

SERVICES & FACILITIES ANNUAL REPORT - FY April 2014 to March 2015

SERVICE NERC Isotope Geosciences Laboratory (NIGL)	FUNDING Direct from Swindon via BGS	AGREEMENT SLA	ESTABLISHED as S&F 1987	TERM 5 years
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TYPE OF SERVICE PROVIDED:

Purpose NIGL is a stable and radiogenic isotope laboratory facility focusing on Environmental Change, Chronology, and Science-based Archaeology, in a collaborative research environment, including a strong focus on PhD student training. The science addressed is interdisciplinary, aligned with NERC priorities, and involves problems where isotope analysis is pivotal. NIGL serves many RAE grade 4 and 5 academic departments in the UK, and several NERC institutes, including the British Antarctic and Geological Surveys. NIGL was reviewed by SRG in January 2008 with a score of 4.75/5.0 and was renewed for 5 years until 2014. This has been extended by a further year to allow management changes to bed in between BGS and NERC for the S&F Earth Science Facilities.

The Facility and its equipment and expertise NIGL comprises two nodes of analytical facilities complemented by a skilled scientific and technical staff:

- Stable Isotope Facility: isotope analysis of waters, carbonates, biogenic silica, phosphates, biomass in both organic and inorganic materials for the isotopes of H, C, N, O, S, and Si by gas-source stable isotope mass spectrometry.
- Radiogenic Isotope Facility: high precision U-Th-Pb dating using ID-TIMS, and *in situ* dating using laser-ablation and plasma ionisation mass spectrometry (PIMS); U-Series dating; high precision isotope (U, Pb, Hf, Nd, Sr) analysis of solids and solutions using both solution and laser-ablation PIMS, and TIMS.

Leading capabilities in the UK comprise: U-Th-Pb high precision (isotope dilution) and *in situ* (laser ablation) chronology; environmental change research using C, H, O, and Si isotopes in waters, carbonates, organic materials and biogenic silica especially in the terrestrial environment; N isotopes in gases, soils, plants, waters and ice; high precision measurement of isotopes of U in environmental materials; Hf, Sr, Nd and Pb isotopes using laser microsampling in geological and environmental materials; very high precision Hf-Sr-Nd-Pb isotopes in geological materials using either TIMS or PIMS, U-series dating for carbonate materials <450,000y, and U-Pb dating on carbonate materials of Pliocene-Quaternary age. NIGL has world-leading capabilities in several of these protocols (especially U-Th-Pb chronology applied to a broad range of geoscience topics, biogenic silica oxygen and silicon isotope analysis in palaeoclimate research, and high precision water analysis for marine waters tracing), and students receiving training are exposed to the best approaches and methods available. Analytical innovation and efficiency are ongoing goals of our development work in support of the programme, and also the concept that complex problem-solving requires multiple isotopic methods. It is the integrated laboratory philosophy that remains a very strong and unique aspect of NIGL. The NIGL operates a total of 16 mass spectrometers in addition to chemical and sample preparation laboratories.

ANNUAL TARGETS AND PROGRESS TOWARDS THEM

The approved programme is comparable in resource terms to the financial allocation, demonstrating strong demand for the facility. NIGL continues to win grants and commissions that assist with co-funding of staff and equipment. All instrumentation has performed well this year partly in renovated laboratories. NIGL has continued to refine procedures for U-Pb and U-series and geochronology, with continued leadership in the EARTHTIME Initiative, and continues to work on analysis of 5-10 microgram sized (individual microfossils etc) carbonates. Publication output has continued to be strong, with 57 papers published during the calendar year of 2014, 24 published or in press by April 2015, 40 published abstracts, and 11 PhD theses completed. In total 50 PhD students (35 University-funded, 1 University CASE, 5 NERC CASE, 9 BGS-NEC BUFI), 1 BSc Students, 7 MSc Students, 1 MPhil Student, 7 University-funded Post Docs and 2 NERC Fellows received training.

