Institution: University of Bristol		
Unit of Assessment: 8) Chemistry		
Title of case study: Organic residue analysis delivers a step change in knowledge generation from commercial archaeology		
Period when the underpinning research was undertaken: 2001 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Richard Evershed Lucy Cramp Julie Dunne	Professor of Biogeochemistry Senior Lecturer in Archaeology Senior Research Associate and Commercial Manager	2000 - present 2014 - present 2016 - present
Period when the claimed impact occurred: 2014 - 2020		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact

University of Bristol (UoB) research has led to the recovery of cultural heritage during commercial archaeological investigations, through its pioneering development of **organic residue analysis (ORA)**. Archaeological analysis has been legally required in the UK as a part of all commercial developments since the early 1990s and has proved to be a significant source of new cultural heritage. However, historically important heritage has been lost as commercial investigations have not routinely analysed organic residues such as fats, resins and waxes, on artefacts which can provide unique insights into human diet, agriculture and other cultural activities. UoB researchers created the methodology for the use of ORA and, with support from Historic England, have driven its rapid uptake and integration into mainstream commercial archaeology. Since 2017, over 60 major commercial projects in the UK and overseas have used ORA analysis to provide many new insights into our past.

2. Underpinning research

Over the last two decades, the UoB team led by Professor Richard Evershed FRS, has pioneered the application of ORA techniques to archaeology. Their ground-breaking work has demonstrated the widespread survival and utility of the biomolecular components of organic residues in revealing hitherto unobtainable insights into human foodways, technologies and ritual practices. Key achievements include:

- Development of all the analytical chemical protocols, based on state-of-the-art gas chromatography, mass spectrometry and isotope ratio mass spectrometry, routinely used to study archaeological lipid biomarkers in organic residues[1,2].
- Demonstration of the survival of lipids at sites of deposition for thousands of years in association with all of the major classes of organic remains, including: pottery[1-6], soils and sediments[1], human[1], animal and plant remains[1,4,6].
- Establishing interpretative frameworks built around fundamental studies of organic residue formation, pathways of degradation during burial, together with systematic investigations of chemical and isotopic compositions of modern plants and animals exploited by ancient peoples[1,2].
- Performing experimental archaeological investigations to underpin the understanding of how lipid biomarkers survive in ancient contexts and how they can be used to provide new

archaeological information, while taking account of chemical degradation or technological modification of plant and animal products of diverse origins[2].

- Extensive demonstrations of how lipid biomarkers can provide information on vessel use and diet. Biomarkers in soils and sediments have been used to investigate inputs into ancient rubbish dumps, disused watercourses, latrines and cesspits, and manures in human impacted soils[1].
- Amassing extensive experience in the design and management of archaeological projects, embedding ORA as part of wider archaeological investigations[4-6].

The underpinning research performed by the Bristol group is contained in >200 papers, many of which appear in the highest profile peer-reviewed journals. Notable discoveries using ORA have included:

- The earliest direct evidence for milk use >8000 years ago in the near East, linked to the evolution of lactase persistance[5]
- Association of the honeybee with early farmers of Europe dating back nearly 9,000 years[4].
- The first detection of plant processing in pottery from the Early Holocene period in North Africa, dating back >7,000 years[6].
- Development of a new high precision compound-specific radiocarbon dating tool for archaeology[3].

3. References to the research

1. **R.P. Evershed** (2008). Organic residue analysis in archaeology: the archaeological biomarker revolution. *Archaeometry,* 50, 895-924. 10.1111/j.1475-4754.2008.00446.x
2. **R.P. Evershed** (2008). Experimental approaches to the interpretation of absorbed organic residues in archaeological ceramics. *World Archaeology,* 40, 26-47 10.1080/00438240801889373
3. E. Casanova, T. D. J. Knowles, A. Bayliss, **J. Dunne**, M. Z. Barański, A. Denaire, P. Lefranc, S. di Lernia, M. Roffet-Salque, J. Smyth, A. J. Barclay, T. Gillard, E. Claßen, B. J. Coles, M. Illet, C. Jeunesse, M. Krueger, A. Marciniak, S. Minnitt, R. Rotunno, P. van de Velde, I. van Wijk, MOLA and **R. P. Evershed** (2020). Accurate compound-specific ^{14}C dating of archaeological pottery vessels. *Nature, 580*, 506–510. 10.1038/s41586-020-2178-z
4. M. Roffet-Salque, M. Regert, **R. P. Evershed**, A. K. Outram, **L. J. E. Cramp**, O. Decavallas, **J. Dunne**, P. Gerbault, S. Mileto, S. Mirabaud, M. Pääkkönen, J. Smyth, L. Šoberl, H. L. Whelton, et al. (2015). Widespread exploitation of the honeybee by early Neolithic farmers. *Nature,* 527, 226-230. 10.1038/nature15757
5. **R.P. Evershed**, S. Payne, A. G. Sherratt, M. S. Copley, J. Coolidge, D. Urem-Kotsu, K. Kotsakis, M. Ozdogan, A. E. Ozdogan, O. Nieuwenhuyse, P. Akkermans, D. Bailey, R. R. Andeescu, S. Campbell, S. Farid, I. Hodder, N. Yalman, M. Ozbasaran, E. Bicakci, Y. Garfinkel, T. Levy and M. M. Burton (2008). Earliest date for milk use in the Near East and southeastern Europe linked to cattle herding. *Nature,* 455, 528-531. 10.1038/nature07180
6. **J. Dunne**, A. M. Mercuri, **R. P. Evershed**, S. Bruni and S. Di Lernia (2016). Earliest direct evidence of plant processing in prehistoric Saharan pottery. *Nature Plants,* 3: 1-6 10.1038/nplants.2016.194

