sampling at varve year intervals through the "Younger Dryas" – Holocene transition indicates that the warming/wetting up transition was completed in only ca. 60 varve years. The sequence, duration and rate of change between deglacial climatic events at Eski Acıgöl suggests important coupling of climate across latitudinal bands.

Roberts, N., Reed, J., Leng, M.J., Kuzucuoglu, C., Fontugne, M., Bertaux, J., Woldring, H., Bottema, S., Black, S., Hunt, E., and Karabiyikoglu, M. 2001. The tempo of Holocene climatic change in the eastern Mediterranean region: new high-resolution crater-lake sediment data from central Turkey. The Holocene, 11, 721-736.

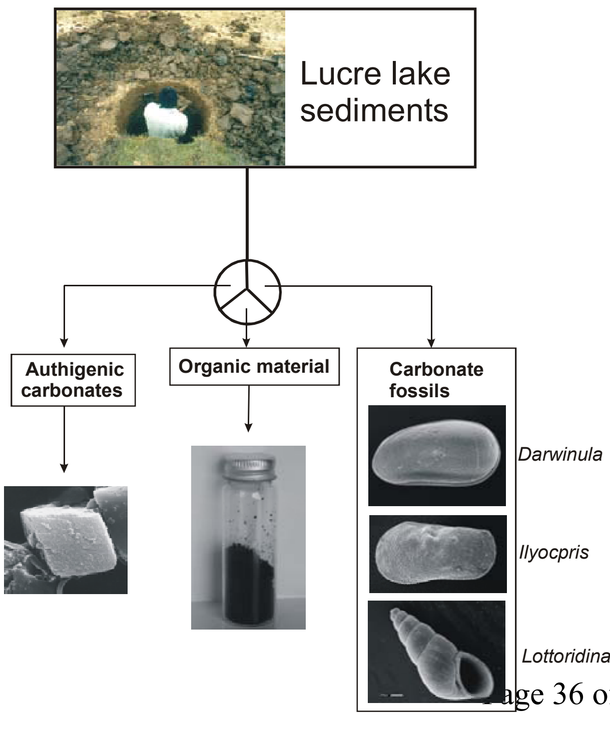
Isotopic evidence for aridity during the Spanish conquest of the Incas in southern Peru

The Andes have long been recognised as a centre for biological and cultural diversity that have given rise to a series of civilisations. In particular, the Inca, whose origins in Southern Peru predate AD 1200, and produced a significant empire (AD 1400–1537), stretching from present-day southern Colombia to central Chile. Whilst Inca society collapsed after the Spanish conquest, the almost simultaneous demise of the earlier cultures has been attributed by some to their apparent inability to adapt their agricultural practices in the face of a possibly globally significant climatic shift. We have evidence for a change after AD 1100 towards a warmer and more arid climate comes from a variety of sources, including accumulation data from the Quelccaya ice core suggesting a decrease in precipitation. However, there are still questions remaining as to the true significance and magnitude of the climatic shift. From a lake sediment record from the Lucre Basin, and have obtained independent evidence of climate variability from the isotopic composition of authigenic carbonate and organic carbon. The Laguna Lucre record shows significant aridity from *c*. AD 1100 peaking at AD 1650, suggesting that drought conditions prevailed prior to and during the Spanish conquest.

(With Michael Frogley University of Sussex)



Lucre Laguna marginal core sequence showing physical properties, $\delta^{13}C$ & $\delta^{18}O_{calcite}$, $\delta^{13}C_{organics}$, and C/N. After AD 1200 the co-variation between $\delta^{13}C$ & $\delta^{18}O_{calcite}$ shows an evaporative control on the isotope record. The amount of evaporation (lake level lowering) is high between AD 1200 and 1800. $\delta^{13}C_{organics}$ suggest a shift to marginal aquatics, a change in aquatic vegetation is indicated by C/N.

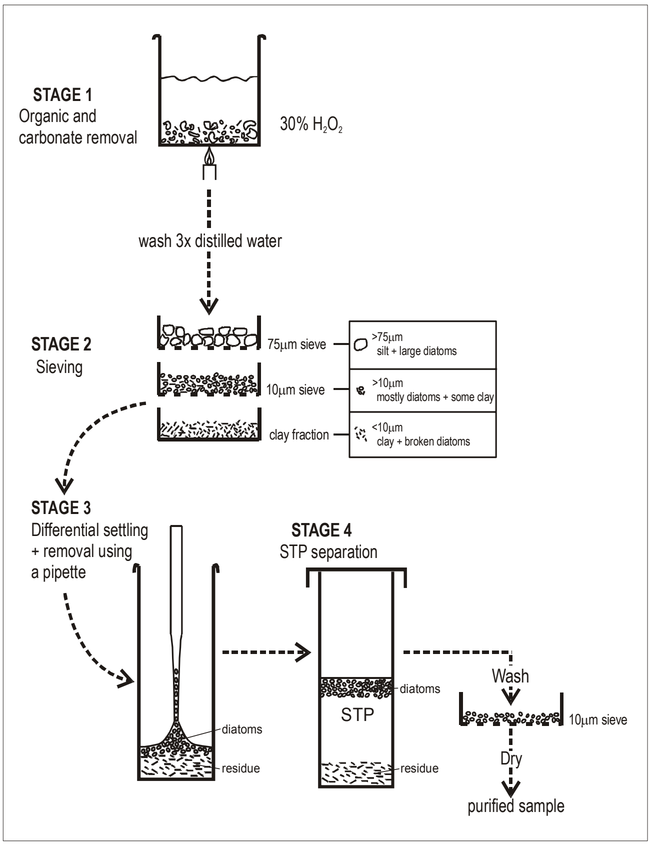


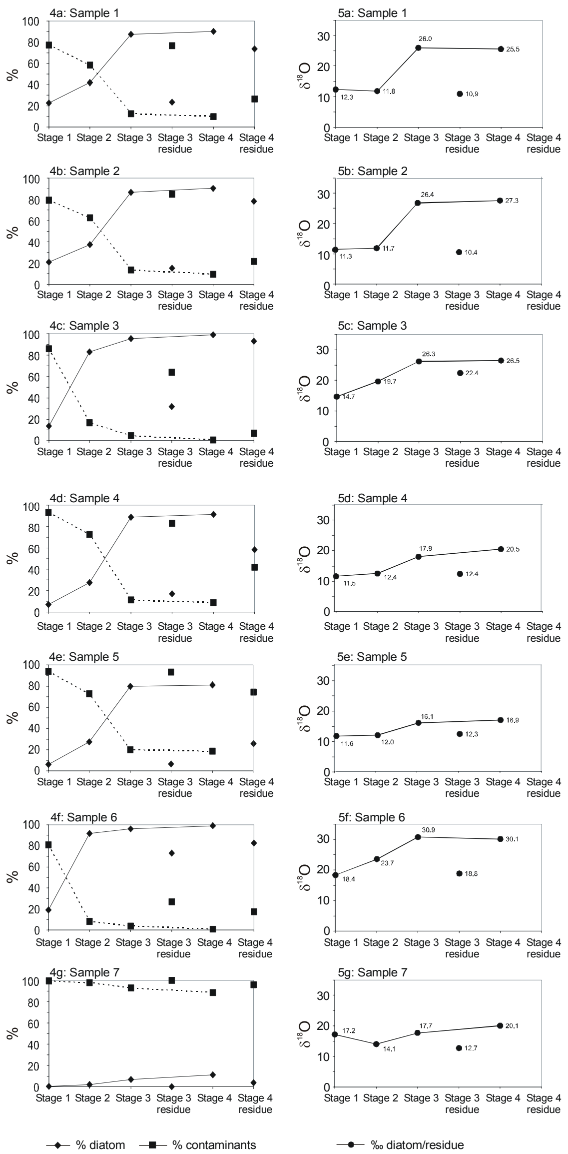
Materials obtained from Laguna Lucre for isotope analysis

Cleaning of sediments for diatom oxygen isotope analysis

Detrital grain contamination in a diatom sample can considerably influence the oxygen isotope ratios. In order to obtain a climatic signal, pure samples must be used. This can be achieved via a series of cleaning stages. A method has been developed to clean sediments which start with as little as 20% diatom content. Based on testing various methodologies, a sequence of 4 clean-up stages including organic and carbonate material removal, sieving, differential settling and heavy liquid separation, produces pure diatom samples from a range of lake sediments types starting with a few grams of sediment. The diatom content and the oxygen isotope composition of the samples at each stage have been assessed in order to quantify the effect of differential amounts of contamination. Results show that a four stage clean up is necessary to produce the cleanest diatom samples and that contamination by silt and clay causes significantly lower $\delta^{18}O$ values which could be mistakenly interpreted as wetter or colder events.

