

Impact case study (REF3b)

Institution: University of Glasgow
Unit of Assessment: B7 – Earth Systems and Environmental Sciences
Title of case study: Forensic, Cultural and Renewable Energy Impacts of Radiocarbon
1. Summary of the impact

The work of the UK’s largest radiocarbon measuring laboratory, at the Scottish Universities Environmental Research Centre (SUERC, University of Glasgow), has had a range of impacts including the identification of the remains of Richard III; [text removed for publication]; providing evidence to solve high-profile murder cases and to prosecute people trading animal parts from endangered species e.g. rhinoceros horn and elephant ivory. The laboratory also leads inter-calibration studies that provide quality assurance to >75% of the world’s radiocarbon laboratories.

2. Underpinning research

Radiocarbon (¹⁴C) is produced at a relatively constant rate in the atmosphere and is taken up by all living organisms. When an organism dies the ¹⁴C decays over time – and this decay is used to derive the age of carbon-containing material.

For over 25 years SUERC has carried out pioneering research to improve the accuracy of ¹⁴C measurement across a variety of applications. The award of a £4M grant from the Natural Environment Research Council (NERC) Joint Infrastructure Fund in 2003 enabled SUERC to change from conventional radiometric analysis technology to an accelerator mass spectrometric (AMS) system. The AMS has delivered a step-change in accuracy and precision that has been widely publicised, ensuring that the findings are available to commercial and research laboratories.

This work has been carried out by Professor Gordon Cook (Lecturer 1985-95; Senior Lecturer 1995-2005; Reader 2005-08; Professor 2008-present) and other researchers at SUERC: Professor Stewart Freeman (AMS Senior Research Scientist SUERC 2000-07; Professorial Research Fellow 2007-present), Dr Sheng Xu (Research Assistant (RA) 2002-present), Dr Christophe Schnabel (RA, 2003-11), Mr Dr Robert Anderson (RA 1987-2010), Mr Philip Naysmith (RA 1986-present), Mr Andrew Dougans (Technical Staff 2002-present), and Professor Marion Scott (Lecturer 1983-91; Senior Lecturer 1991-98; Reader Department of Statistics 1998-2000; Professor School of Mathematics and Statistics, University of Glasgow, 2000-present).

As co-organisers of six major inter-calibration studies, these researchers have been at the forefront of worldwide quality assurance in ¹⁴C research. Over 20 peer-reviewed publications and reports to participating laboratories have resulted from this work.

The research has led to significant improvements in the accuracy of dating human remains, which has played an important role in forensic and archaeological investigations. These include:

- Using AMS analysis on different components of a single tooth from modern human remains to estimate year of birth to within 1-2 years. This research was carried out in 2005-6 by Cook, with Elaine Dunbar (RA 2001-present), Xu and Professor Sue Black (University of Dundee, Department of Anatomy and Forensic Anthropology).
- Continually developing and refining a process to correct age calculations based on analyses of human bone collagen where a significant proportion of the diet has been marine food, which contains a lower concentration of ¹⁴C than food from the land. Work on this ‘Marine Reservoir Effect’ has been ongoing since 2004, and involves AMS ¹⁴C analysis of multiple paired marine and terrestrial samples from single archaeological contexts.

In addition to the technical advances in ¹⁴C analysis, the development and use of Bayesian statistics has enabled significant improvements in chronological modelling for archaeological sites. Dr Derek Hamilton (RA 2011-present) combines ¹⁴C data with historical facts and observed archaeological relationships. This approach results in more precise dating and robust chronological models for sites where the age cannot be determined from a single analysis. The Bayesian approach constrains timescales to decades rather than centuries.

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Funding for the quality assurance activity has come from NERC, the Engineering and Physical Science Research Council (EPSRC), Ministry of Agriculture Fisheries and Food, English Heritage and Historic Scotland. Financial support for the Bayesian work has come principally from Historic Scotland, English Heritage and the European Research Council.

3. References to the research

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2. Xu, S., Anderson, R., Bryant, C., Cook, G.T., Dougans, A., Freeman, S., Naysmith, P., Schnabel, C. and Scott, E.M. (2004) [Capabilities of the new SUERC 5MV AMS Facility for ¹⁴C dating](#). *Radiocarbon* 46, 59–64 [or available from HEI].
3. Cook, G.T., Dunbar, E., Black, S.M. and Xu, S. (2006) [A Preliminary assessment of age at death determination using the nuclear weapons testing ¹⁴C activity of dentine and enamel](#). *Radiocarbon* 48, 305–313 [or available from HEI]. *
4. Cook, G.T., Dixon, N., Russell, N., Naysmith, P., Xu, S. and Andrian, B. (2010) [High precision radiocarbon dating of the construction phase of Oakbank crannog, Loch Tay, Perthshire](#). *Radiocarbon* 52, 346–355 [or available from HEI].
5. Hall, D.W., Cook, G.T. and Hamilton, W.D. (2010) [New dating evidence for North Sea trade between England, Scotland and Norway in the 11th century AD](#). *Radiocarbon* 52, 331–336 [or available from HEI].
6. Russell, N., Cook, G.T., Ascough, P., Barrett, J.H. and Dugmore, A. (2011) [Species specific marine radiocarbon reservoir effect: a comparison of \$\Delta R\$ values between *Patella vulgata* \(limpet\) shell carbonate and *Gadus morhua* \(Atlantic cod\) bone collagen](#). *Journal of Archaeological Science* 38, 1008–1015. *

* best indicators of research quality

4. Details of the impact

Led by Cook, the SUERC radiocarbon laboratory is a world leader, with its research having significant impact on a number of organisations including Police and Customs authorities, commercial archaeology companies, local authorities, Historic Scotland, English Heritage and commercial radiocarbon laboratories worldwide. Examples of impacts are listed below.