Major grants

(i) **Evershed** (PI leading consortium). NeoMilk: The Milking Revolution in Temperate Northern Europe, ERC Advanced Grant, 2013 - 2018, EUR2.5 million

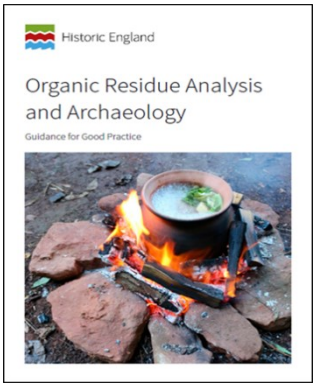
(ii) **Evershed** (PI) (with Mulville (Cardiff)). Changing patterns of marine product exploitation in human prehistory via biomarker proxies in archaeological pottery, NERC Standard Grant, 2009 - 2012, GBP482,000

4. Details of the impact

In the early 1990s the UK Government made it a legal obligation that when significant archaeological artefacts were found during building projects, archaeological assessments must be undertaken. At this time scientific analytical techniques, except for radiocarbon dating, were rarely employed. The widespread adoption of ORA by developers, driven by the UoB group and the increased cultural heritage information generated has changed substantially the practice of commercial archaeology in the UK and is now increasingly becoming used across Europe [A]. We document below how ORA techniques have been widely adopted by the commercial archaeology community and illustrate how major cultural heritage finds in the UK and internationally have followed, as a consequence of UoB research.

(I). Creating awareness in the commercial sector

In 2014 Evershed and Cramp approached Historic England **(HE)**, as the public body charged with looking after England's historic environment, with the idea of developing a guidance document for commercial developers. The aim was to make archaeological professionals aware of the potential of ORA for generating new cultural insights during post-excavation assessments. HE strongly supported the concept as biomolecular signals are widely preserved at archaeological sites and a rich source of information relating to the human past was, at that point, being lost.



Development of best practice for archaeological professionals

In 2015, Dunne drafted detailed guidance for commercial archaeologists in the use of ORA for the protection of cultural heritage. This guidance was formally adopted by HE in 2016 and published as two freely downloadable pdfs [B]. Co-designed with other expert groups, including the Medieval Pottery Research Group, Prehistoric Ceramics Research Group and academic practitioners of ORA at the Universities of York and Bradford, the guidance has become accepted as best practice by the commercial archeology community and has now been downloaded over 3500 times since publication [A].

Training sessions to promote awareness of ORA in the commercial sector

In 2017, Evershed and Dunne led a series of training sessions throughout the UK, organised and funded by HE, to promote the guidance to archaeological and heritage professionals. They were attended by more than one hundred delegates, including Archaeological Planning Officers from 21 county councils, representatives from the major UK commercial archaeological units (Wessex Archaeology, Museum of London Archaeology (MOLA), Oxford Archaeology), leading heritage organisations (National Trust, Vindolanda Charitable Trust, New Forest National Park Authority, Rubicon Heritage, Somerset Heritage Trust) and curators from Bristol City Museum and the National Museum of Wales. These training events were enthusiastically received, with the commercial archaeology professionals present remarking on the hitherto unappreciated potential of ORA for their work, e.g. *"I ..came away with a much better understanding of organic residues and more aware of the benefits of carrying out such analysis."* [C] and *"The Organic Residues and Pottery Production guidance will be added into our specifications for archaeological fieldwork and I will ensure that it is included in contractors Written Scheme of Investigation (WSIs)".* [C]

(II). Commercial deployment of ORA at over 60 UK sites since 2017

ORA has become a powerful new tool in the commercial archaeology community. To enhance the cultural benefits to stakeholders we have developed a commercial ORA service at Bristol. Recognizing our unique expertise, this is used by all major commercial archaeology units within the UK including: Wessex Archaeology, MOLA, Oxford Archaeology and other organisations including HE and the National Museums of Scotland and Ireland [D]. As a result of these training sessions (II) more than 60 commercial projects have been commissioned and completed [E]. This volume of work has led us to employ a dedicated full-time chemical analysis technician to carry out commercial analyses, with Julie Dunne acting as commercial manager, liaising with customers, interpreting results and writing reports for each project [E].

