

UKAS 2011

UK Archaeological Science
Biennial Conference

15 – 18 September 2011

University of Reading

Programme and Abstracts

UKAS²⁰¹¹

UK Archaeological Science Biennial Conference 2011

Hosted by the Department of Archaeology, University of Reading

15 – 18 September 2011

Conference Organisers

John Allen

Martin Bell

Robin Bendrey

Stuart Black

Nick Branch

Heather Browning

Helen Crossman

Sarah Elliott

Pascal Flohr

Rob Hosfield

Mary Lewis

Gundula Müldner

Michelle Pashley

Fiona Shapland

Philip Stastney

Victoria Taylor

Justine Tracey

Cindy van Zwieten

Gillian Walker

Jade Whitlam

UKAS 2011 – Student Prizes

Prize for Best Student Podium Presentation

Winner:

Chris Standish (Bristol): A lead isotope provenance study of Irish Bronze Age gold artefacts using LA-ICP-MS

(Abstract 1.7)

Runner-Up:

Isabella von Holstein (York): Keratin degradation and multi light stable isotope analysis of archaeological wool samples.

(Abstract 4.9)

Specially commended:

Domingo C. Salazar-García (Leipzig): Dietary adaptations in the Middle and Upper Palaeolithic of Eastern Iberia.

(Abstract 4.1)

Prize for Best Student Poster Presentation

Winner:

Pascal Flohr (Reading): Suitability of archaeobotanical samples for carbon and nitrogen stable isotope analysis.

(Abstract 20)

Runner-Up:

Kim Quintelier (Brussels and Ghent): Dietary patterns in the mixed lay and monastic population from the postmedieval Carmelite friary burial grounds at Aalst (Flanders, Belgium) and their relationship with DISH.

(Abstract 42)

Specially Commended:

Lucija Soberl (Bristol): Were dairy products important foodstuffs in prehistory or just a widely used post-firing waterproofing treatment?

(Abstract 45)

The following changes to the programme were made after the hardcopy of the handbooks went to press

Thursday 15 September

SESSION 1: Scientific Approaches to Artefacts and Ancient Materials

Allen & Black's presentation is replaced by:

15:00 Hayward, K.M.J.: The geological source of the earliest tombstones and architectural fragments from southern Britannia: A petrological and geochemical investigation of stone from Claudian Colchester.

The second half of the session (from 16:00) will now be chaired by John Allen.

The WELCOME WINE RECEPTION in the Department of Archaeology will begin half an hour earlier (from 18:00).

Friday 16 September

SESSION 3: Mobility, Migration and Culture Contact

Black et al.'s 16:15 presentation had to be withdrawn. The poster session will begin 15 minutes earlier than advertised (16:15 instead of 16:30).

Saturday 17 September

SESSION 5: New Directions

Kirke et al.'s presentation is replaced by:

14:15 Cramp, L.J.E., Whelton, H., Mulville, J., Evershed, R.P.: Tracing economic patterns from the Neolithic to the Late Norse period on Shetland through the application of lipid biomarker and compound specific stable isotope proxies to organic residues preserved in pottery.

Sunday 18 September

SESSION 6: Humans and Environmental Change

Cussan's 12:30 presentation had to be withdrawn. The conference will now close at 12:45.

Posters

The following posters were withdrawn after the Programme Handbooks went to press:

23. Gosling et al. 29. Jones 37. Martins 53. Walker & Gray Jones

Conference Programme and Timetable

Thursday 15 September

AFTERNOON

From 12 noon: Coffee and Registration

13:50 Welcome

SESSION 1: Scientific Approaches to Artefacts and Ancient Materials 1

Session Chair: Rob Hosfield

14:00 Dias, R., Cascalheira, J., Gonçalves, C., Detry, C., Bicho, N.: Linking the bones to the stones: preliminary spatial analysis in the Cabeço da Amoreira shellmidden.

14:15 Evans, A.: New Directions in Lithic Microwear Analysis

14:30 Hilditch, J., Pirie, D., Knappett, C., Momigliano, N.: Taking the coarse with the fine: the application of automated SEM-EDS with QEMSCAN® to ceramic assemblages in the Bronze Age Aegean.

14:45 Alonso-Lopez, E., Roppa, A. van Dommelen, P.: Colonial traditions: ceramic production in Iron Age and Punic Sardinia.

15:00 Allen, J.R.L., Black, S.: The source of coloured early Roman *tesserae* and *opus sectile*: An experimental and geological approach.