SCORES AT LAST REVIEW (each out of 5)			Date of Last Review: 2008			
Need 5.0	Uniqueness 4.5	Quality of Service 4.5	Quality of Science & Training 5.0	Average 4.75		
CAPACITY of HOST ENTITY FUNDED by S&F	Staff & Status 17 NERC BGS Staff supported c.15-80% with S&F funds Administration-management provided by BGS BGS and commissions support PDRAs and remainder of staff		Next Review (March) not known	Contract Ends (31 March) 2015		
FINANCIAL DETAILS: CURRENT FY						
Total Resource Allocation £k 1320	Unit Cost £k			Capital Expend £k 13	Income £k 355	Full Cash Cost £k 1,566.17
	Unit 1 576	Unit 2 N/A	Unit 3 N/A			
FINANCIAL COMMITMENT (by year until end of current agreement) £k						
2014-2015	1320	2015-2016 1309	2016-2017 NERC to confirm	2017-2018 NERC to confirm	2018-2019 NERC to confirm	

STEERING COMMITTEE	Independent Members	Meetings per annum	Other S&F Overseen
NIGFSC	10	2	AIF, ICSF

APPLICATIONS: DISTRIBUTION OF GRADES (current FY — 2014/15)

	10	9	8	7	6	5	4	3	2	1	0	R*	Pilot	Ungraded
NERC Grant projects*	0	1	2	3	0	0	1	0	0	0	0	3	2	0
Other academic	1	0	2	4	0	2	2	5	3	0	0	5	3	3
Students	0	0	3	6	6	0	5	1	1	1	0	10	6	0
TOTAL	1	1	7	13	6	2	8	6	4	1	0	18	11	3

APPLICATIONS: DISTRIBUTION OF GRADES (per annum average previous 3 financial years —2011/2012, 2012/2013 & 2013/2014)

	10	9	8	7	6	5	4	3	2	1	0	R*	Pilot	Ungraded
NERC Grant projects*	3	4	6	5	1	0	0	0	0	1	1	7	2	0
Other academic	2	7	2	9	1	3	2	1	1	2	10	9	8	0
Students	3	5	7	14	12	3	3	2	2	4	5	4	11	0
TOTAL	8	16	15	28	14	6	5	3	3	7	16	20	21	0

PROJECTS COMPLETED (current FY – 2014/15)

	10 (α5)	9	8 (α4)	7	6 (α3)	5 (α2)	4	3 (α1)	2	1 (β)	0 (Reject)	Pilot
NERC Grant projects*	1		14	2								
Other Academic	2		4	6								2
Students			5	6	7							6

Project Funding Type (current FY – 2014/15) (select one category for each project)

Grand Total	Infrastructure						PAYG				
	Supplement to NERC Grant *		PhD Students		NERC Centre	Other	NERC Grant*	PhD Students		NERC Centre	Other
	NERC	Other	NERC	Other			NERC	Other			
125.00	20		22	44	4	35	0	0	0	0	0

Project Funding Type (per annum average previous 3 financial years - 2011/2012, 2012/2013 & 2013/2014)

Grand Total	Infrastructure						PAYG				
	Supplement to NERC Grant *		PhD Students		NERC Centre	Other	NERC Grant*	PhD Student		NERC Centre	Other
	NERC	Other	NERC	Other			NERC	Other			
106.67	12.00		30.67	34.67	4.00	25.33	0	0	0	0	0

User type (current FY – 2014/15) (include each person named on application form)

Academic	NERC Centre	NERC Fellows	PhD Students	Commercial
50	4	5	66	32

User type (per annum average previous 3 financial years - 2011/2012, 2012/2013 & 2013/2014)

Academic	NERC Centre	NERC Fellows	PhD Students	Commercial
28.33	4.00	9.00	65.33	32.00

OUTPUT & PERFORMANCE MEASURES (current year)
Publications (by science area & type) (calendar year 2014)

SBA	ES	MS	AS	TFS	EO	Polar	Grand Total	Refereed	Non-Ref/ Conf Proc	PhD Theses
9	77	5	0	15	0	2	108	57	40	11

