SERVICES & FACILITIES ANNUAL REPORT - FY April 2016 to March 2017

SERVICE	FUNDING	AGREEMENT	ESTABLISHED as S&F	TERM
NERC Radiocarbon Facility (NRCF)	**Block**	**EK: PR130030** **Ox:**	**EK: 1975 Ox: 1991** **Joint NRCF nodes: 2007**	**5 years**

TYPE OF SERVICE PROVIDED:

Radiocarbon dating has revolutionized the fields of Environmental Science, Archaeology, and Palaeoenvironmental Change since its inception. This has been achieved by providing a unique way of pinpointing the timing of events and rates of processes over the past 50,000 years, and the means to track the pathway of carbon through biogeochemical cycles. It is therefore difficult to overstate the importance of radiocarbon in answering some of the most pressing questions regarding our climate, global environment, and human history. The UK is at the forefront of this research through the activities of the NERC Radiocarbon Facility (NRCF http://www.c14.org.uk/), which both supports and initiates globally competitive science at its two nodes **NRCF-East Kilbride (NRCF-E)**, hosted by the Scottish Universities Environmental Research Centre (SUERC), East Kilbride, and **NRCF-Oxford (NRCF-O)**, within the Oxford Radiocarbon Accelerator Unit (ORAU), University of Oxford. The joint facility increases flexibility in operation, as the two nodes have complementary expertise, working closely together to enhance collaborative opportunities between NRCF and the user community, to the benefit of all.

The two nodes enable a truly comprehensive service for the NERC research community, including Universities and NERC Centres BGS, CEH, BAS, NOC. This service covers all facets of radiocarbon-based science, and provides:

- Advice and essential support to users at all project stages, including initial design and preparation of grant proposals, equipment and personnel for field sampling, storage and preparation to optimise results, and assisting data interpretation enabling reporting and publication
- Access to scientists and technical support at the forefront of application and development of radiocarbon techniques
- Training and practical assistance in the application of novel and cutting edge equipment for sampling and measurement, leading to unique research opportunities
- Training of students and visiting researchers, including project-customised practical laboratory experience, residential radiocarbon courses, and access to state-of-the art equipment, including three accelerator mass spectrometers (AMS)

The remits of the nodes are determined by science area and technique, project requirements and capacity. NRCF-O largely supports Archaeological Science applications, with additional expertise in the calibration and statistical modelling of radiocarbon data. NRCF-E supports Earth and Environmental Science applications, but projects using the expertise of both nodes are encouraged. NRCF supported science therefore covers the entire biosphere, hydrosphere, cryosphere, and atmosphere, including human evolution, cultural development, and interactions with the environment.

ANNUAL TARGETS AND PROGRESS TOWARDS THEM

Approved projects are allocated analyses on a per sample basis, but capacity is calculated as analytical units, taking into account resources required to process samples and standards and project-related development. Facility management and administration (including steering committee related) and science contribution to publications, grants etc. is not separately accounted so is included in the overall unit cost.

NRCF-E: 1619 units were processed in 2016-17, c.25% above the funded capacity of 1300 units. Average turnaround time dropped to 3.4 months (compared to 5.6 months in previous FY), samples requiring greater turnaround times generally required specialised project-specific development work, or repeated measurements.

NRCF-O: Funded capacity for NRCF-SC approved work is 500 AMS analytical units. In 2016-17 616.5 units were processed which 23% above capacity, despite a drop in funding. Notwithstanding this the average turnaround time dropped to 3.1 months, which is the shortest it has been.

SCORES AT LAST REVIEW (each out of 5)			Date of Last Review:	March 2012
Need 5.0	**Uniqueness** 4.5	**Quality of Service** 5.0	**Quality of Science & Training** 5.0	**Average** 4.9

CAPACITY of HOST ENTITY FUNDED by S&F	Staff & Status	Next Review (March)	Contract Ends (31 March)
NRCF-E: 100% **NRCF-O: ~30%**	**NRCF-E Scientific:** Glasgow University- Head Grade 8 (1 FTE); Deputy Head Grade 8 (1 FTE), Grade 7 (2.5 FTE); Technical: Grade 6 (4FTE) **NRCF-O:** Head Grade 10 (0.4FTE); Deputy Head Grade 10 (0.6); 2 PDRAs Grade 7 and 8 (0.4,0.4); Technical Grades 4 and 5 (5 x 0.3). Administrative: Grades 6-8 (0.4, 0.3, 0.1, 0.05)	**TBC**	**2018**