15:15 COFFEE

SESSION 1: Scientific Approaches to Artefacts and Ancient Materials 2

Session Chair: Stuart Black

16:00 van der Laan, J., Huisman, H., van Os, B., Roymans, N., Kars, H. Swinkels, L.: Iron Age glass in the Netherlands: XRF-analysis of La Tène bracelets.

16:15 Standish, C.D., Dhuime, B., Chapman, R.J., Cahill, M., Hawkesworth, C.J., Pike, A.W.G.: A lead isotope provenance study of Irish Bronze Age gold artefacts using LA-ICP-MS.

Conference Programme and Timetable

16:30 Bray, P., Pollard, M.: Beyond provenance: Using chemical composition to create life histories for early copper-alloy objects.

16:45 Caspers, S., Huisman, H., van Os, B., Koopstra, C.: Scrapheap challenge: deriving the origin of tableware fragments from the Roman period Hallum copper alloy hoard.

17:00 Jones, L., Bell, M., Almond, M., Robinson, S.: *In Situ* Preservation: Hydrological and Chemical Change in the Burial Environment of the Somerset Levels, UK.

17:15 SESSION END

18:30 Wine Reception in the Department of Archaeology (Atrium)

Friday 16 September

MORNING

SESSION 2: Biomolecular Approaches to Animal-Human Relationships 1

Session Chair: Robin Bendrey

09:00 Wooding, J., Taylor, M.G. Minnikin, D., Knüsel, C., Bond, J.: The Application of Macroscopic and Biomolecular Methods of Analysis to the Study of Bovine Tuberculosis in Zooarchaeological Assemblages.

09:15 Trinks, A., Burger, P., Benecke, N., Burger, J.: Ancient DNA Reveals Domestication Process: The case of the two-humped camel.

09:30 Lebrasseur, O., Larson, G., van Neer, W.: Mitochondrial DNA provide insights on the origins of goats, pigs, cattle and Java deer from Mauritius.

09:45 Gerbault, P., Powell, A., Thomas, M.: Investigating the goat domestication process using mtDNA sequences.

10:00 Balasse, M., Tresset, A., Boury, L.: Stable isotope insights into domestic animal birth patterns at Bercy (Paris, France, IVth millennium BC)

10:15 Frémondeau, D., Horard-Herbin, M.-P., Cucchi, T., Casabianca, F., Ughetto-Monfrin, J., Balasse, M.: Seasonality of birth and diet in pigs from tooth enamel sequential isotope analysis ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$): a case-study on the Celtic site of Levroux Les Arènes (France).

10:30 COFFEE

Conference Programme and Timetable

SESSION 2: Biomolecular Approaches to Animal-Human Relationships 2

Session Chair: Kate Britton

11:15 Dunne, J.B., Di Lernia, S., Evershed, R.P.: Autonomous uptake of dairying as a subsistence strategy in the Libyan Sahara in the fifth and sixth millennium BP.

11:30 Henton, E.: 'He maketh me to lie down in green pastures: he deadeth me beside the still waters'? The contribution made by sheep and shepherds to Central Anatolian herding decisions in the later Neolithic; the use of dental microwear and oxygen isotope analysis.

11:45 Viner, S., Evans, J., Albarella, U., Parker Pearson, M.: Cattle congregations? An investigation of cattle movement in Late Neolithic Southern Britain.

12:00 Bendrey, R., Lepetz, S., Balasse, M., Zazzo, A., Turbat, T. Giscard, P.-H., Seltmann, R., Francfort, H.-P., Vigne, J.-D.: Tracking the Iron Age nomads of the Altai region: isotopic analyses of horse tooth enamel from funerary barrows.

12:15 Hartman, G.: Silence of the Lambs: Reconstructing the Pilgrimage Economy of Jerusalem during the Early Roman Period.

12:30 Guiry, E., Tourigny, E., Noël, S., Grimes, V.: Animal Husbandry in New World Colonial Fishing Stations: Insights from Stable Isotope Analyses.

12:45 LUNCH

AFTERNOON

SESSION 3: Mobility, Migration and Culture Contact 1

Session Chair: Colin Smith

14:00 Chenery, C.A., Pashley, V., Lamb, A.L., Sloane, H., Evans, J.A.: Can we establish a robust relationship for oxygen isotopes between the phosphate and structural carbonate components of human teeth?