Distribution of Projects (by science areas) (FY 2014/15)

Grand Total	SBA	ES	MS	AS	TFS	EO	Polar
125	17.10	56.50	11.20	8.10	17.80	2.90	11.40

OUTPUT & PERFORMANCE MEASURES (per annum average previous 3 years)
Publications (by science area & type) (Calendar years 2011, 2012 & 2013)

SBA	ES	MS	AS	TFS	EO	Polar	Grand Total	Refereed	Non-Ref/ Conf Proc	PhD Theses
12	55	8	0	25	0	3	103	74	20	9

Distribution of Projects (by science areas) (FY 2011/2012, 2012/2013 & 2013/2014)

Grand Total	SBA	ES	MS	AS	TFS	EO	Polar
106.67	13.32	55.10	8.67	4.37	14.85	3.10	7.27

Distribution of Projects by NERC strategic priority (current FY 2014/15)

Grand Total	Climate System	Biodiversity	Earth System Science	Sustainable Use of Natural Resources	Natural Hazards	Environment, Pollution & Human Health	Technologies
125	28.75	3.20	70.60	6.85	1.85	9.35	4.40

OVERVIEW & ACTIVITIES IN FINANCIAL YEAR (2014/15):

The NERC Isotope Geosciences Facilities Steering Committee (NIGFSC) approved 28 new projects with a mean grade of 7, together with eleven pilot projects. During the last financial year 125 projects were worked on, most of a multi-year nature, and more than 68 PhD students, post-doctoral researchers and NERC Fellows received training. U-series and U-Pb carbonate Quaternary dating capability (by LA-ICP-MS and/or ID-TIMS/PIMMS, respectively) together represent important growth areas for NIGL, while U-Pb on silicates and phosphates remains a flagship activity with international leadership. Speleothems and methane derived authigenic carbonate (MDAC) studies are the backbone of the current program, the MDAC work is currently industry supported however it is an area of interest to NERC and actively developing collaborations (UK and international) and track record. Development of LA-MC-ICP-MS analysis of U-Th in carbonates was undertaken in late 2014/early 2015 and shows promise, we are currently undertaking experiments to quantify the limits of precision for given sample size/concentration, characterisation of reference materials etc. U-Pb geochronology by ID-TIMS has focussed this year on completion of projects due to a significant approval level in the preceding years with success however capacity for this laboratory has been hampered by infrastructure failings leading to an increased requirement for repeat analyses. NIGL has continued to lead the EARTHTIME effort of improving the U-daughter chronometer, and developed a series of high purity Pb isotope solutions for the new EARLYTIME geochronology initiative in aid of the early solar system research community. These materials were supplied to a select group of labs and the first results of lab intercalibration were presented at the LPI meeting in Houston March 2015. The preparation and calibration of NERC grant-funded synthetic U-series "age" solutions were largely completed are ready for distribution to the global U series community, and a number of papers documenting this work are in progress (from in-prep to published). Development of traditional and non-traditional isotope tracers continues in response to NERC user community need (including BGS), including U and Sr isotopes as tracers of fluid-rock interaction.

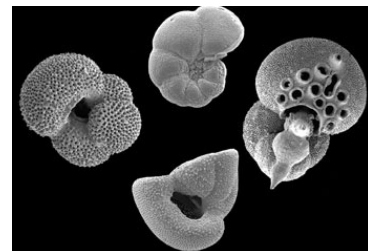
Environmental change research continues to develop analytical protocols for the measurement of the major element stable isotopes in particular Si, O and N. In biogeochemical cycling these area definite growth areas. Professor Leng is now central to both the UK-ICDP membership, as well as being on the International ICDP Executive Board, and represents ICDP on the ICDP-IODP outreach initiatives. The UK involvement in ICDP projects is increasing with several workshops funded and major drilling proposals with UK (as well as NIGL/BGS) partners. Strategic applications in stable isotopes are beginning to be developed and include: research into the use of isotopes in understanding the interaction between groundwater, CO₂ and methane in potential CCS/fracking lithologies; nutrient and pollution cycling using non-traditional stable isotopes; and understanding the effect of increasing atmospheric CO₂ on carbon cycling in soils/lakes/oceans.