FINANCIAL DETAILS: CURRENT FY						
Total Resource Allocation £k	**Unit Cost £k**			**Capital Expend £k**	**Income £k**	**Full Cash Cost £k**
	Unit 1 Total Res Alloc/Units provided	**Unit 2 FCC/Units provided**	**Unit 3**			
NRCF-E: 805.15	0.50	0.60		-	77.63	925.05
NRCF-O: 311.00	0.50	1.00		-	-	612.81
2016-17 £k	NRCF-E: 805.15	NRCF-O: 311.00				

STEERING COMMITTEE	Independent Members	Meetings per annum	Other S&F Overseen
	Joint Chair + O:6 E:9	2	

APPLICATIONS: DISTRIBUTION OF GRADES (current FY — 2016/17)

	10	9	8	7	6	5	4	3	2	1	0	R*	Pilot
NERC Grant projects*	0	4	5	0	0	0	0	0	0	0	0	0	0
Other academic	0	7	8	12	1	2	1	1	3	0	2	3	0
Students	0	0	4	3	4	0	3	3	2	0	1	3	0
TOTAL	0	11	17	15	5	2	4	4	5	0	3	6	0

APPLICATIONS: DISTRIBUTION OF GRADES (per annum average previous 3 financial years —2013/2014, 2014/2015 & 2015/2016)

	10	9	8	7	6	5	4	3	2	1	0	R*	Pilot
NERC Grant projects*	1.33	3.67	7.33	7.00	0.67	1.00	0.50	0.50	0.50	0.00	0.50	2.33	0.50
Other academic	0.00	2.00	6.33	9.00	2.67	2.33	1.67	1.00	0.67	0.00	1.50	6.00	0.33
Students	0.50	2.33	7.67	10.33	12.33	0.33	1.00	1.67	1.00	0.67	0.00	6.00	0.00
TOTAL	1.67	8.00	21.33	26.33	15.67	3.33	2.67	2.67	2.00	0.67	2.00	14.33	0.50

PROJECTS COMPLETED (current FY 2016/17)

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

Project Funding Type (current FY – 2016/17) (select one category for each project)

Grand Total	Infrastructure					PAYG				
	Supplement to NERC Grant *	PhD Students NERC	PhD Students Other	NERC Centre	Other	NERC Grant*	PhD Students NERC	PhD Students Other	NERC Centre	Other
94	NERC 24 AHRC 5 TOT 29	13	17	0	35	0	0	0	0	0

Project Funding Type (per annum average previous 3 financial years - 2013/2014, 2014/2015 & 2015/2016)

Grand Total	Infrastructure					PAYG				
	Supplement to NERC Grant *	PhD Students NERC	PhD Students Other	NERC Centre	Other	NERC Grant*	PhD Student NERC	PhD Student Other	NERC Centre	Other
96	28	13	25	1	23	0	1	0	1	2

User type (current FY – 2016/17) (include each person named on application form)

Academic	NERC Centre	NERC Fellows	PhD Students	Commercial
190	**19**	**4**	**42**	**1**

User type (per annum average previous 3 financial years - 2013/2014, 2014/2015 & 2015/2016)

Academic	NERC Centre	NERC Fellows	PhD Students	Commercial
181.75	**13.5**	**2.5**	**33.5**	**1.5**

OUTPUT & PERFORMANCE MEASURES (current year)

Publications (by science area & type) (calendar year 2016)										
SBA	**ES**	**MS**	**AS**	**TFS**	**EO**	**Polar**	**Grand Total**	**Refereed**	**Non-Ref/ Conf Proc**	**PhD Theses**
46.1	13.7	11.0	2.7	22.5	0.0	5.0	101.0	86.0	9.0	6.0

Distribution of Projects (by science areas) (FY 2016/17)							
Grand Total	**SBA**	**ES**	**MS**	**AS**	**TFS**	**EO**	**Polar**
94	**24.7**	**24.25**	**15.75**	**1.45**	**23.35**	**0**	**4.5**

OUTPUT & PERFORMANCE MEASURES (per annum average previous 3 years)

Publications (by science area & type) (Calendar years 2013, 2014 & 2015)										
SBA	**ES**	**MS**	**AS**	**TFS**	**EO**	**Polar**	**Grand Total**	**Refereed**	**Non-Ref/ Conf Proc**	**PhD Theses**
30.33	10.37	11.83	1.37	21.57	2.25	4.17	**79.67**	60.67	8.67	10.33