14:15 Gerling, C., Pike, A.W.G., Heyd, V., Kaiser, E., Schier, W.: Did they stay or did they go? Finding answers on mobility and diet in the Bronze Age Western Eurasian steppes using isotopic analyses.

14:30 Hunt, H., Lawes, M., Park, Y.-J., Bower, M., Howe, C., Jones, M.: Pioneering agricultural contact across the Eurasian steppe: phylogeographic signals in broomcorn millet (*Panicum miliaceum*).

14:45 Grimes, V., Poinar, H., Marshall, I., Dawe, K., Youngusband, B.: A biomolecular study into the lifeways and genetics of prehistoric human populations from Newfoundland.

Conference Programme and Timetable

15:00 COFFEE

SESSION 3: Mobility, Migration and Culture Contact 2

Session Chair: Vaughan Grimes

15:45 Hamilton, J., Hedges, R., Bickle, P., Fibiger, L., Bentley, R.A., Whittle, A.: Diversity in the LBK: using isotopic analysis to investigate lifeways and regional variation in the early Neolithic.

16:00 Evans, J., Chenery, C., Montgomery, J.: 6000 years of migration and 15 years of measurements- what do we know about human movement across Britain?

16:15 Black, S., Hubbard, C.G., Hodson, M.E., Eley, Y.: Towards the construction of a strontium isotope map of the world: Application to archaeological science

FROM 16:30 POSTER SESSION (with drinks)

Saturday 17 September

MORNING

SESSION 4: Palaeodiet: Questions of Marine Resource Consumption

Session Chair: Oliver Craig

09:15 Salazar-García, D.C., Villaverde, V., Richards, M.P.: Dietary adaptations in the Middle and Upper Palaeolithic of Eastern Iberia

09:30 Mannino, M.A., Nehlich, O., Talamo, S., Di Salvo, R., Tagliacozzo, A., Piperno, M., Tusa, S., Richards, M.P.: The exception that proves the rule: an isotopic investigation on the role of marine resources in the diets of early Holocene Mediterranean humans (Grotta dell'Uzzo, NW Sicily).

09:45 Friedman, L.G., Koike, H., O'Connell, T.C.: Re-interpreting the Jomon-Yayoi Transition Using Stable Carbon and Nitrogen Isotopic Evidence.

10:00 Britton, K., Knecht, R., Richards, M., Hillerdal, C., Davis, R.S.: Diachronic reconstructions of hunter-gatherer diets in prehistoric Western Alaska through the stable isotope analysis of permafrost-preserved hair.

Conference Programme and Timetable

10:15 Mulville, J., Best, J., Bruford, M., Cramp, L., Evershed, R., Jones, J., Madgwick, R., Powell, A., Stanton, D., Svensson, E.: La Isla Bonita? Diversity and Specialisation in Insular Environments.

10:30 Ervynck, A., Boudin, M., Fuller, B., Müldner, G., Quintelier, K., Van Neer, W., Van Strydonck, M.: Fish without a signal? Can stable isotopes trace documented dietary changes in historical populations from Belgium?

10:45 COFFEE

SESSION 4: Palaeodiet: New Approaches to Methodological Problems

Session Chair: Mike Richards

11:30 Evershed, R.P., Honch, N., Dunn, P.J.H., Pollard, C.J., Stewart, A.I., Miller, B., Eriksson, G., Lidén, K.: Testing collagen amino acid stable isotope dietary proxies using animal feeding experiments, reference organisms and archaeological populations.

11:45 Smith, C.I., Mora, A., Fuller, B., Nehlich, O., Richards, M.: Investigating archaeological bone collagen at the amino acid level using liquid chromatography-isotope ratio mass-spectrometry

12:00 von Holstein, I., Newton, J., Walton Rogers, P., Craig, O.E., Collins, M.J.: Keratin degradation and multi-light stable isotope analysis of archaeological wool samples.

12:15 Heron, C., Chamberlain, P., Frankovsky, I., Kiura, P.: Quantitative and Qualitative Investigations of Lipid Residues in Modern Luo Pottery from Lake Victoria, Kenya: Implications for Archaeology

12:30 Salgue, M., Kirk, S.M., Ryan, K., Evershed, R.P.: Investigation on the influence of C₄ plants on the isotopic composition of adipose and dairy fats.

12:45 LUNCH

SESSION 5: New Directions 1

Session Chair: Carl Heron

14:00 Linderholm, A., Evin, A., Dobney, K., Larsson, G.: Unravelling the complexity of the Austronesian expansion and dispersal.