See: Morley, D.W., Leng, M.J., Mackay, A.W., Sloane, H.J., Rioual, P. and Batterbee, R.W. Cleaning of lake sediment samples for diatom oxygen isotope analysis. *Journal of Palaeolimnology – in press.*



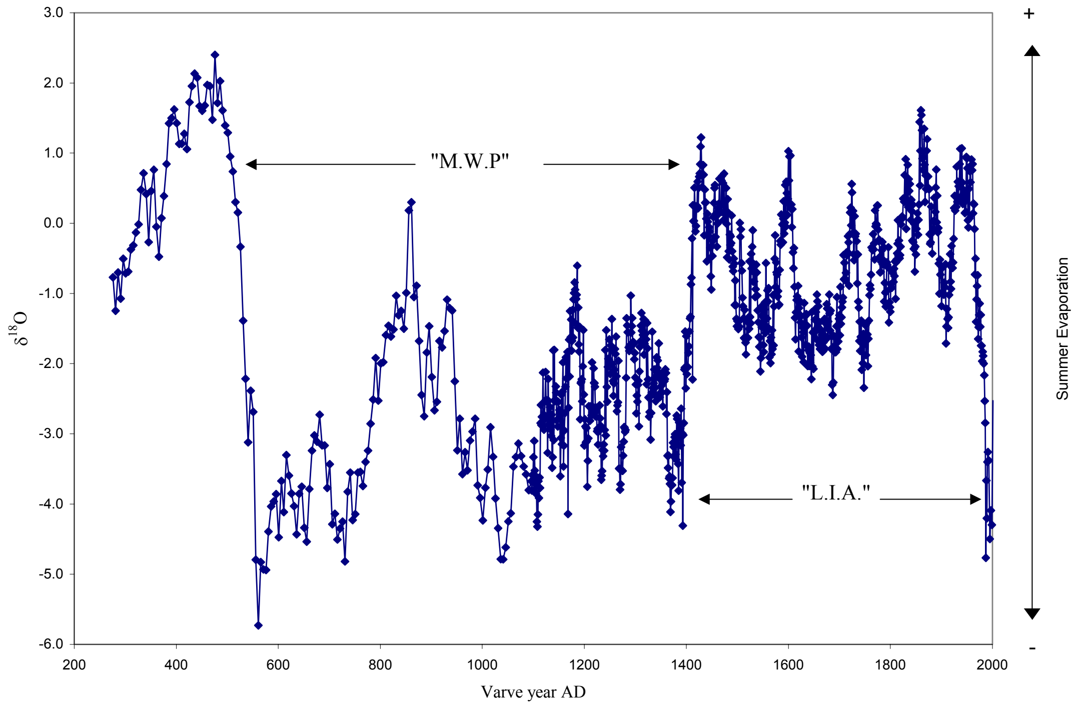


The four stage cleaning method developed to produce pure diatom separates for oxygen isotope analysis used to investigate climate change recorded in lake and marine sediments. Graphs show how the $\delta^{18}O$ changes with increasing purification.

Stable isotope records from annual lamination from a Mediterranean lake sediment provide high resolution climate reconstruction

A high resolution record of lake oxygen isotope change, recording changes in summer evaporation, was obtained from Nar Gölü a varved crater lake in central Turkey. Comparisons with records of the Indian and African (Sahel) Monsoon at an annual-decadal resolution through the instrumental time period show periods of increased evaporation in Turkey associated with periods of increased monsoon rains in India and Africa, and this relationship is also found to hold through the last 2000 years when using comparative proxy records of both monsoon systems.

The largest inferred shifts in the atmospheric circulation system over this time frame occurred c. AD 530 and AD 1400, and are associated with shifts between relatively warm



The oxygen isotope record from Nar Gölü. More positive isotope results reflect periods of increased evaporation such as during the northern European Little Ice Age (L.I.A), and are associated with increased summer temperatures and reduced relative humidity (from climate/isotope relationships observed during the instrumental time period 1926-2001).

and cold states of northern hemisphere climate. Decadal scale cycles, found in the 900-year long annually resolved part of the lake isotope record and proxy records of the Indian monsoon suggest a solar forcing control on the Eastern Mediterranean-Indian-African summer climate system throughout the last two millennia. *(With Matthew Jones and Neil Roberts, University of Plymouth).*

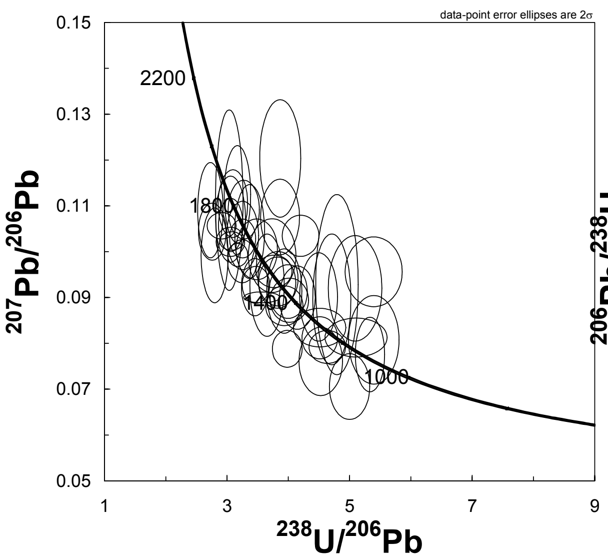
Understanding the solid earth and geochronology

LA-PIMMS U-Pb dating: success on extreme challenges in isotopic measurement !

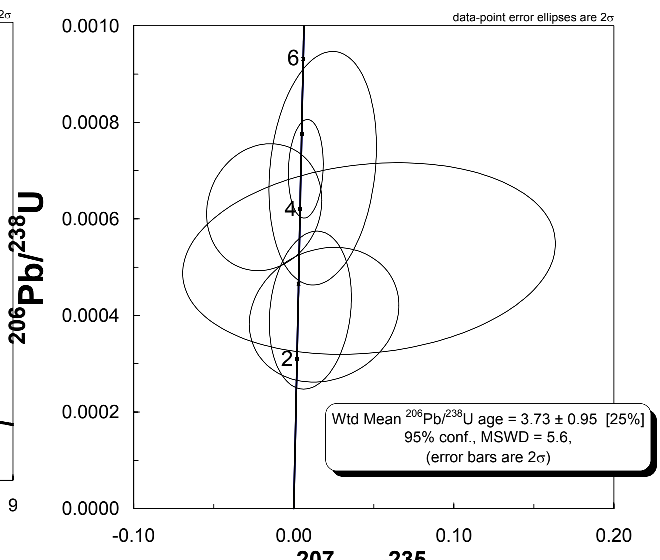
Over the last year, demand for NIGL's capability in laser ablation (LA) U-Pb geochronology has increased significantly. Aside from attracting commercial revenue, publication of the definitive protocol (Horstwood, et al 2003) by which this technique is carried out, has promoted and encouraged its use amongst the UK academic community.