Distribution of Projects (by science areas) (FY 20123/2014, 2014/2015 & 2015/2016)							
Grand Total	**SBA**	**ES**	**MS**	**AS**	**TFS**	**EO**	**Polar**
96.00	22.17	32.37	9.33	1.39	26.07	0.67	4.00

Distribution of Projects by NERC strategic priority (current FY 2016/17)							
Grand Total	**Climate System**	**Biodiversity**	**Earth System Science**	**Sustainable Use of Natural Resources**	**Natural Hazards**	**Environment, Pollution & Human Health**	**Technologies**
94	22.9	21.82	23.99	8.65	4.35	11.04	1.25

Either Discovery Science (Responsive Mode) or Strategic Science (Directed Programme) grants

NOTE: All metrics should be presented as whole or part of whole number NOT as a %

OVERVIEW & ACTIVITIES IN FINANCIAL YEAR (2016/17):

NRCF-E

The majority of activities in the NERC-E are highly specialised and the facility has continued to work closely with the user community to develop novel sampling and measurement techniques, making much of the work globally unique. This has covered not only measurement for sample dating, but also interrogating the global carbon cycle over short and long timescales.

For the May and November 2016 NERC-SC meetings there were 45 applications to the NRCF-E for a total of 2532 sample measurements. Of these, 686 samples were funded in the first instance and applications for 980 samples were invited to provide more information before funding could be awarded (total 1666 samples).

NERC grant projects

22 applications to the NRCF-E were in support of NERC grants. Of these 15 were approved, and 6 were graded R* (more information required before funding could be approved). Of applications approved and graded R* in support of (already awarded) NERC grants, the largest numbers of samples were for the following:

- Will more productive Arctic ecosystems sequester less soil carbon? A key role for priming in the rhizosphere ('PRIMETIME'). PI P Wookey, Heriot-Watt Univ; **362 samples**
- NEGIS 1000: Exploring controls on ice stream and ice shelf dynamics in a warmer world. PI D Roberts, Durham University; **140 samples**
- Addressing a significant knowledge gap in fluvial system atmospheric CO2 efflux: the contribution from karst landscapes. PI S Waldron, Glasgow University. **138 samples**
- Do past fires explain current carbon dynamics of Amazonian forests? PI T Feldpausch, Exeter University. **400 samples**
- Plant nutrition as an Earth Science: understanding the links between plant nutrient gain and soil organic matter turnover. PI L Street, Edinburgh University. **363 samples**

Staff involvement in NERC projects

Along with supporting applications, managing awarded projects, and undertaking project-specific development work, NRCF-E staff are regularly named as project partners and co-Is on NERC grants. An example of this involvement is in NERC-funded BRITICE CHRONO (**587 samples awarded; 647 analytical units**), with S. Moreton as co-I coordinating the radiocarbon component, co-writing applications, presenting data at meetings, and formulating project-specific background corrections.

NRCF-O

NRCF-O has been involved in radiocarbon dating samples for NERC and AHRC funded projects. This includes NE/K005243/1, Deciphering dog domestication through a combined ancient DNA and geometric morphometric approach. AHRC supported grants include: AH/K0060291/1 (Understanding Cultural Resilience and Climate Change on the Bering Sea through Yup'ik Ecological Knowledge, Lifeways, Learning and Archaeology (ELLA)), which focuses on cultural resilience and climate change in the recent Alaskan prehistoric period, AH/J006068/1, dating the Anglo-Saxon royal centre at Lyminge, Kent, and AH/M005259/1; Celtic Connections and Crannogs: A New Study Across the Irish Sea, exploring the archaeology of artificial islands constructed from the Iron Age to Medieval period in Scotland and Ireland.

Training: The annual NRCF joint training course on radiocarbon dating and Bayesian analysis was hosted at Oxford. There were 31 participants ranging from doctoral students to experienced academics (the largest roll we have had on the course so far). Participants came from UK & European Universities, commercial archaeological units, Historic England, and one from Namibia. The course included background on radiocarbon dating with a visit to NRCF-O and instruction on Bayesian analysis for dating techniques. NRCF-O has undertaken in-lab training and teaching for several students linked with NRCF projects as well as the Short Course in Radiocarbon Dating and Bayesian Modeling which was attended by 10 students. At NRCF-E eleven PhD students had training visits of 1-3 days, to discuss projects and samples and receive project-specific hands-on laboratory training. Positive responses to these visits were received directly and in the annual user survey.