14:15 Kirke, G.C., Bayliss, A., Evershed, R.P.: Identifying Chemical Markers for Anomalous Radiocarbon Dates from Surface Organic Residues.

Conference Programme and Timetable

14:30 Flohr, P., Müldner, G., Jenkins, E.: Reconstructing past water availability using plant carbon and nitrogen stable isotopes: (im)possibilities of the method

14:45 Wallace, M., Jones, G., Charles, M., Heaton, T., Fraser, R., Bogaard, A.: Crop watering in Neolithic and Bronze Age Western Asia: the stable carbon isotope approach.

15:00 Fraser, R., Bogaard, A., Charles, M., Jones, G., Wallace, M., Evershed, R., Styring, A., Heaton, T.: Plants in palaeodiet: incorporating crop stable isotope ratios in dietary reconstruction.

15:15 COFFEE

SESSION 5: New Directions 2

Session Chair: Gundula Müldner

16:00 Walker, G.C., Jackson, B.J., Matthews, W., Bowen, J.W., Labaune, J., Mourou, G., Naftaly, M., Dudley, R., Whitaker, J.F., Menu, M., Hodder, I.: Seeing Through Walls: Çatahöyük.

16:15 Kovacevic, M., Shennan, S., Thomas, M.G.: Modelling the spread of Aurignacian material culture: Were the first modern humans in Europe ethno-linguistically structured?

16:30 THE LEO BIEK MEMORIAL LECTURE 2011: Richard Bradley FBA: 'A straight line through the undergrowth': A prehistorian's perspective on archaeological science.

17:15 SESSION END

From 19:00: Bar and Pre-Dinner Drink at Wantage Hall

20:00: Conference Dinner at Wantage Hall

Sunday 18 September

MORNING

SESSION 6: Humans and Environmental Change 1

Session Chair: Rhiannon Stevens

09:30 Anderson, J.K.: Vikings, post-Vikings and Volcanic Ash: Using tephrochronology to understand the relationship between environmental change and human settlement at Vatnsfjöður, Iceland.

09:45 . Young, D., Stastney, P., Black, S., Branch, N., Pritchard, O., McCarroll, J., Whitaker, J.: Holocene Hydrological and Vegetation Changes in Ombrotrophic Bogs in Central Ireland: Implications for our Understanding of Climate History and Human Activities.

10:00 Reade, H., Barker, G., O'Connell, T., Stevens, R.: Investigations into Late Quaternary Climate Change and Human Behaviour in North Africa: Isotopic Analysis of Mammalian Tooth Enamel

10:15 Pryor, A., O'Connell, T.C., Svoboda, J., Oliva, M., Sinitsyn, A., Stevens, R.E.: AMH and the Dansgaard-Oeschger events in Northern Europa: an investigation using oxygen isotopes of faunal remains.

10:30 Lee-Thorp, J., Morin, E.: Comparing isotope ecology across the Middle Palaeolithic - Upper Palaeolithic transition at St Cesaire, France

10:45 COFFEE

SESSION 6: Humans and Environmental Change 2

Session Chair: Martin Bell

11:30 Versteegh, E.A.A., Black, S., Hodson, M.E.: Earthworm secreted calcium carbonate: a new palaeothermometer?

11:45 Stevens, R.E., Reynard, L., Higham, T.F.G.: Investigating the late-glacial warming and the Magdalenian re-colonization of Northwest Europe.

12:00 Black, S., Branch, N., Maggi, R., Marini, N., Neville, S., Wilkinson, K.: Early Holocene Rapid Climate Change and Vegetation Succession at the Mesolithic-Neolithic Transition in the Central-Western Mediterranean.

12:15 Riddiford, N., Branch, N.P., Green, C.P., Armatage, S.J., Olivier, L.: Prehistoric salt production and the palaeoenvironmental record: a case-study from the Seille Valley, Eastern France.

Conference Programme and Timetable

12:30 Cussans, J.E.: Biometry and Climate Change in Norse Greenland: The Effect of Climate on the Size and Shape of Domestic Mammals.

12:45 AWARD OF STUDENT PRESENTATION PRIZES

13:00 CONFERENCE ENDS

Podium Presentations Abstracts

1.1 Linking the bones to the stones: preliminary spatial analysis in Cabeço da Amoreira shellmidden (Muge, Portugal)

Dias, R¹, Cascalheira, João², Gonçalves, Célia³, Cleia Detry⁴ and Bicho, Nuno⁵

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³ Núcleo de Arqueologia e Paleoecologia da Universidade do Algarve, Campus Gambelas, 8005 – Faro, Portugal.