Forensic Remains: Police and Customs Authorities

Since 2008 Cook has worked with 13 police forces in the UK. He has provided ¹⁴C analysis and expert reports for police authorities and forensic science companies for over 30 cases involving human skeletal and dental remains. Radiocarbon analysis provides an estimate of the year of birth and can be used to tell whether death occurred after 1955 (i.e. during the nuclear era). Cook's work has been invaluable to police authorities by helping to determine whether cases require further investigation, and has been influential in the progress or closure of a number of high profile legal cases.

- Haut de la Garenne children's home, Jersey: analysis of bone remains discovered at the site during a child abuse investigation in 2008 proved that, although human, they were not from modern times and therefore not the result of murder when the home was open in the 1960s-80s. No further investigation was required.
- A Victorian murder: when a skull was unearthed in Sir David Attenborough's garden, ¹⁴C analysis helped to identify the victim as Julia Thomas, killed in 1879 by her maid.

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- Operation Malachi, featured on BBC Crimewatch: analysis determined that a body discovered behind hoardings in Manchester was that of a woman who was born in the early to mid-1950s and who died in the late 1960s to early 1970s. This case is ongoing.

Radiocarbon analysis has been carried out for Revenue – Irish Tax and Customs, Merseyside Police and TRACE Wildlife Forensics Network to establish whether animal parts such as elephant ivory and rhinoceros horn came from animals that were alive during the nuclear weapons era and therefore traded illegally. In the context of this work, Cook has appeared as an expert witness at Winchester Crown Court (23 June 2009). One client, Cellmark Forensic Services, undertakes commercial forensic and genetic profiling for many police forces, and has engaged Cook's expertise to provide accurate analysis of bone and ivory on 12 occasions during 2011-13. The quality of the service that they have received has enabled the company to grow its caseload during 2012.

Archaeology: Invaluable Cultural Treasures

In 2012 Cook and Hamilton collaborated with researchers from the Universities of Leicester and Oxford to analyse bones excavated from a car park that were believed to be those of Richard III. Standard ^{14}C analysis alone did not provide the correct timeframe to confirm his identity. However, applying Bayesian techniques and taking data on his diet and the marine reservoir effect correction into account made it possible to pinpoint the time of death to demonstrate that the remains were consistent with Richard III (later absolutely confirmed by DNA analysis). In 2008 the National Trust for Scotland asked Cook to date artefacts from the Isle of Iona, where St Columba established a monastery in 563 AD and where, during the following century, his church played a major role in the expansion of Christianity in northern Britain. The work at SUERC demonstrated human colonisation of the island many centuries prior to construction of the monastery. This finding has been recognised by the Scottish Parliament for its cultural importance. In 2011, Historic Scotland asked Cook to provide a chronology for the formation of the Ring of Brodgar, which is a key monument in the Heart of Neolithic Orkney World Heritage Site. Analysis determined that the standing stones pre-date Stonehenge, thus underscoring their national and international importance.

Bayesian statistical methods were added to the SUERC laboratory in 2011. These methods enable the laboratory to provide a complete analytical approach from advice on the optimum number and type of samples for a particular study to actual ^{14}C analyses and a detailed Bayesian report.

Commercial archaeology companies have benefitted in multiple ways from the inclusion of Bayesian statistics in post-excavation programmes. Perhaps most importantly, by developing Bayesian chronologies they have been able to produce historic and prehistoric narratives that engage the community's interest, e.g. Gwynedd Archaeological Trust – Site: Ysgol yr Hendre. In turn this has led to developers funding ^{14}C dating that includes Bayesian modelling, e.g. Cambridge Archaeology Unit – Site: Must Farm.

Renewable Energy Impacts

[Text removed for publication.] The drive for this research has been international obligations for reporting and reducing carbon emissions. [Text removed for publication.]

International impact on commercial ^{14}C analysis

The SUERC radiocarbon laboratory has led the six international radiocarbon inter-comparisons, the two most recent since 2008. Laboratory staff have developed and distributed ^{14}C reference materials (e.g. bone, charcoal, humic acid, wood, etc) to the majority of the world's radiocarbon laboratories. The results are collated and reported back to individual laboratories for quality assurance. These inter-comparisons have underpinned improvements in working practices in the ^{14}C measurement community, and have set the benchmark for laboratory practice for commercial ^{14}C analyses.

5. Sources to corroborate the impact

- Statement from Scientific Lead and Team Leader, Anthropology, Archaeology and Ecology, Cellmark Forensic Services (corroborates the impact on police investigations and decisions made by the police and Crown Prosecution Service)
- [University of Leicester news release regarding Richard III](#)
- Senior Archaeologist, Historic Scotland (corroborates the impact that SUERC research has had on historic and cultural treasures)
- Statement from Member of Scottish Parliament, East Kilbride (corroborates the cultural importance of Cook's radiocarbon work)
- Motion Lodged in Scottish Parliament by MSP for East Kilbride re SUERC expertise
- [Text removed for publication.]
- Statement from Professor, Geosciences and Physics, NSF Arizona AMS Laboratory (corroborates the impact on the radiocarbon community worldwide through SUERC leadership of the international radiocarbon intercomparisons)