Recently, case studies include studies of Scottish sedimentary rocks with colleagues from St. Andrews (Dr. Tony Prave) and Keele (Chris Banks, PhD student) Universities, to examine the detrital zircon populations, age of the sources and correlations between sedimentary basins. The data compare extremely well to those from adjacent basins, recently published and acquired using ion-probe (SHRIMP) methodologies. The data constitute some of the lowest U concentrations (5-20ppm) ever analysed in zircons by microprobe techniques. The concordant nature of the data, whether before or after common-Pb correction, illustrates the power of the technique to accurately define the necessity and degree of common-Pb correction required.

Most recently, a NIGFSC supported PhD student (Mark Caddick, Cambridge University) has dated some Himalayan monazites in-situ by LA-PIMMS. These crystals were often <30µm, smaller than the spot size of the laser itself, but were surrounded or contained in Pb-free phases (garnet). Through careful ablation, these monazites could be analysed and demonstrated a 4Ma metamorphic event. Analysis of minerals this young would normally be impossible by microprobe techniques but a combination of the high U nature of monazite and the synchronous data collection and common-Pb correction of PIMMS, coupled with time-resolved data analysis, has resulted in success. This is one of the youngest coherent U-Pb dates ever achieved by any microprobe technique and demonstrates NIGL's world leadership in this field!



a) LA-PIMMS U-Pb data for Scottish detrital zircons averaging <20ppm U.



b) Common-Pb corrected LA-PIMMS U-Pb data for c.4Ma Himalayan monazites

Plots reproduced by kind permission of Chris Banks and Mark Caddick, (PhD students)

Constraining Models of Continental Deformation

The Karakoram Fault is a major strike-slip fault in Asia, and this study is concerned with determining the fault's significance in the deformation of the Asian lithosphere since the mid-Miocene. Models of continental deformation remain polarized between two end-member views, each offering a profoundly different philosophy of continental tectonics. While one end-member view suggests that regional deformation is distributed through a continuously deforming upper mantle with an overlying brittle crust, the other interprets deformation as being constrained by slip on lithospheric-scale discontinuities that separate rigid plates. A significant factor in this debate is the role of active strike-slip faults in Asia and in particular that of the Karakoram Fault (see figure). The Karakoram Fault, an 800km dextral strike-slip fault that bounds the south-western margin of Tibet, is suggested to be one of the main faults that controls the eastward extrusion of the deforming Asian lithosphere. As the end-member models for continental deformation differ in the significance that they attach to the 'extrusion hypothesis', the models can be tested by establishing an accurate geological offset and a precise age for the initiation of the Karakoram Fault. These parameters will then constrain the long-termslip-rate of the fault and the extent of extrusion in southwest Tibet. We have dated samples from the Karakoram Fault in Ladakh, northwest India. Our data, taken from five variably deformed samples within the main Karakoram Fault shear zone, suggest that ductile deformation, and hence fault initiation, must have occurred between 15.32 ± 0.32 Ma and 13.73 ± 0.02 Ma (Figure 2). Coupled with a minimum offset of Baltoro-type granites of 40 km, this data provides a minimum long-term average slip-rate of *c.*3 mm/yr, a rate compatible with GPS, InSAR and cosmogenic data for the fault. An upper offset bound of 120 km suggests a long-term average slip-rate of no more than *c.*9 mm/yr. These small offsets and low slip-rates do not support the model of rapid, large-scale extrusion of Tibet along lithospheric-scale faults and strengthens the argument that Tibet does not behave in a rigid, plate-like, manner. *(NERC CASE PhD student: Richard Phillips, University of Oxford)*

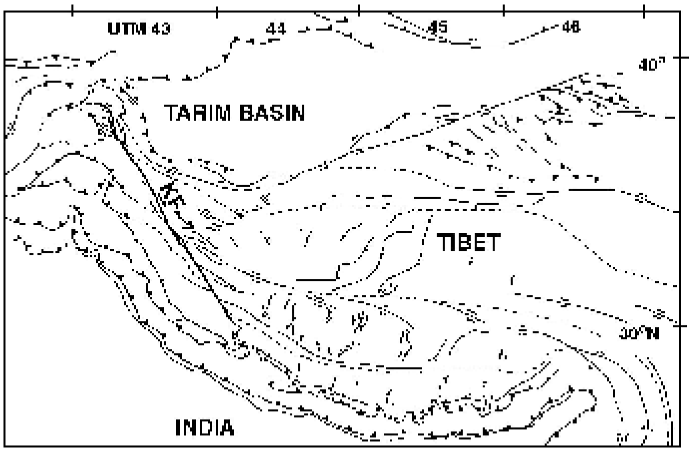
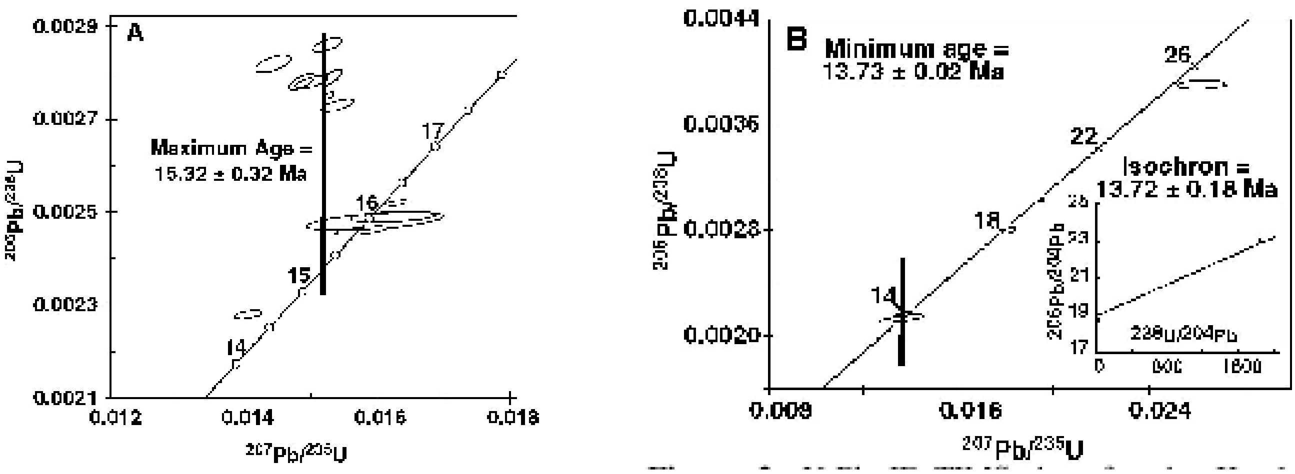
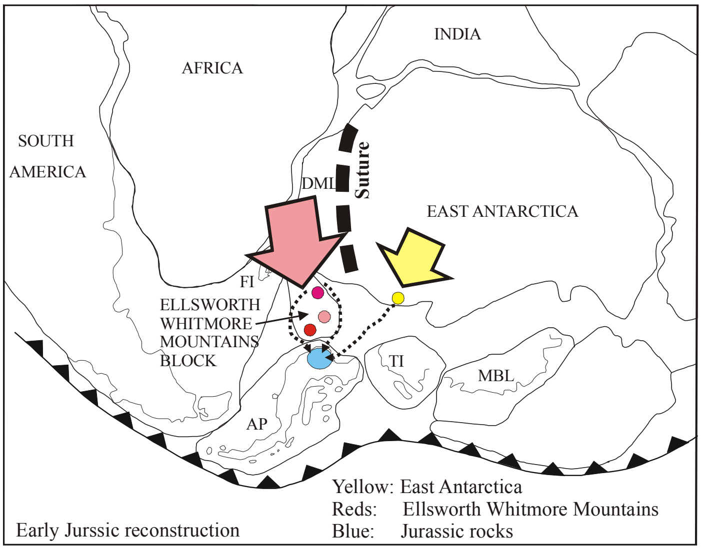


Figure 1 (above): Asian tectonic framework (KF: Karakoram Fault)
Figure 2: U-Pb ID-TIMS data for the Karakoram Fault shear zone:
A) Mylonitic granite sheets & dykes; B) Undeformed cross-cutting granite dykes