Technique Development and Capital Funding:

NRCF-E development 2016-2017

1. Field collection methods for 14C in dissolved methane- NRCF-E is one of few labs worldwide that can perform radiocarbon analysis of methane. Responding to user community need, the lab continues to develop these techniques. SUERC has funded a PDRA (Dr Josh Dean, currently of Vrije Universiteit Amsterdam) to work with Dr. Mark Garnett on a new method for field collection of aquatic methane. This was very successful, allowing sample collection from previously impossible locations. The technique has since been used to collect some of the first radiocarbon methane samples from the Siberian tundra, and a paper is recently published (Dean JF, Billett, MF, Murray, C, Garnett, MH. 2017. Ancient dissolved methane in inland waters revealed by a new collection method at low field concentrations for radiocarbon analysis. Water Research 115: 236-244.)

2. A plasma source positive-ion mass spectrometer for next generation radiocarbon and beyond. Funded by NERC Strategic Environmental Science Capital to SUERC (£475k) in 2014/15. The entirely novel form of radiocarbon measurement was pioneered by the SUERC AMS Laboratory who continue to lead this project. The new measurement technique will provide a 100-fold reduction in sample size and greater throughput, with reduced labour requirements and operating costs. It will be developed in partnership with NRCF-E (graphites have been produced in 2016/17 for the AMS lab and future development work will include interfaces for introducing samples, including automated techniques). This will have important implications on, for example, our ability to undertake cutting-edge compound-specific radiocarbon measurements.

3. Database and electronic lab record keeping In collaboration with SUERC, we have developed new electronic procedures to greatly increase the efficiency of sample processing. These include: (i) a bespoke interface for rapid upload of sample information into the RCF database and production of materials for the analysis and tracking of samples; (ii) an in-house electronic lab sheet replacing paper-based records; staff now enter sample data using touchscreen PCs which allow automated calculation of sample variables, reducing the possibility of errors and eliminating manual data input; (iii) a further bespoke database interface streamlines the production of age reports. Together, these improvements greatly reduce the administrative burden associated with the processing of samples (particularly beneficial given the loss of a lab administrator in August 2016).

4. Development of automated sample processing rig NRCF-E continues to develop methodologies for increasing capacity. An example is automation of sample processing made possible through NERC capital funding. The system can recover purified CO_2 from all sample pre-treatment types currently used in the Facility (from quartz tube, molecular sieve, gas sample bags etc). The prototype rig has been completed, and allows for fully automated purification of sample CO_2, focussing on reducing processing time and improving functionality Testing using radiocarbon standards is continuing, and the next phase will focus on processing of multiple samples leading to substantial reductions in operator time.

5. New graphitisation procedures and trialling of an automated carbonate hydrolysis system. More rapid graphitisation would reduce turnaround times and be beneficial during periods of high sample submission. Current efforts are: 1) Vessel modifications, reducing volume and enabling rapid production. Early indications are that this approach could halve graphitization time, increasing capacity, 2) Tests on an automated carbonate hydrolysis system. This reduces operator time by automatically preparing carbonates (e.g. shells/foraminifera, 3) Testing the sealed-tube graphitisation method (Khosh et al., 2010. Small-mass graphite preparation by sealed tube zinc reduction method for AMS ^{14}C measurements. doi:10.1016/j.nimb.2009.10.066). This method greatly reduces operator time for graphitisation of small samples.

NRCF-O Development 2016-2017

1. Developments in Single Amino Acid Dating. Research and development into single amino acid methods for AMS dating is on-going and highly encouraging results have been obtained this year showing that, in some instances, the extraction and dating of the single amino acid Hydroxyproline, will produce accurate AMS dates from excessively contaminated bone. This includes bone treated with preservatives in museums, as well as bone contaminated with organic acids in archaeological sites. Work is also proceeding on the dating and analysis of samples using the SFE (Supercritical Fluid Extraction) and SFC (Supercritical Fluid Chromatography) approaches outlined in previous annual reports. Like the single amino acid work, this promises to significantly speed up the extraction of contaminants from material that is to be AMS dated, as well as enabling the characterisation of the products removed.