Training continues to be a priority. In addition to the hands on training for researchers involved with projects, NIGL has focussed on delivering training to a wider audience via short courses (e.g., Geochronology Short Course, January 2015) and an effort to develop online training materials, and delivers advanced training in isotope geochemistry and mass spectrometry through the Isotope Apprentice scheme (see Appendix 14).

SCIENCE HIGHLIGHTS.

The Paleocene–Eocene Thermal Maximum reached 40°C at the tropics? The Paleocene–Eocene Thermal Maximum (PETM), ca. 56 Ma, was a major global environmental perturbation attributed to a rapid rise in the concentration of greenhouse gases in the atmosphere.

Geochemical records of tropical sea-surface temperatures from the PETM are rare and are typically affected by post-depositional diagenesis. To circumvent this issue, we have analyzed oxygen isotope ratios ($\delta^{18}\text{O}$) of single specimens of exceptionally well-preserved planktonic foraminifera from the PETM in Tanzania ($\delta 19^\circ\text{S}$ paleolatitude), which yield extremely low $\delta^{18}\text{O}$, down to $<-5\text{‰}$. After accounting for changes in seawater chemistry and pH, we estimate from the foraminifer $\delta^{18}\text{O}$ that tropical SSTs rose by $>3^\circ\text{C}$ during the PETM and may have exceeded 40°C . Calcareous plankton are absent from a large part of the Tanzania PETM record; extreme environmental change may have temporarily caused foraminiferal exclusion. Aze, T., Pearson, P.N., Dickson, A.J., Badger, M.P.S., Bown, P.R., Pancost, R.D., Gibbs, S.J., Huber, B.T., Leng, M.J., Coe, A.L., Cohen, A.S., and Foster, G.L. 2014. Extreme warming of tropical waters during the Paleocene–Eocene Thermal Maximum. *Geology*, 42.



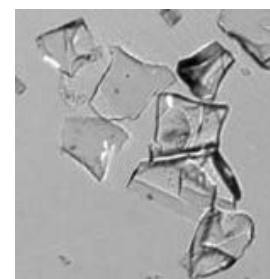
Nitrogen sources, transport and processing in urban floodplains. Urban floodplains are an important interface between developed land and the aquatic environment and may act as a source or sink for contaminants moving from urban areas towards surface water courses. With increasing pressure from urban development the functioning of floodplains is coming under greater scrutiny. A number of peri-urban sites have been found to be populated with legacy landfills which could potentially cause pollution of adjacent river bodies. Here, a peri-urban floodplain adjoining the city of Oxford, UK, with the River Thames has been investigated and repeatedly sampled. A nearby landfill has been found to be the source of particularly high concentrations of ammonium and generally low concentrations of nitrate and dissolved oxygen. This study of nitrogen dynamics through the use of N-species chemistry, nitrogen isotopes and dissolved nitrous oxide shows little or no denitrification in the landfill plume, and neither is the ammonium significantly retarded by sorption to the aquifer sediments. A simple model reveals that up to 15% of the ammonium loading at the study site and over the length of the reach could increase in-stream concentrations by nearly 40%. Catchment management plans that encompass floodplains in the peri-urban environment need to take into account the likely risk to groundwater and surface water quality that these environments pose. Goody, D.C., Macdonald, D.M.J., Lapworth, D.J., Bennett, S.A., Griffiths, K.J. 2014. Nitrogen sources, transport and processing in peri-urban floodplains, *Science of the Total Environment* 494-495, 28-38.