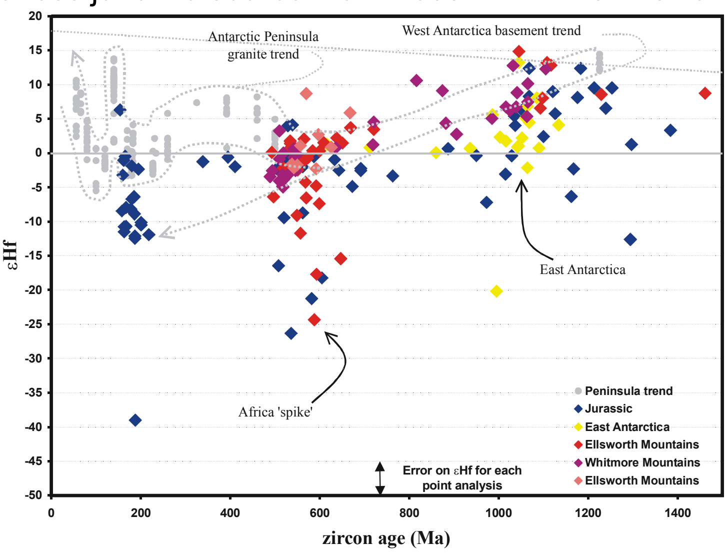


LA-PIMMS Hf: identifying provenance and recycling of Antarctic sediments using Hf isotope measurements from detrital zircon

U-Pb age distributions carried out on detrital zircons from clastic sedimentary rocks indicate sedimentary provenance and simplistically the age of rocks present at the sediment source. However, the resistance of zircon to chemical attack and mechanical abrasion during weathering, erosion and sedimentary transport, means that detrital zircon present within any sediment may have experienced several sedimentary cycles. Similar protolith ages and extensive recycling of zircons means that sediments deposited along the Palaeopacific margin of Gondwana have similar detrital zircon age patterns, more specifically important populations at 500-600 Ma and 1000-1200 Ma, and do not distinguish between source regions for thousands of kilometres. Given that recent models propose significant terrane movement along the margin, and that the rocks of the Antarctic Peninsula represent a collage of terranes; we are investigating whether the analysis of the Hf isotopes of detrital zircons carried out by laser ablation PIMMS analyses, following on from ion-microprobe (SHRIMP) U-Pb geochronology, can tie sequences to particular parts of the margin, that U-Pb age populations cannot alone.



Initial results are promising. Jurassic rocks deposited in eastern Ellsworth Land in the Antarctic Peninsula have apparently recycled their early Palaeozoic and older zircons from late Cambrian to early Ordovician sediments of the Ellsworth Whitmore Mountains micro-continental block, and from similarly aged sediments from Stewart Hills. Interestingly, of the 500-600 Ma zircons within the Ellsworth Whitmore Mountains sediments, the low □Hf values tell us that many zircons of that age were formed from material sourced by Archean crust, most likely the Kapvaal Craton of southern Africa. This African 'spike' is not present within the sediments sampled from East Antarctica, but here the 1000-1200 Ma zircons are, on average, formed from material with a less juvenile source than those within the Ellsworth Whitmore Mountains (Fig. 2). Thus, although the Jurassic rocks a show mixed provenance, Hf isotopes combined with U-Pb SHRIMP dating allow for a distinction between the sediment sources, and ultimately the origin of the zircon; East Antarctic or Africa/west Antarctica. Future work will assess how robust this conclusion is, and document how the pattern Africa versus East Antarctica provenance changes within Jurassic sediments along the Antarctic Peninsula. (BAS & NIGL)



Absolute age and underlying cause of hot-spring activity at Rhynie, NE Scotland from high-precision geochronology

(NIGL and University of Aberdeen)

The Lower Old Red Sandstone Rhynie Outlier, Aberdeenshire, NE Scotland is renowned worldwide on account of the existence of the Rhynie Chert(s). These fossil siliceous sinters, of which there are at least 53 individual horizons, preserve in unrivalled anatomical detail the remains of terrestrial and freshwater biotas that are amongst the earliest known. Furthermore, the cherts constitute the surficial manifestation of a Au-As-W-Mo bearing hydrothermal system. Indeed, Rhynie ranks as the oldest known example of a subaerial hot-spring system.

Rhynie-related research has, until recently, focused upon the palaeontology of the cherts. Two key questions concerning the absolute age of the Rhynie Chert and the magmatic drive for the Rhynie hot-spring system – have thus remained unanswered. High-precision geochronology has resolved both of these outstanding issues. A 409.6 ± 1.1 Ma U-Pb titanite - zircon age of an andesite lava dates hot-spring activity. Given the well-constrained palynological age of the Rhynie Chert, this new U-Pb age has important ramifications for the Early Devonian timescale. Variably mineralized, intermediate-to-acidic minor intrusions occurring within the Rhynie area (candidate representatives of the magma which powered and supplied metals to the hot-spring system) yield ages of either *c.* 427 Ma or *c.* 470 Ma, clearly precluding direct involvement with the hot-spring activity. The magmatic episode evidenced by the dated andesite lava must therefore have been responsible for hydrothermal activity at Rhynie. Beyond Rhynie, these new data contribute to our knowledge of the magmatic history and tectonic evolution of the Scottish Caledonides.

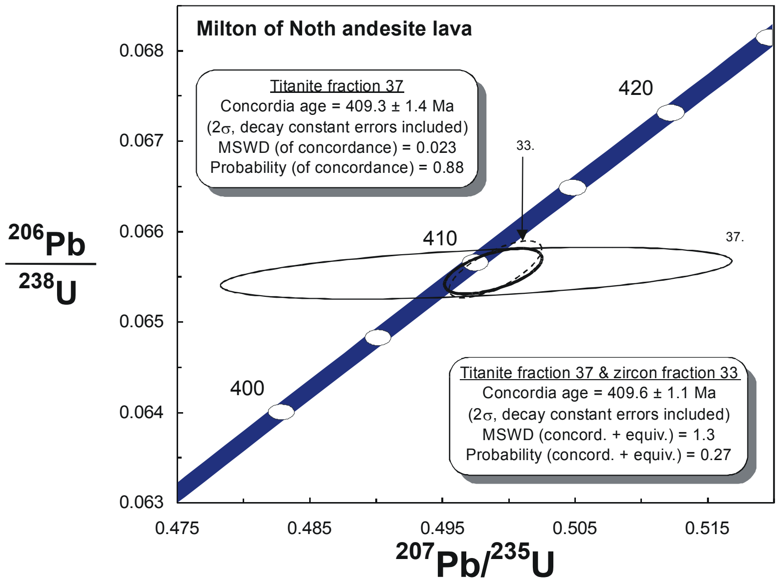
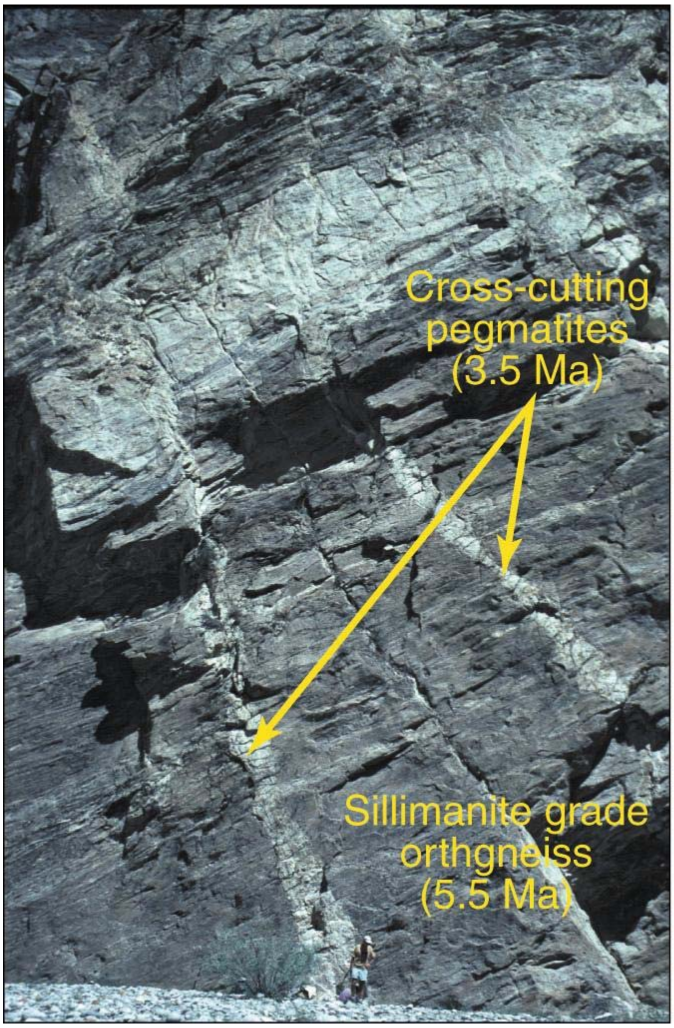


