A database of NERC radiocarbon measurements determined by accelerator mass spectrometry

Garnett MH[1], Bryant CL[1], Freeman SPHT[2], Gulliver P[1,2], Ascough PL[1]

[1]Scottish Universities Environmental Research Centre, NEIF Radiocarbon Laboratory, East Kilbride, United Kingdom

[2]Scottish Universities Environmental Research Centre, AMS Laboratory, East Kilbride, United Kingdom

ABSTRACT

Radiocarbon measurements undertaken by the NERC Radiocarbon Laboratory using accelerator mass spectrometry are now freely available on a new on-line database. The data presented covers measurement of the wide range of sample types that are processed for research projects in the fields of Earth and environmental science, supported by the United Kingdom's Natural Environment Research Council. Sample types within the database include organic remains, soils, sediments, carbonates, dissolved organic and inorganic carbon, and carbon dioxide. Currently, the database contains radiocarbon data for over 2400 individual samples that were measured and reported between 2005 and 2013, but it is envisaged that this will expand considerably as more data are made available. Contextual information such as sampling location and associated publications are provided where available, and searches can be performed on sample location, sample type, project number and publication code. This new database compliments an existing, publicly available database of measurements performed using radiometric methods by the laboratory which has recently been expanded to present over 2000 measurements. It is hoped that this archive will prove useful to workers in the community who would benefit from greater availability of measurements for particular locations or sample types, and for the purposes of performing meta-analyses, and/or synthesis of larger datasets.

INTRODUCTION

In 1971 the UK Natural Environment Research Council (NERC) established the NERC Radiocarbon Laboratory at East Kilbride, near Glasgow. The laboratory became a NERC central facility in 1976, enabling UK researchers in the Earth and environmental sciences to apply for radiocarbon (^{14}C) analyses via application and peer review by the NERC Radiocarbon Laboratory Steering Committee. Since 2019, the laboratory has been a member of the National Environmental Isotope Facility (NEIF) which is "an integrated platform of state-of-the-art isotope and organic geochemistry analytical capabilities and specialisms", being delivered for eligible researchers by five organisations spread across the UK (https://www.isotopesuk.org/). The laboratory is now known as the NEIF Radiocarbon Laboratory and is hosted by the Scottish Universities Environmental Research Centre (SUERC) at the same location that was established in 1971.

A key principle of NERC's data policy is that "environmental data produced by the activities funded by NERC are considered a public good and they will be made openly available for others to use" (NERC Data Policy, 2022). In support of this, the NERC Radiocarbon Laboratory published date lists in *Radiocarbon* during the first decade of its operation (Harkness and Wilson 1973, 1974, 1979; Harkness 1981). Subsequently, radiocarbon data have been made available by the lab as a CD-ROM in an issue of *Quaternary Science Reviews* (Harkness et al. 1997), and most recently, on an

interactive spreadsheet accessible via the World Wide Web (Garnett et al. 2010). This latter compilation of radiocarbon results has subsequently been expanded and transferred to a searchable web database (https://www.environmental14c.co.uk/form.php).

The radiocarbon results in these collections of data previously presented to the community were all determined from radiometric measurements using liquid scintillation counters. However, since the 1990s the laboratory has prepared graphite targets for ^{14}C analysis using Accelerator Mass Spectrometry (AMS); the SUERC AMS Laboratory, commissioned by the NERC Radiocarbon Laboratory to undertake the AMS analyses considered here, was itself a NERC Recognised Facility before its role was included in NEIF. Here, we describe a new, freely available, web database of these AMS radiocarbon results.

ACCESSING THE WEB DATABASE OF AMS RESULTS

The web address for the new database of AMS radiocarbon results is https://www.environmental14c.co.uk/form_ams.php and it can also be accessed via the laboratory's website (https://environmental14c.co.uk/). The database can be searched using four fields which are accessed in dropdown boxes or textboxes: sampling location, sample type, project allocation number and publication code. Sample locations are mostly classified by country or water body (e.g. sea or ocean for marine samples). The type of sample material analysed has been classified using the scheme of sample types shown in Table 1. Allocation number is a unique identifier for the project for which the samples were analysed, with the numbers after the decimal point representing the month and year (last 2 digits) of the original project application. Publication code is the unique identifier for individual radiocarbon measurements provided by the AMS Laboratory. Location and sample type can be specified individually in searches, or the entire database can be interrogated using the "All" option.