2. New version of OxCal. A new version of OxCal has been released this year providing improved capabilities for Age-Depth modelling and a new statistical tool for combining proxy information with dating information on different time-scales is now at an advanced stage (trialled at our short course). A new approach for linking Ice-Core and Radiocarbon timescales was presented at EGU this year which will be of central importance when comparing radiocarbon dated records with those from ice-cores.

3. Databases. There has been further work on integration of the different databases maintained at Oxford (the INTIMATE database for environmental record data, the RESET database for tephrochronology and the Egyptian Radiocarbon database which covers specific contextual information for Egyptian chronology. These are all integrated with OxCal and are being modified to allow URL-based access to data for big-data analysis (allowing data to be read directly into packages like R and Python). This is an approach that could be expanded across NERC ES chronology services.

4. Capital Investment. Oxford has secured significant capital investment towards a new AMS and the modifications to the existing buildings required for such an installation. We are currently going through a tendering process for an instrument and building work is planned to start later this year.

Facility demand and user community feedback: High demand for analytical support at NRCF-E continued this year, with 1619 analytical units processed, and efforts were focused on minimising turnaround times. In this we were very successful, resulting in an average turnaround of 3.4 months, compared to 5.6 months in 2015-16. This was partly driven by innovation and streamlining of processes. There is a continued demand for our unique measurement capabilities, for example, several approved NERC standard grants included several hundred measurements of $^{14}CO_2$ using our molecular sieves. There is also demand for specialist capability, e.g. small sample analysis, which we can achieve with as little as 16 micrograms of carbon after pre-treatment. In the year we reported 218 small samples, covering the full range of sample types, benefitting 21 allocations.
NRCF-O exceeded capacity this year (analytical units were 1.23 times nominal capacity) but, despite this, turnaround continued to get faster and this year averaged 3.1 months.

The annual on-line survey was sent to users of the NRCF who had either applied for, or received NRCF support during the previous calendar year. NRCF user community feedback for both nodes was excellent, with researchers praising the high quality analysis and reporting of data.

SCIENCE HIGHLIGHTS:

NRCF-EAST KILBRIDE *(NRCF staff co-authors underlined)*

CONTINUED NORTH ATLANTIC DEEP WATER FORMATION DURING THE LAST GLACIAL MAXIMUM

At present, the production of deep water in the north Atlantic Ocean forms the northern overturning limb of the global thermohaline circulation system; a mechanism by which heat is transported around the globe in the surface ocean, and by which carbon is stored in the deep ocean. Both of these have fundamental impacts on Earth's climate, and therefore understanding changes in this circulation, particularly during big climate shifts, is imperative to reconstructing past climate and forecasting future changes. The most recent such climate shift was the transition from the maximum of the last Glacial period to the Holocene, but despite its importance, the circulation in the glacial deep Atlantic Ocean and the mechanism by which it may have sequestered carbon remain elusive. In this work, cores were taken across virtually the whole Atlantic Ocean, north to south, to address the problem. Radiocarbon dating at NERC-RCF was central to providing a chronology for these cores, and neodymium isotopes were used to reconstruct the way water masses were moving in the glacial period. The researchers found that there was sustained production of North Atlantic Deep Water during the glacial period, meaning the deep Atlantic contained water sourced from the North. This directly contradicts the notion that the deep Atlantic was dominated by water from Antarctica during the glacial, and supports the idea of a deep, slowly overturning mass of water in the glacial North Atlantic, with longer residence times than in the modern North Atlantic. This stored a large amount of respired carbon in the deep Atlantic during the glacial, something which resolves problems with understanding how CO_2 was stored in the oceans during this time, and provides a new explanation for the increase in atmospheric CO_2 at the end of the glacial, when carbon was flushed out of the deep ocean.

REFERENCE: *Howe, J. N. W., Piotrowski, A. M., Noble, T. L., Mulitza, S., Chiessi, C. M. and Bayon, G. (2016). North Atlantic Deep Water Production during the Last Glacial Maximum. Nature Communications 7 doi:10.1038/ncomms11765.*