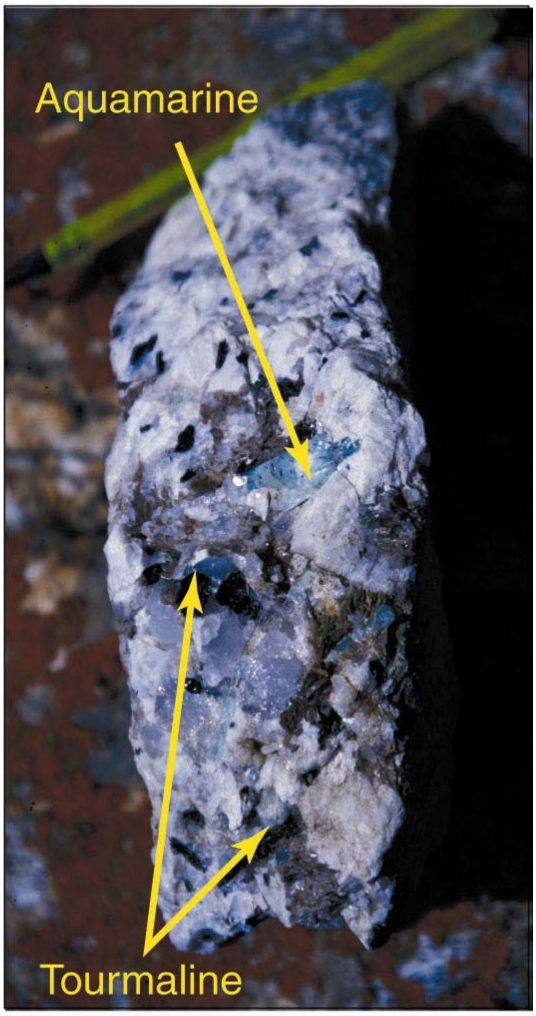
Figure Caption: Milton of Noth andesite U-Pb data. Numbers adjacent to error ellipses correspond to fraction numbers in Table F1 and the concordia curve shows ages in Ma. Ellipses indicate 2σ errors.

Ultra-Young metamorphism and magmatism in the Karakoram Mountains, Pakistan.

Recent application of U-Th-Pb geochronology techniques to rocks from the Karakoram Mountains have provided important information about the most recent evolution of the Himalaya-Tibet orogen. The Karakoram is an important part of the Himalayan chain because it provides one of the few exposures of the middle and deep crust on the Asian side of the collision zone. The rocks studied came from the Dassu area, in northern Pakistan, where sillimanite grade orthogneiss and cross-cutting pegmatites (see figure) are exposed in the core of a dome that overlies the Main Karakoram Thrust.

U-Th-Pb dating of monazite from the Dassu orthogneiss shows that peak metamorphic conditions were reached at 5.5 ± 0.2 Ma. Zircon crystals from the aquamarine-bearing pegmatite dykes (lower right figure) that cross-cut the gneissic fabric have been dated at 3.5 ± 0.1 Ma. The fact that such young rocks are exposed at the surface today suggests that the exhumation rate in this area of the orogen has been extremely fast during the last 5 Ma (~2.2 mm/yr). Mid-crustal rocks as young as those at Dassu are apparently restricted to the Karakoram, Nanga Parbat western Himalayan syntaxis and possibly also the Namche Barwa eastern Himalayan syntaxis. They are not present along the main Himalayan range and this might imply that more recent exhumation has been focussed at the syntaxes.

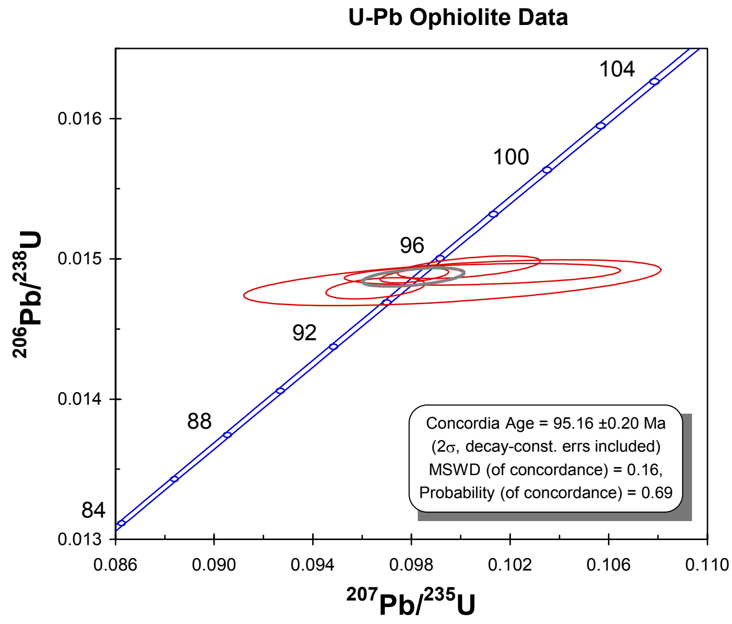


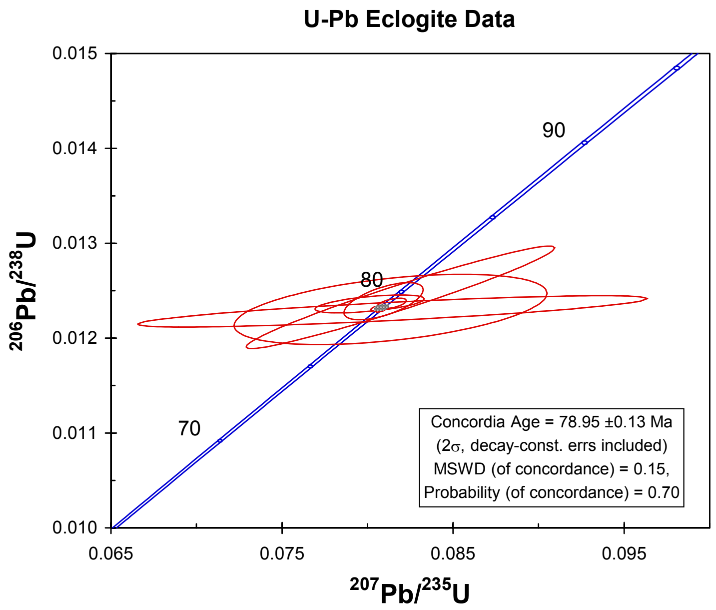


Dating the Semail Ophiolite, Oman

The Semail ophiolite in Oman is one of the world's best exposed and most studied natural geological laboratories for studying the processes involved with the formation of oceanic crust and the subsequent emplacement of oceanic crust onto a passive continental margin. Detailed geochronology of the age of the ophiolite, timing of emplacement and timing of continental margin subduction beneath the oncoming ophiolite is crucial for a complete geological and tectonic history.

U-Pb dating of zircons extracted from plagiogranites intruded into the ophiolite sequence, amphibolites from the metamorphic sole and eclogites from the high pressure continental succession has been carried out at NIGL. This data was then compared to published ages calculated from decay schemes such as $^{39}Ar/^{40}Ar$ for the metamorphic sole and the high pressure rocks, and U-Pb ages for the ophiolite analysed in 1981.