Millennial-scale climate variability in East Africa. Late Cenozoic climate history in Africa was punctuated by episodes of variability, characterized by the appearance and disappearance of large freshwater lakes within the East African Rift Valley. In the Baringo-Bogoria basin, a well-dated sequence of diatomites and fluviolacustrine sediments documents the precessionally forced cycling of an extensive lake system between 2.70 Ma and 2.55 Ma. One diatomite unit was studied, using the oxygen isotope composition of diatom silica combined with X-ray fluorescence spectrometry and taxonomic assemblage changes, to explore the nature of climate variability during this interval. Data reveal a rapid onset and gradual decline of deepwater lake conditions, which exhibit millennial-scale cyclicity of 1400–1700 yr, similar to late Quaternary Dansgaard-Oeschger events. These cycles are thought to reflect enhanced precipitation coincident with increased monsoonal strength, suggesting the existence of a teleconnection between the high latitudes and East Africa during this period. Such climatic variability could have affected faunal and floral evolution at the time. Wilson, K.E., Maslin, M.A., Leng, M.J., Kingston, J.D., Deino, A.L., Edgar, R.K., Mackay, A.W. 2014. East African lake evidence for Pliocene millennial-scale climate variability. *Geology*.



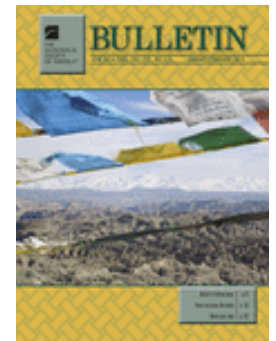
Toba-eruption drives environmental change in the Balkans. The 74 (75) ka Toba eruption in Sumatra, Indonesia, is considered to be one of the largest volcanic events during the Quaternary. Tephra from the Toba eruption has been found in many terrestrial and marine sedimentary deposits, and acidity peaks related to the eruption have been used to synchronize ice core records from Greenland and Antarctica. Seismic profiles and sedimentological data from Lake Prespa on the Balkan Peninsula, SE Europe, indicate a lake level lowstand at 73.6 ± 7.7 ka. Tephrostratigraphy, radiocarbon dating and tuning of the total organic carbon content with the NGRIP isotope record, corroborate that the lake level lowstand was a short-term event superimposed on the general cooling trend at the end of MIS 5, most likely at the onset of the Greenland Stadial GS-20. Acknowledging that tectonic events or karst processes could have triggered this lake level lowstand, the chronological correspondence between the lowstand and the Toba eruption is intriguing. Therefore a Toba-driven short-term shift to aridity in the Balkan region, leading to lake level changes and triggering spatial expansion events in one of the lake's most abundant benthic species, the carino mussel *Dreissena presbensis*, cannot be excluded. Wagner, B., Leng, M. J., Wilke, T., Böhm, A., Panagiotopoulos, K., Vogel, H., Lacey, J. H., Zanchetta, G., and Sulpizio, R. 2014. Distinct lake level lowstand in Lake Prespa (SE Europe) at the time of the 74 (75) ka Toba eruption, *Clim. Past*, 10, 261-267.



Dispersal of humans out of Africa linked to climate change. The dispersal of human populations out of Africa into Arabia was most likely linked to episodes of climatic amelioration, when increased monsoon rainfall led to the activation of drainage systems, improved freshwater availability, and the development of regional vegetation. This paper presents the first dated terrestrial record from southeast Arabia that provides evidence (including stable isotopes) for increased rainfall and the expansion of vegetation during both glacial and interglacial periods. Findings from extensive alluvial fan deposits indicate that drainage system activation occurred during Marine Isotope Stage (MIS) 6 (ca. 160–150 ka), MIS 5 (ca. 130–75 ka), and during early MIS 3 (ca. 55 ka). The development of active freshwater systems during these periods corresponds with monsoon intensity increases during insolation maxima, suggesting that humid periods in Arabia were not confined to eccentricity-paced deglaciations, and providing paleoenvironmental support for multiple windows of opportunity for dispersal out of Africa during the late Pleistocene. *Parton, A., Farrant, A.R., Leng, M.J., Telfer, M., Groucutt, H., Petraglia, M.D., Parker, A.G. 2015. Alluvial fan records from southeast Arabia reveal multiple windows for human dispersal. Geology doi:10.1130/G36401.1.*