Supported by NERC-SC Allocation number 1752.1013

GLOBAL SEA LEVEL RISE IS FASTER THAN ANY TIME OVER THE PAST 27OO YEARS

Global Sea Level (GSL) is rising, with potentially catastrophic impacts for the hundreds of millions living on low-lying and coastal land. However, we do not know exactly what the drivers of this rise are, and how much GSL rise we can expect for the different future scenarios of climate change included in the recent IPCC report. This project resulted in the first estimate of GSL change over the last ∼3,000 years that is based upon statistical synthesis of a truly global database of regional sea-level reconstructions, the chronology for which was based on radiocarbon dates. The work showed that GSL in the 20th century rose faster than in any preceding century since at least 800 BCE. Temperature seems to have been a driver; for example, GSL decline over 1000–1400 CE coincided with ∼0.2 °C of global cooling. Patterns in the western Atlantic were linked to weakening, strengthening, or polar migration of the Gulf Stream. Wind stress also may be an important driver. The estimates of GSL differ markedly from previous reconstructions, and reconcile differences between IPCC and model projections. Without global warming, GSL in the 20th century would have risen by up to 7 cm, rather than the ∼14 cm observed. The path we follow in IPCC projections will determine the impacts on environment and society. For 2100 CE, high-end "business-as-usual" greenhouse gas emissions, moderate emissions abatement, and extremely strong emissions abatement give GSL rises of 52–131 cm, 33–85 cm, and 24–61 cm, respectively. Yet a reduction in 21st century sea-level rise of ∼30 to 70 cm could be achieved by strong mitigation efforts, even though sea level is a particularly "slow responding" component of the climate system.

REFERENCE: *Kopp, R. E., Kemp, A. C., Bittermann, K., Horton, B. P., Donnelly, J. P., Gehrels, W. R., Hay, C. C., Mitrovica, J. X., Morrow, E. D. and Rahmstorf, S. (2016). Temperature-driven global sea-level variability in the Common Era. Proceedings of the National Academy of Sciences. doi:10.1073/pnas.1517056113*

Supported by NERC grant NE/G003440/1.

CHANGES IN VEGETATION COVER PROMOTE LOSS OF ANCIENT CARBON 'LOCKED UP' IN PEATLANDS

Northern peatlands are extremely important in the global carbon cycle, containing one third of the Earth's soil carbon stock since the last Ice Age. Now, these stores of ancient carbon 'locked up' in the peat are under threat from global warming, as the rate of peat ecosystem respiration (and hence release of carbon as CO_2) is accelerating. This stands to tip the balance between sequestration of carbon through plant growth versus CO_2 release from the soil, making northern peatlands a source of atmospheric CO_2. Climate warming is expected to increase ecosystem respiration but the magnitude of its impact will depend on additional factors that may themselves be temperature dependent. Ecosystem respiration is the largest land to CO_2 flux, accounting for more than half of all biospheric CO_2 emissions. Understanding the factors influencing ecosystem respiration in peatlands is therefore vital, and one factor about which almost nothing is currently known about is how changes in vegetation composition affect the source and age of respired CO_2. This is despite the fact that changes in plant communities have been observed in response to global warming. This novel project used *in situ* ^{14}C measurements based on technologies developed in the NERC-RCF on a warming and vegetation manipulation experiment. The researchers found that organic inputs from vascular plants can promote ancient peatland carbon release, and that warming of approximately 1 °C promotes respiration of ancient peatland carbon (up to 2100 years old). In particular, increases in dwarf-shrubs and graminoids led to decomposition of previously 'locked-up'ancient organic matter, and startlingly, that plant-induced peat respiration could contribute up to 40% of ecosystem CO2 emissions, something not currently factored in to global carbon cycle models. Ultimately, greater contribution of ancient carbon to ecosystem respiration may signal the loss of a previously stable peatland carbon pool, creating potential feedbacks to future climate change.

REFERENCE: *Walker, T. N., Garnett, M. H., Ward, S. E., Oakley, S., Bardgett, R. D. and Ostle, N. J. (2016). Vascular plant presence promotes ancient peatland carbon loss under climate warming. Global Change Biology 22: 1880-1889. doi: 10.1111/gcb.13213*. Supported by NERC-SC allocation number 1709.0413, a NERC CASE Studentship and NERC award NE/E011594/1