Improved techniques and high analytical precision at NIGL have lead to a much more precise age for the formation of the ophiolite (95.5 Ma cf. 94-97 Ma), an age for the sole (94.3 Ma) which matches the published $^{39}Ar/^{40}Ar$ age, and a highly precise age of 79.1 Ma for the age of the high pressure metamorphism. This latter age casts doubt on published $^{39}Ar/^{40}Ar$ data that produced a spread of older ages (72-131 Ma). This matches a pattern shown in other high pressure regimes such as China and the Alps where the $^{39}Ar/^{40}Ar$ ages have been shown to be older than U-Pb ages from the same rocks. (NERC CASE PhD project of Clare Warren, Oxford University). See Warren, C.J., Parrish, R.R., Searle, M.P. and Waters, D.J. 2003. Dating the subduction of the Arabian continental margin beneath the Semail ophiolite, Oman. Geology, v. 31, p. 889-892.

Knoydartian metamorphism recorded in calc-silicates sphenes.

Scottish geology is occupied by two contrasting theories to explain the tecto-metamorphic evolution of the highlands. One model suggests that the Laurentian section on which the Moine was deposited was subjected to continuous extension between >900- 470 Ma. Other models advocate Precambrian metamorphism. This study undertook to date sphenes found within calc silicate bands within the Moine because the metamorphic grades achieved by these lithologies is well documented and more sensitive to changing PT conditions that the host psammites. Results from the Glenfinnan area of the highlands yields a U-Pb Discordia age of 737 ± 5 Ma (2σ) providing evidence of Precambrian metamorphism in this area.

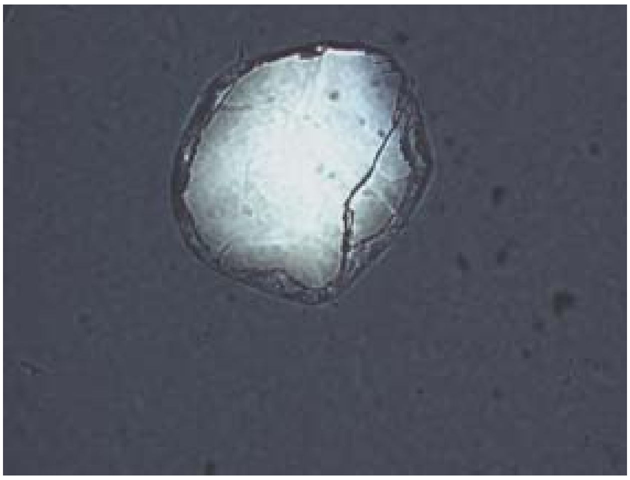
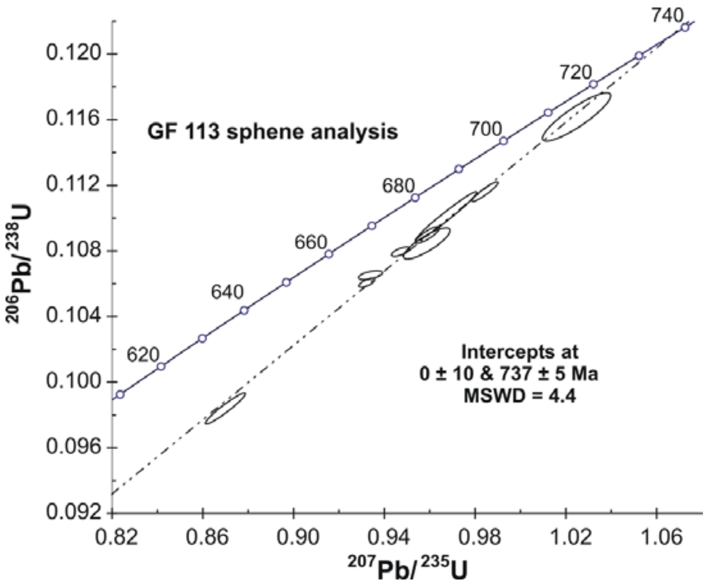


Figure 1. Titanite from Moine calc-silicates



Concordia diagram showing titanite data from the Glenfinnan area of Scotland

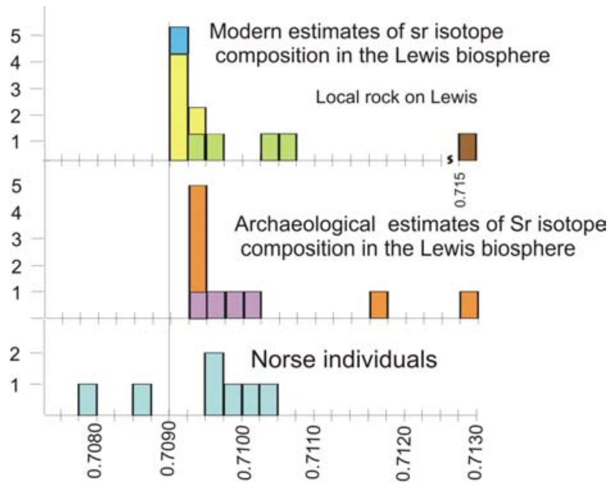
For further details see Tanner, P.W.G. and Evans, J.A., 2003. Late Precambrian U-Pb titanite age for peak regional metamorphism and deformation (Knoydartian orogeny) in the western Moine, Scotland. *Journal of the Geological Society*, 160: 555-564.

Science-based Archaeology

Viking slaves found on Lewis, Outer Hebrides?

Strontium isotope analysis of tooth enamel from a Norse community found at Cnip, Lewis are typified by $^{87}Sr/^{86}Sr$ isotope composition close to seawater (c. 0.7092) and Sr concentrations between 152 and 417ppm. However two individuals do not fit this pattern, have Sr concentrations of 169 and 58.2 ppm and and unradiogenic $^{87}Sr/^{86}Sr$ ratios of 0.70780 and 0.70858 respectively. As the Sr isotope composition of the Lewis biosphere is dominated by seawater contributions and Lewisian gneisses (c 0.715, average modern day value) these two individuals are unlikely to have been raised on Lewis. Having identified these anomalous individuals on Lewis the question arose - how did they end up on Lewis? The Viking lifestyle supplies a likely answer. It is well documented that the Vikings sent raiding parties to Ireland, which was Christian, to round up slaves. In fact, they often timed their arrival to coincide with the times the population was at church and scooped up the whole lot. Documentary evidence shows they also raided the southern English coast from bases in Scotland, where they could have captured chalk dwellers. And so it is possible that Christian English and or Irish slaves have been identified within the pagan Norse community on the Outer Hebrides.

1A.



1B.

photograph courtesy of Dr T Neighbour, Edinburgh University

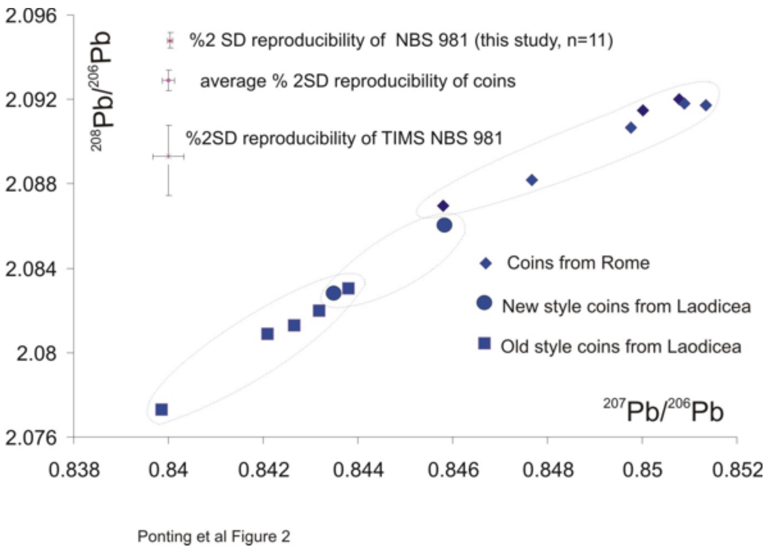
Figure 1a. The very low $^{87}Sr/^{86}Sr$ ratios of two individuals in comparison with estimate of local isotope composition and other burials.