(III). Enhancing Cultural Heritage

ORA is now yielding an abundance of new discoveries revealing the rich cultural history of the British Isles and Europe. Notable recent examples include:

Dating the first farmers in prehistoric London to nearly 6,000 years ago

Excavations carried out by MOLA during the commercial redevelopment of the new Amazon Building in Shoreditch yielded an assemblage of pottery which provided the earliest evidence of Early Neolithic farming in London. ORA showed dairy products were processed in the pots. Jon Cotton, a consultant prehistorian working for MOLA commented *"Organic residue analysis of this remarkable collection helps to fill a critical gap in London's prehistory. Archaeological evidence for the period after farming arrived in Britain rarely survives in the capital, let alone still in-situ. This is the strongest evidence yet that people in the area later occupied by the city and its immediate hinterland were living a less mobile, farming-based lifestyle during the early Neolithic period"* [F]. The discovery generated widespread media and public attention [F].

Locating Medieval Oxford's Jewish community

Excavations in the historic heart of Oxford (undertaken by Oxford Archaeology) yielded remarkable evidence of 11th-12th century houses. Forensic-style ORA of pottery from the site revealed an absence of pork-derived chemicals which, together with assessments of animal bones, confirmed the presence of Oxford's early medieval Jewish community, later expelled from England by Edward I. Investigations focussed on individual Jewish houses and showed for the first time the power of ORA to reveal the religious dietary practices of the occupants. Senior project manager for Oxford Archaeology, noted *"Archaeological remains of the Jewish Quarter up til then had been very limited, and so the results of the residue analysis, which looked for traces of adherence to Jewish dietary laws, offered rare and stunning evidence"* [Db]. This work [G] was featured in *Current Archaeology*, the popular archaeology magazine read by over 45,000 people monthly and was nominated for the Current Archaeology 'rescue project of the year' award [H].

Investigating the use of intricately decorated Bronze Age pottery vessels found across Ireland's monumental megalithic landscape

Lipid analysis was carried out for the National Museum of Ireland on their remarkable collection of putative 'Food Vessels', notable because each vessel is decorated differently. Found in cist and passage tomb burials across Ireland, they have long been believed to have served some distinct purpose. ORA of 20 vessels showed all were used to process dairy products, such as milk, butter and cheese, demonstrating their specialist function. Evidence for milk production and processing is especially important in Ireland as animal bones rarely survive in the acid soils, so pots offer the only means of revealing ancient dairy practices.

These examples demonstrate how our commercial ORA projects, which have ranged from identifying ancient lamps at the Scottish Iron Age Broch at Clachtoll, Assynt [Ia] through to Bronze Age 'fridges' in Somerset [Ib] have generated widespread media attention and public interest (online articles and videos in The Independent, The Times, Smithsonian Magazine, YouTube and others [J]). ORA has ultimately enhanced the social and economic value of heritage assets and tourism across the length and breadth of the British Isles and beyond.

5. Sources to corroborate the impact

[A] Letter from CEO Historic England (2020) about guidance document

[B] Historic England, Guidance for Good Practise, 2017,
a) Organic Residue Analysis and Archaeology: Guidance for Good Practice,
b) Organic Residue Analysis and Archaeology: Supporting Information

[C] Reports and feedback from training sessions.

[D] a) MOLA (2020). Supporting Letter – Senior Post-Excavation Manager
b) Oxford Archaeology (2020). Supporting Letter – Senior Project Manager
c) Cotswold Archaeology (2020). Supporting Letter – Principal Post-Excavation Manager

[E] UoB (2017 - 2020). Reports to commercial archaeology units (55 reports)

[F] London pottery finds reveal Shoreditch agricultural past , The Guardian, 8th April 2020

[G] You are what you eat?, Current Archaeology, April 4th, 2019

[H] Rescue Project of the year 2020, Current Archaeology, December 2019

[I] a) Scratching the surface: residue analysis on ceramic and steatite vessels, 20th December 2019, Scottish Iron Age Broch at Clachtoll, Assynt
b) Residue analysis reveals function of Bronze Age sunken pots, 9th July 2020, Oxford Archaeology

[J] Public outreach in popular magazines and other media:
a) The Independent (09.04.20). New discovery suggests London's story goes back more than 3,000 years longer than previously thought
b) Smithsonian Magazine (15.04.20). Traces of Millennia-Old Milk Help Date Pottery Fragments to Neolithic London
c) Daily Mail (08.04.20). Neolithic 'dirty dishes' dug up in Shoreditch High Street were used by London's earliest East Enders who feasted on goat, beef, lamb and dairy products 5,600 years ago, new carbon dating technique reveals
d) Current Archaeology (16.05.20) Science Notes – Bridging the Gap in London's prehistory