U-Pb geochronology of globally significant Ediacaran deep-water fossil assemblages. This work is the culmination of two NIGFC projects. The study contributes new geochronology constraints on a globally significant Ediacaran macrobiota. High-precision ages show that the relatively high-diversity biotas in the upper parts of the deep water settings exposed in Charnwood, one of only two such settings worldwide that preserve a deep ocean record of early macroscopic multicellular life on Earth, date from between 569.1 ± 0.9 Ma to 561.85 ± 0.34 Ma. Together these new data permit comparison of Charnwood with the other key Ediacaran macrofossil sites in Canada and Russia and allowed us to conclude a primary role for ecological sensitivity in determining the composition of these critical, late Neoproterozoic communities. *Noble, S.R., Condon, D.J., Carney, J.N., Wilby, P.R., Pharaoh, T.C., and Ford, T.D., 2015. U-Pb geochronology and global context of the Charnian Supergroup, UK: Constraints on the age of key Ediacaran fossil assemblages. GSA Bulletin 127, 250-265, doi: 10.1130/B3103.1*



Dating global C-cycle perturbations prior to Snowball Earth. This NIGFSC and US NSF funded work develops new physical stratigraphic data and high-precision U-Pb dates from intercalated tuffs lead to a new stratigraphic framework for the Tambien Group that confirms identification of negative $\delta^{13}C$ values from Assem Formation limestones with the ca. 800 Ma Bitter Springs carbon isotope stage. Integration with data from the Fifteenmile Group of northwestern Canada constitutes a positive test for the global synchronicity of the Bitter Spring Stage and constrains the stage to have started after 811.51 ± 0.25 Ma and to have ended before 788.72 ± 0.24 Ma. These new temporal constraints strengthen the case for interpreting Neoproterozoic carbon isotope variation as a record of large-scale changes to the carbon cycle and provide a framework for age models of paleogeographic change, geochemical cycling, and environmental evolution during the radiation of early eukaryotes. *Swanson-Hysell, N., Maloof, A., Condon, D.J., Jenkin, G.R.T., Alene, M., Tremblay, M.M., Tesema, T., Rooney, A.D., Haileab, B. (2015) Stratigraphy and geochronology of the Tambien Group, Ethiopia: Evidence for globally synchronous carbon isotope change in the Neoproterozoic. Geology, DOI:10.1130/G36347.1*



From continent to intra-oceanic arc: the crustal evolution of the Solomon island arc from xenocrystic zircon. The first U-Pb ages from a ca. 26-24 Ma pluton on Guadalcanal, in the intra-oceanic Solomon island arc (southwest Pacific Ocean), reveal Eocene- to Archean-aged zircon xenocrysts. The data demonstrate that continentally derived zircons may be transported thousands of kilometers from their source and added to intra-oceanic arc magmas, a process likely facilitated by cyclical subduction zone advance and retreat. The findings highlight the continuum of arcs that occurs between continental and oceanic end members, and the caution with which zircons should be used to determine the provenance and setting of ancient arc terranes accreted to the continental crust. *Tapster, S., Roberts, N.M.W., Petterson, M.G., and J. Naden, J. (2015), From continent to intra-oceanic arc: Zircon xenocrysts record the crustal evolution of the Solomon island arc, Geology, DOI:10.1130/G36033.1*