Figure 1b. Individual with low $^{87}Sr/^{86}Sr$ tooth enamel value- was he a Viking slave?

For details see Montgomery, J., Evans, J.A. and Neighbour, T., 2003. Sr isotope evidence for population movement within the Hebridean Norse community of NW Scotland. Journal of the Geological Society, 160: 649-653.

Fingerprinting ancient mints using lead isotope signatures.

Laser ablation plasma mass spectrometry (LA-PIMMS) has been used to fingerprint the lead isotope ratios of well provenanced Roman and Syrian coins. Each mint with its own particular ore supplies and “coin recycling” policies will develop a unique Pb isotope signature. Results demonstrate inherent heterogeneity within coins that can reflect aspects of the manufacturing process. Due to the relatively simple sample preparation, this is a fast analytical method. The first application of this technique has shown that Roman and Syrian coins from 192-211AD can be clearly discriminated. *(With M Ponting, University of Nottingham)*



Pb isotope diagrams of Pb in silver coins from Rome and Syria & image of Roman silver coin (image from the web).

For further information see: Ponting, M., Evans, J.A. and Pashley, V. 2003. Fingerprinting of Roman mints using laser-ablation MC-ICP-MS lead isotope analysis. Archaeometry, v. 45, p. 591-597.

The Amesbury Archer

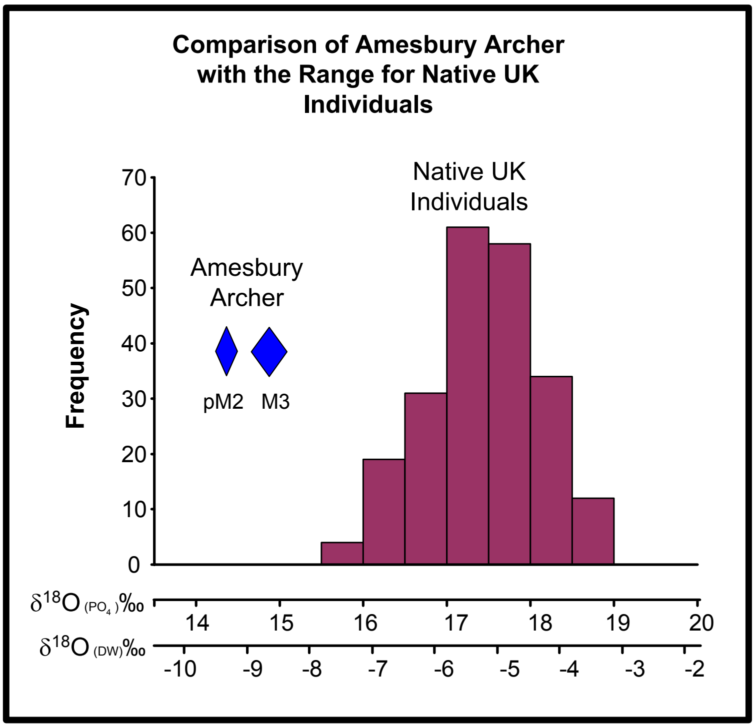
In the spring of 2002 a routine excavation of a building site at Amesbury, near Stonehenge, led to the discovery of the richest Bronze Age burial site found in Britain. The grave contained the skeleton of a man together with almost a hundred valuable artefacts: arrow heads and wrist-guards - suggesting he was an archer – together with well-formed pottery, copper knives, and the earliest example of good jewellery found in Britain. The man died about 2300 BC, in the period when the stones were being erected at Stonehenge. He was clearly of high status, and familiar with metal technology at a time when metal artefacts were extremely rare.

$^{18}O/^{16}O$ analysis of phosphate in the enamel of two of the Archer's teeth, formed during his childhood (pre molar 2 at c. 1-3 years, molar 3 at c. 7-10 years), yielded $\delta^{18}O$ values of –9.9 and –9.3 ‰. Such values are substantially lower than those of teeth in individuals born in Britain (see Figure). Since the oxygen in tooth phosphate is derived from oxygen in the water consumed in childhood, the Archer spent his childhood – i.e. was probably born - in an area where the local water has a lower $\delta^{18}O$ value than that in Britain. Patterns of $\delta^{18}O$ values for modern waters suggest that this area may have been somewhere in Central Europe.

This isotope data constitutes the first firm evidence for the migration of individuals from mainland Europe to Britain at an important time of Stonehenge's development, and raises the question: was the arrival of such people, with their advanced technical skills, a catalyst for such development?

With Dr. Andrew Fitzpatrick (Wessex Archaeology) and Julian Richards (BBC)

This research featured in the 19th February 2003, *BBC2 programme* "Meet the ancestors" BBC Broadcast



Trophic level shift in hydrogen isotopes

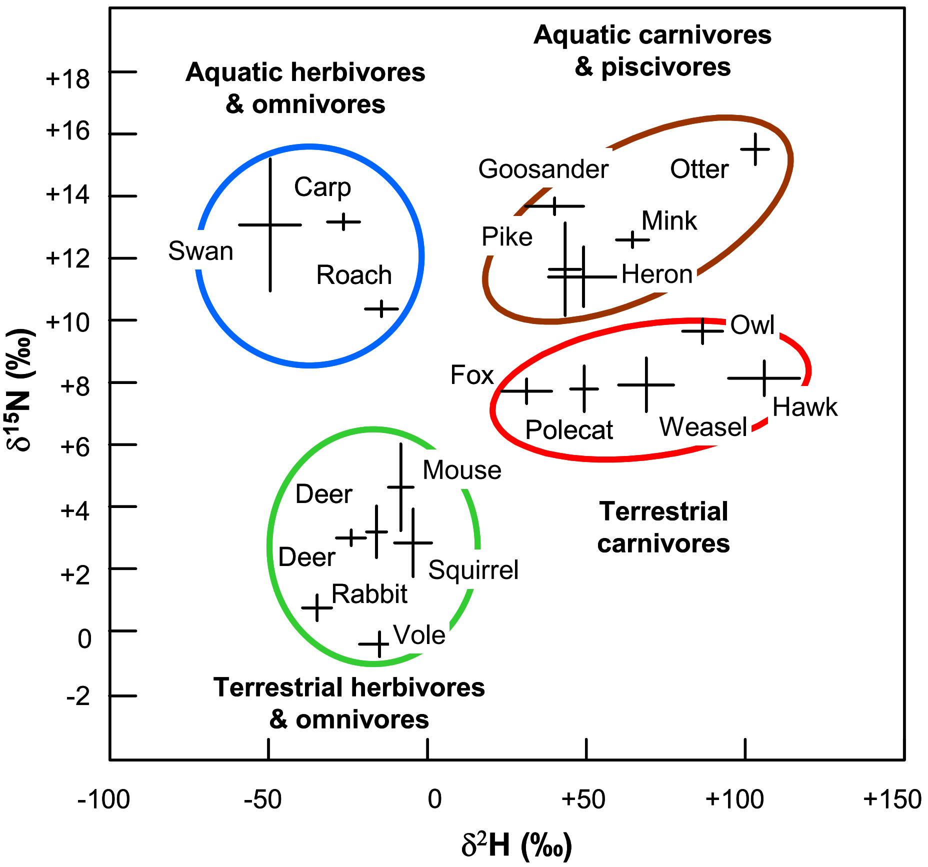
We have completed a pioneering study of trophic level effects on the $^{2}H/^{1}H$ ratio of animal protein (collagen). Previous work has concentrated on using geographically-imposed variations in the δD values of individual species, caused by geographic variation in the δD values of meteoric water, as an aid to the study of migration. In this project the animals were from mainland Britain, which shows relatively little variation in the δD value of water, and included 19 species of herbivorous and carniverous mammals, birds and fish. Special experimental procedures, involving isotopic exchange of the collagen hydrogen with ^{2}H-enriched water, allowed determination of the $^{2}H/^{1}H$ ratio of the non-exchangeable, carbon-bound hyrogen.