ARSENIC CONTAMINATION OF DRINKING WATER IN ASIA DEPENDS ON ORGANIC MATTER SOURCE

In south and southeast Asia, arsenic contamination of drinking water is a public health catastrophe, causing e.g. 20% of deaths in arsenic impacted areas of Bangladesh. There is an urgent need to predict locations and human activities that risk As contamination, as this is crucial for mitigating the effects of the current crisis, and preventing future As hazards. Our ability to do this is currently limited by our understanding of the As release process. While we know that the As source is in the Himalayas, and what biogeochemical process release As into groundwater from alluvial floodplains, identification of the source of organic matter (OM) that drives these processes remains unresolved, and even controversial. This study examined ground and surface waters at a known arsenic hotspot in Cambodia, in which radiocarbon of aqueous OM was used to determine groundwater residence times and provenance OM. The results show that As mobilization rates are controlled by the age of dissolved groundwater OM. Arsenic concentrations in shallow groundwaters (<20 m) increase by 1 lg/l for every year increase in OM age compared to only 0.25 lg/l for every year increase in deeper (>20 m) groundwaters. It is shallow aquifers containing young OM that release the most As at present, but As-rich young, surface-derived OM is being naturally transported to depths of 44m in deep aquifers. Thus, both surface and deep aquifers are important in controlling As in Asian groundwaters. Transport of young OM into deep aquifers is exacerbated by the extensive pumping of groundwaters, and any human activities that alter the source and/or rate of groundwater recharge may affect the OM concentration, and therefore the shape and size of the current Asian arsenic hazard.

REFERENCE: *Lawson, M., Polya, D. A., Boyce, A. J., Bryant, C. and Ballentine, C. J. (2016). Tracing organic matter composition and distribution and its role on arsenic release in shallow Cambodian groundwaters. Geochimica et Cosmochimica Acta 178: 160-177. doi:10.1016/j.gca.2016.01.010*Supported by NERC-SC Allocation numbers 1411.0409, 1029.0403; NERC grants NE/D013291/1, NER/S/A/2006/-
14038, KH/Asia-Link/04 142966

SCIENCE HIGHLIGHTS: ARCHAEOLOGY-OXFORD

EYE LENS RADIOCARBON DATING REVEALS CENTURIES OF LONGEVITY IN THE GREENLAND SHARK

Bayesian radiocarbon age modelling at the NRCF of eye lens protein from the Greenland shark (*Somniosus microcephalus*), an iconic species of the Arctic Seas, has shown that this is the world's oldest vertebrate. Dating of these organisms is tricky, because they do not have ear otoliths and generally lack hard body parts that provide sequential growth layers. Scientists therefore focused on dating eye protein because they are metabolically inert and once synthesised in the body, are not renewed any more. The availability of radiocarbon dates from a carefully isolated part of the proteins in growth order meant that Bayesian age modelling could be undertaken. The age ranges of pre-bomb sharks showed that they reached sexual maturity at least by 156 ± 22 years, and the largest animal (502 cm) was 392 ± 120 years old. The results showed that the Greenland shark is the longest-lived vertebrate known. The data raise concerns about the conservation of the Greenland shark, because they are commonly recovered as by-catch in arctic and subarctic groundfish fisheries.

REFERENCE: Nielsen, J., Hedeholm, R. B., Heinemeier, J., Bushnell, P. G., Christiansen, J. S., Olsen, J., Bronk Ramsey, C., Brill, R. W., Simon, M., Steffensen, K. F., & Steffensen, J. F. (2016). Eye lens radiocarbon reveals centuries of longevity in the Greenland shark (Somniosus microcephalus). *Science*, 353(6300), 702-704.

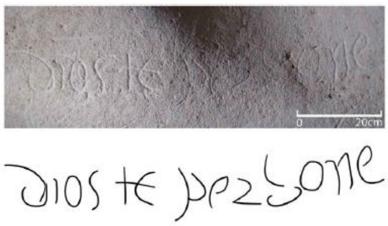
BISON PHYLOGEOGRAPHY AND THE ICE FREE CORRIDOR IN WESTERN CANADA

Evidence from bison fossils has been used to determine when an ice-free corridor opened up along the Rocky Mountains during the late Pleistocene. This has long been considered a potential route for human and animal migrations between the far north (Alaska and Yukon) and the rest of North America, but when and how it was used has long been uncertain. Using NRCF radiocarbon dating and DNA analysis to track the movements of bison into the corridor, the data showed that it was fully open by about 13,000 years ago. This suggests that the corridor could not account for the initial dispersal of humans south of the ice sheets, but could have been used for later movements of people and animals, both northward and southward. It appears far more likely that the initial southward movement of people into the Americas more than 15,000 years ago was by a Pacific coastal route. The Rocky Mountains corridor remains of interest as a potential route for later migrations.