Petrochronology used to deconvolve Himalayan evolution

Two papers have been published as a result of a NIGFSC supported PhD research by Catherine Mottram (Open University) which use a combination of U-Th-Pb geochronology combined with isotope and elemental data to constrain the structural and thermal evolution of key structures within the Himalayan orogen. In-situ LA-ICP-MS U-Th-Pb monazite ages, linked to pressure-temperature conditions via trace-element reaction fingerprints, allow key aspects of the evolution of the thrust zone to be understood for the first time. The ages show that peak metamorphic conditions were reached earliest in the structurally highest part of the inverted metamorphic sequence, in the Greater Himalayan Sequence in the hanging wall of the Main Central Thrust. *Mottram, C. M., C. J. Warren, D. Regis, N. M. W. Roberts, N. B. W. Harris, T. W. Argles, and R. R. Parrish (2014), Developing an inverted Barrovian sequence; insights from monazite petrochronology, Earth and Planetary Science Letters, 403, 418-431. Mottram, C. M., T. W. Argles, N. B. W. Harris, R. R. Parrish, M. S. A. Horstwood, C. J. Warren, and S. Gupta (2014), Tectonic interleaving along the Main Central Thrust, Sikkim Himalaya, Journal of the Geological Society, 171(2), 255-268.*



FUTURE DEVELOPMENTS/STRATEGIC FORWARD LOOK

The stable isotope programme continues to focus on the environment, in particular climate change with increasing importance on the anthropocene and the modern calibration period. Using stable isotopes as tracers in modern pollution studies and the hydrological cycle is becoming a more critical issue with enhanced emphasis on mans' impact on the environment, resource security and environment and health. Strategic applications in stable isotopes will be/are being developed and include: research into the use of stable isotopes in understanding the interaction between groundwater, CO₂ and methane in potential CCS/fracking lithologies; nutrient and pollution cycling using non-traditional stable isotopes; and understanding the effect of increasing atmospheric CO₂ on carbon cycling in soils/lakes/oceans. Developing methodologies around the use of biogenic silica in environmental change and biogeochemical cycling is still a priority given the International leadership NIGL has in this area.

The Geochronology and isotope Tracers programme will continue to have a breadth of geoscience and environmental applications, ranging from the chronology of planet formation to using isotope tracer and chronology to inform CCS and other fluid-rock interaction topics (radio-active waste, unconventional hydrocarbons). Both high-precision/accuracy ID-TIMS and high-spatial resolution LA-ICP-MS U-Pb geochronology demand is continuing in a wide variety of fields, from planetary evolution to fluid-rock interaction and recent environmental change. Conventional applications still represent a major demand, especially where early stage researcher training is included. Recent efforts have seen an increase in demand in the following areas: mineralisation, with a number of projects related to Cu porphyry systems underway and industry commission research in the pipeline; detrital minerals as tracers of landscape evolution; and using geochronology to constrain records of 'Earth System' evolution. The latter is the focus of a major international initiative (with interest from NASA, US and Chinese NSFs) and NIGL currently play a lead role supporting the interests of the strong UK based Precambrian research community. Evolving demands in geo- and environmental sciences for chronology and isotope tracers for a number of non-traditional applications will see efforts focussed towards a number of these topics, particularly CCS, unconventional hydrocarbon plays (hydrates, shale gas) with a focus on the combined use of chronology (U-Th and U-Pb carbonate dating) and isotope tracers (stable U, Sr, Mg, Si) is being applied to a number of pilot studies. This currently supported by some industry commission research in collaboration with NGU, and the USGS. Another major foci of technique development and application is in the field of environmental radioactivity. Recent collaboration with Loughborough will continue to develop and apply LA-ICP-MS methods to produce isotope analysis, including the minor isotopes ²³⁴U and ²³⁶U, on ~1µm UO_x particles, highly relevant to the nuclear forensics international community.

Training will continue to be a top priority (see Appendix 14). The established programme of isotope apprenticeships will continue to provide hands on training for appropriately motivated candidates wishing to pursue a career in some aspect of mass spectrometry, and we anticipate that effort to be oversubscribed. During 2015 NIGL will contribute to a NIGF training strategy document, contribute to planned short courses (e.g., nuts and bolts of mass spectrometry, GW4+ DTP, May 2015) and develop online training materials. NIGL staff continue to play a lead role in international workshops (2x workshops at Goldschmidt 2015 with NIGL staff co-convening) and invited speakers (e.g., Goldschmidt 2015), and a continued contribution to peer-reviewed journal articles is expected to continue

Non-Mandatory Facility-specific OPMs: utilisation, allocation of capacity etc

See Attached Annexes.