The data (see Figure) display a clear trophic level shift in $^{2}H/^{1}H$ ratios, with the δD values for carnivores/piscivores being, on average, about 90‰ higher than those for herbivores/omnivores. Of special significance is the fact that the values are largely independent of environment (aquatic versus terrestrial). In this regard the $^{2}H/^{1}H$ ratios appear to be more discriminating of trophic level differences than the traditionally-used $^{15}N/^{14}N$ ratios (see Figure).

δD analysis may therefore provide a valuable additional tool, complementary to $\delta^{15}N$, for disentangling food web patterns in ecological and palaeodietary studies. In addition, whilst we are not able to provide a convincing biochemical explanation for the observed trophic enrichment in ^{2}H, the work clearly has implications for a better understanding of the metabolism of whole-body hydrogen.

With Jenny Birchall, Tamsin O'Connell, and Robert Hedges (University of Oxford)

Figure. Non H-exchangeable $^{2}H/^{1}H$ ratios and $^{15}N/^{14}N$ ratios of collagen in animals from mainland Britain. Bars show one standard error of n =5 to 7 individuals



Pollution and Waste

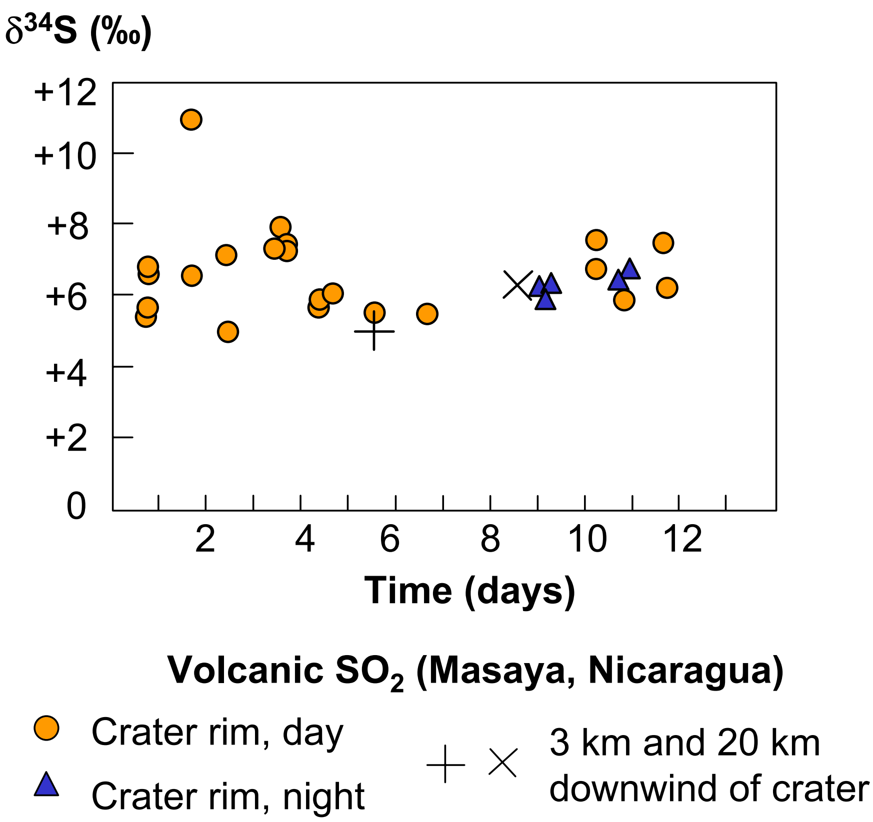
Volcanic SO_2

Volcanic emissions make a substantial contribution to the global budget of a number of atmospheric pollutants. The Masaya volcano in Nicaragua, for example, releases up to one thousand metric tonnes of SO_2 per day, and constitutes a major tropospheric point source of S pollution. The plume of this volcano is the subject of one of the first detailed $^{34}S/^{32}S$ studies. Unlike many other investigations, examining long-term average bulk atmospheric S, we undertook careful filter-pack sampling of SO_2 separately from SO_4^{2-} over intervals of only a few hours. We are using these data, together with $\delta^{34}S$ analysis of freshly-erupted magma, to assess different magma degassing models and understand more about the chemical evolution of the plume.

The Figure shows initial data for the $\delta^{34}S$ of SO_2 in the Masaya plume. Samples taken several kilometres downwind of the crater rim have a similar composition to those taken at the rim. This suggests either that there is little oxidation of SO_2 to SO_4^{2-}, or that the process involves little isotope fractionation. In addition, there is no obvious distinction between samples collected during the day and those collected under quite different atmospheric conditions prevailing at night. Both these features suggest that the $\delta^{34}S$ values are not substantially affected by sampling conditions. Instead the slight temporal variation in $\delta^{34}S$ values, typically between +5 to +8‰, is believed to reflect actual changes in the composition of the emitted SO_2, implying that the magma is not well mixed. The magnitude of the $\delta^{34}S$ values, compared with lower values found in the Chilean Andes, is consistent with a greater component of subducted marine sulphur in Massaya's magma.

With Tamsin Mather and David Pyle, Universiy of Cambridge.

Figure. $\delta^{34}S$ of SO_2 from Masaya volcano, Nicaragua, during 2 week period in December 2001. Samples collected on 2-stage filters, after removal of particulate sulphate, at pump speeds of 30 l.min^{-1}.



Fate of atmospheric nitrate on the Arctic tundra

We have studied the chemistry and isotopic characteristics of snowmelt and stream drainage in a non-glaciated catchment in Svalbard, 79^{o}N. The study formed part of a project assessing the impact of atmospheric nitrogen deposition on the High Arctic, funded as part of NERC's 'GANE' thematic programme. Nitrate in snowpack accumulated during the winter months represents an important source of N released into the nutrient-poor tundra soils during the spring snowmelt, the time at which active plant growth starts. We used recently-developed techniques for the collection and analysis of NO_3^- $^{18}O/^{16}O$ ratios to determine the fate of this nitrate.

Very low concentrations of nitrate, but high levels of dissolved organic matter, meant that the samples were the most difficult type attempted for such analyses. It proved impossible to remove all traces of organics from the nitrate prepared for mass spectrometry, so new methods were devised to assess the effect of the contaminant organic oxygen on the measured $^{18}O/^{16}O$ ratios. This involved simultaneous analysis of the silver nitrate' s N/O atomic ratio, and independent analysis of the $^{18}O/^{16}O$ ratio of the organic matter. The results for the 2001 field season are shown in the Figure. Nitrate in the accumulated winter snowpack, sampled in April, had high $\delta^{18}O$ values, >+50‰. These are to be expected for nitrate of atmospheric origin, where all the O is derived from O_2. The stream waters display a range of values between two end-members: pure nitrate with an N/O atomic ratio of 0.33 and a $\delta^{18}O$ = c. –5‰, with different amounts of contaminant organic oxygen having having N/O <0.1 and $\delta^{18}O$ = c. +25‰. The low □^{18}O for the nitrate is characteristic of microbially-formed soil nitrate, where two thirds of the oxygen is derived from low $\delta^{18}O$ soil water.

The $^{18}O/^{16}O$ ratios allow clear distinction between atmospheric nitrate and soil-produced nitrate. Atmospheric nitrate was not detectable in the stream waters at any time during the 2½ month summer season, even during the earliest period of stream flow immediately after snow-melt (19 June). The data call for an environment in which the atmospheric nitrate is *very* rapidly assimilated into the soil nitrogen cycle. Concurrently, organic matter is being mineralised and nitrified to produce soil-derived nitrate which is released into the drainage waters.

With Andy Tye and Johanna Laybourn-Parry (University of Nottingham)