Performing a search of the database using the project allocation number returns a table of results listing all sample records associated with the specified allocation number. Sample details include publication code, material identifier, radiocarbon concentration (as percent modern; pMC), conventional radiocarbon age (in years BP, where 0 BP = AD 1950; Stuiver and Polach 1977), sample location details (as provided by the submitter) and the date that the age results were formally reported (samples were usually reported in the same year that they were measured). In addition, details of the project (surname and institute of the lead applicant, and project title) are provided as well as publications associated with the project.

A search on location and sample type returns a table of samples that meet the specified location and sample type criteria. This table provides the same output for individual samples as a search on project allocation number, but also includes a web link in the column titled "Allocation". Clicking on this link performs a search using the project allocation number as described above and can be used to retrieve the additional project information and samples of other types or locations associated with the project. Searching using publication code returns the same data as a search on location or sample type, but for a single sample only.

PROCESSING METHODS AND DEFINITIONS OF RESULTS

Methods for processing the samples described in the new database follow relevant protocols of: pretreatment for particular sample types and project aims, conversion to carbon dioxide (CO_2),

cryogenic purification of the CO_2, graphitisation, pressing of the iron/graphite mixture into an aluminium target, and AMS measurement. Organic samples were combusted either using the sealed quartz tube method (Boutton et al. 1983) or an elemental analyser (Costech ECS 4010, Italy) with the combusted gases transferred to a vacuum rig for cryogenic purification without passing through a gas chromatography column. Carbonates were hydrolysed to CO_2 in sealed glass vessels using orthophosphoric acid. The Fe: Zn reduction method (Slota et al. 1987) was used to convert all samples to graphite. Ascough et al. (this issue) presents an overview of current sample processing methods at the NEIF Radiocarbon Laboratory which are mostly identical to those applied to the samples in the new database. More details of pretreatments and sample processing, including sample- or project- specific information are not included within the new database, but this information was reported to the project researchers and therefore the reader should consult publications that refer to the analytical data to obtain further details.

All ^{14}C results currently in the database were measured by AMS at SUERC, using either a National Electrostatics Corporation (NEC) 5 MV tandem accelerator mass spectrometer (Freeman et al. 2004) or a NEC 250 kV single-stage accelerator mass spectrometer (Freeman et al. 2010). Prior to the establishment of SUERC AMS in 2003, AMS samples prepared at the NERC Radiocarbon Laboratory were analysed at the NSF Accelerator Facility at the University of Arizona (Donahue et al. 1990) or Center for Accelerator Mass Spectrometry, Lawrence Livermore National Laboratory, University of California (Roberts et al. 1997), and these results will be included in future updates of the database.

Laboratory background contamination was quantified using ^{14}C-dead standard materials (e.g. coal and calcite) for each processing method and used to correct results that were significantly above background. Conventional radiocarbon ages are not reported by the database if a background correction was not applied (for samples <100 pMC), or if the samples were modern (>100 pMC). NIST Oxalic acid II (SRM 4990 C; National Institute of Standards and Technology, USA) was used as the primary reference standard. Following convention (Stuiver and Polach 1977), ^{14}C results were normalised to a delta ^{13}C of -25 ‰ using isotope ratio mass spectrometry (IRMS) measurements of an aliquot of carbon dioxide from the pretreated sample on a VG Optima (Micromass, UK) or Delta V (Thermo-Fisher, Germany). For a small number of samples, on-line AMS delta ^{13}C measurements were used to normalise the ^{14}C results, but these are not reported by the database. Analytical confidence of age measurements incorporates uncertainty from the background and delta ^{13}C corrections, in addition to that derived from AMS counting statistics and measurement scatter. In-house quality assurance was monitored to verify the reliability of results via processing of internationally-accepted standard materials of known ^{14}C value alongside the unknown samples. These materials were derived from either international standards agencies (i.e. IAEA or NIST), from the International Radiocarbon Intercomparisons (Gulliksen and Scott 1995), or from in-house materials whose ^{14}C value and homogeneity had been verified by repeated measurements in comparison to the aforementioned international standards.