REFERENCE:
Heintzman, P. D., Froese, J. W….& Shapiro, B. (2016). Bison phylogeography constrains dispersal and viability of the Ice Free Corridor in western Canada. *PNAS* 113 (29) 8057-8063.

DATING EARLY RELIGIOUS ENCOUNTERS IN THE NEW WORLD

The Carribean island of Mona has been the focus of new archaeological fieldwork led by Jago Cooper of the British Museum. The island was on a key Atlantic route from Europe to the Americas, and central to the 16th C Spanish colonial project. Columbus stopped at the island in 1494 on his second voyage. Island communities were therefore exposed to the earliest wave of European impacts. In 70+ subterranean caves on the island extraordinary evidence for these face-to-face encounters between the two groups has been found, inlcuding finger-fluted drawings, historic inscriptions, as well as numerous drawings of Christian symbols and graffiti, in Spanish, asking God to forgive the indigenes for their pagan icons (see figure). NRCF-funded radiocarbon dating (NF/2014/2/7) has been used to provide a context for objects, artefacts and charcoal rock art in the caverns, giving ages for the pre- as well as post-contact archaeology.



d i o s t e p e r d o n e

'God forgive you'

REFERENCE:
Cooper, J., Samson, A. V. M., Nieves, M. A., Lace, M. J., Caamano-Dones, J., Cartwright, C., Kambesis, P. N., & Olmo Frese, L. D. (2016). The Mona Chronicle: the archaeology of early religious encounter in the New World. *Antiquity*, 90(352), 1054-1071.

FUTURE DEVELOPMENTS/STRATEGIC FORWARD LOOK

NRCF capitalises on world-class staff expertise in not only analytical methods, but also in the wider applications of radiocarbon measurement, enabling advanced sampling methodologies and sophisticated scientific interpretations. This means that NRCF is highly responsive to the evolving needs of the user community as scientific fields advance and important new research questions emerge. NRCF is consequently poised to align with NERC's changing research agendas and priorities, in order to deliver the highest quality service. To achieve this, both nodes will continue to work closely with the NRCF-steering committee, BGS, and the user community to provide unique opportunities for science in the UK.

There is a high demand for NRCF services over at least the next three years. For example, over 2000 samples are already approved or written in to successful NERC grants as of March 2017 for the NRCF-E alone. These numbers will continue to grow as further funded projects come online, with a high proportion of grants including several hundred measurements. As the field evolves, large-scale studies of this type are increasingly required, particularly within the biological and ecological sciences, to maintain the UK's position at the forefront of global environmental scientific research. The NRCF-E is well-equipped to deliver these projects, with the necessary in-house expertise, capability, and close working relationships with the leading researchers in these fields. Both nodes will focus on maintaining fast turnaround times, together with streamlining analytical and electronic processes while ensuring the facility strengths continue to expand. The two laboratories will continue to work closely for technique development and service provision, enabling cross-disciplinary work and enhanced opportunities for collaboration

NRCF-E will focus on novel method development for global carbon cycle research, and enhancing field sampling techniques for samples that are presently difficult to collect. These aspects of our development programme presently underpin many NERC grants, and will continue to do so. This will run in parallel with expanding laboratory capabilities through analytical development, and exploiting emerging technologies for advanced radiocarbon measurement. For example, an entirely new methodology has recently been developed in-house for collection of previously inaccessible methane samples, and will be made ready for deployment in a range of environments worldwide. Our unique hydropyrolysis capability is also written in to pending NERC grants by the use community, and is in use by UK and EU researchers, enabling further exploitation of this technology. Examples of laboratory enhancements include significantly speeding up our processing speeds through sealed-tube graphitization, and automation of certain sample preparation stages. Our method development will occur alongside the NERC-funded positive ion technology programme spearheaded by the AMS group at East Kilbride, which is opening exciting possibilities for measurement of ultra-small samples (e.g. compound-class and compound-specific) that are unique on a worldwide scale.

NRCF-O is progressing with replacement of the AMS facility, with space allocated and elements of funding now secured. This is a major priority for improved efficiency, precision, sensitivity and reduced unit costs. Methods for compound-specific dating on bone in conjunction with the ERC Palaeochron project led by Tom Higham will be ready for use in facility projects over the next year. Statistical methods and databases are a key priority for NRCF-O over the next year with plans for statistical tools which, can be used for a whole range of different dating techniques. NRCF-O is also closely involved in the next IntCal update, which is expected within the next year and will build on both data and methods developed by the NRCF.