ACKNOWLEDGEMENTS

We thank all staff, past and present, at the NERC Radiocarbon Laboratory (NRCF010001) and SUERC AMS Laboratory. We are grateful to the Chairs and Members of the NERC Radiocarbon Facility Steering Committee for their time and expertise, and the UK Natural Environment Research Council for funding.

REFERENCES

Ascough P, Bompard N, Garnett M, Gulliver P, Murray C, Newton J-A, Taylor C (Submitted) ^{14}C Measurement of Samples for Environmental Science Applications at the National Environmental Isotope Facility (NEIF) Radiocarbon Laboratory, SUERC, UK. Radiocarbon:

Boutton TW, Wong WW, Hachley DL, Lee LS, Cabrera MP, Klein PD (1983) Comparison of quartz and pyrex tubes for combustion of organic samples for stable isotopes. Analytical Chemistry 55: 1832-1833. https://doi.org/10.1021/ac00261a049

Donahue DJ, Jull AJT, Toolin LJ (1990) Radiocarbon measurements at the University of Arizona AMS facility. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 52(3): 224-228. https://doi.org/10.1016/0168-583X(90)90410-V

Freeman S, Bishop, P, Bryant, C, Cook, G, Fallick, A, Harkness, D, Metcalfe, S, Scott, M, Scott, R and Summerfield, M (2004) A new environmental sciences AMS laboratory in Scotland. Nuclear Instruments and Methods in Physics Research B 223-224: 31-34. https://doi.org/10.1016/j.nimb.2004.04.010

Freeman SPHT, Cook GT, Dougans AB, Naysmith P, Wilcken KM, Xu S (2010) Improved SSAMS performance. Nuclear Instruments and Methods in Physics Research B 268: 715–717. doi: 10.1016/j.nimb.2009.10.012

Garnett MH, Harkness DD, Miller BF, Fallick AE, Bryant CL (2010) NERC radiocarbon age measurements determined by radiometric counting 1996-2005. Radiocarbon 52(4): 1553-1555. doi:10.1017/S0033822200056307

Gulliksen, S., Scott, M., 1995. Report of the TIRI workshop, Saturday 13 August, 1994. Radiocarbon 37, 820-821. doi:10.1017/S0033822200031404

Harkness DD, Miller BF, Tipping RM (1997) NERC radiocarbon measurements 1977-1988. Quaternary Science Reviews 16(8): 925-927. https://doi.org/10.1016/S0277-3791(95)00092-5.

Harkness DD, Wilson HW (1973) Scottish Universities Research and Reactor Centre Radiocarbon measurements I. Radiocarbon 15(3): 554-565. doi:10.1017/S0033822200009000

Harkness DD, Wilson HW (1974) Scottish Universities Research and Reactor Centre Radiocarbon measurements II. Radiocarbon 16(2): 238-251. doi:10.1017/S0033822200001582

Harkness DD, Wilson HW (1979) Scottish Universities Research and Reactor Centre Radiocarbon measurements III. Radiocarbon 21(2): 203-256. doi:10.1017/S0033822200004380

Natural Environment Research Council (2022) NERC Data Policy 2022. https://www.ukri.org/wp-content/uploads/2022/03/NERC-080322-policy-data-021219.pdf

Roberts ML, Bench GS, Brown TA, Caffee MW, Finkel RC, Freeman SPHT, Hainsworth LJ, Kashgarian M, McAninch JE, Proctor ID, Southon JR, Vogel JS (1997) The LLNL AMS facility. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 123(1): 57-61. https://doi.org/10.1016/S0168-583X(96)00426-0

Slota P, Jull AJT, Linick T, Toolin LJ (1987) Preparation of small samples for ^{14}C accelerator targets by catalytic reduction of CO. Radiocarbon 29(2): 303-306. doi.org/10.1017/S0033822200056988

168 Stuiver M, Polach HA (1977) Reporting of ^{14}C data. Radiocarbon 19(3): 355-363.
169 doi:10.1017/S0033822200003672

170

171 **Table 1 Types of sample material in the AMS radiocarbon web database**

Calcite	Carbon dioxide	Charcoal
Coral	Dissolved inorganic carbon	Dissolved organic carbon
Foraminifera	Freshwater sediment	Gyttja
Litter	Marine sediment	Mesofauna
Other organic	Particulate organic carbon	Peat
Plant macrofossils/material	Pollen	Sediment
Shell	Soil	Wood

172