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From very early on, the origins of social complexity among human communities have been associated with the expansion of the first farmers. Recent studies, pointed that such complexity seems increasingly evident in earlier hunter-gatherers populations. In recent times a review and new investigation on one of the most important Mesolithic complex of Europe - the Muge shell middens - argued about the existence of complexity patterns in the archaeological record including spatial organization within and between shellmiddens, as well as symbolic and stylistic aspects on lithic and body adornments, suggesting co-existence of different social groups in the same landscape.

In this paper we present spatial distribution (GIS) of faunal remains from the top layer of Cabeço da Amoreira shellmidden and their relation with lithic remains. The main objective is to clarify concentrations of different faunal elements, probably reflecting spatial organization for the different tasks – butchering, adornments and prestige elements, and a possible relation between them and lithics and the signification of this eventual relationship.

See linked posters #1, 9, 40.

1.2 New directions in Lithic Microwear Analysis

Adrian A. Evans^{1*}

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¹ *University of Bradford*

Lithic microwear analysis is the technique used to understand stone tool function and answer questions of early prehistoric societies that can be derived from this; these include site function, social organisation, and changes in landscape use and organisation over time. The widely used approach has previously come under criticism for lack of a scientific founding and the qualitative nature of the approach used (autoptic microscopy). This paper outlines research aimed to progress the method towards quantitative approaches, including the use of trace-element analysis and laser scanning confocal microscopy (LSCM). Trace-element analysis can be used as a bolt-on method to traditional approaches by aiding the further identification of contact material class. This is afforded by the nature of the wear process during tool use in which material can be adsorbed within the tool surface structure. LSCM allows the digital modelling of surfaces at nanometre resolution and this presents the opportunity to quantitatively describe surface attributes such as roughness and orientation. It can differentiate worn surfaces, produced by different tool use processes, based on direct analysis rather than human interpretation. Experiments using these techniques show promise and these results are presented along with a discussion of the potential problems these new techniques face.

1.3 Taking the coarse with the fine: the application of automated SEM-EDS with QEMSCAN® to ceramic assemblages in the Bronze Age Aegean

Jill Hilditch^{1*}, Duncan Pirrie², Carl Knappett³ and Nicoletta Momigliano⁴

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² *Helford Geoscience LLP, Menallack Farm, Treverva, Penryn, Cornwall, TR10 9BP, UK*

³ *Department of Art, Room 6036, Sidney Smith Hall, University of Toronto, 100 St. George Street, M5S 3G3, Canada*

⁴ *Department of Classics and Ancient History, University of Bristol, 11 Woodland Road, Bristol, BS8 1TU, UK*

A persistent problem within ancient ceramic analysis is the study of whole assemblages from both a compositional and technological perspective. Existing techniques, such as optical microscopy, ICP-MS and INAA, struggle to integrate compositional datasets with the textural information that is crucial for reconstructing technological choices. However, advances in automated scanning electron microscopy with linked energy dispersive spectrometers (SEM-EDS) have created the potential to offer a seamless combination of textural and mineralogical data based on the acquisition of energy dispersive spectra. The combination of mineral quantification, using QEMSCAN® technology, and compositional mapping allows the standardised comparison of diverse datasets to address wider issues of social interaction within the ancient world. To demonstrate the potential of this new application for SEM-EDS, this paper discusses the results of an integrated macroscopic, petrographic and automated SEM-EDS study of Bronze Age ceramics from Iasos in western Anatolia. This site has long been associated with the expansion of Minoan influence within the Bronze Age Aegean, though the extent of participation within regional exchange networks has only recently been addressed. In addition to characterising the local suite of fabrics for this coastal region, the analysis has shown a much higher degree of interaction with neighbouring Dodecanese island centres than previously thought, as well as offering the first evidence for the presence of non-Cretan Minoanized vessels within the settlement. Automated SEM-EDS not only refines petrographic descriptions but also provides unique insight into clay mineral composition and clay mixing, a traditionally difficult behaviour to identify analytically.

1.4 Colonial traditions: ceramic production in Iron Age and Punic Sardinia

Elisa Alonso-Lopez^{1*}, Andrea Roppa² and Peter van Dommelen³

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¹ *Research Technician, School of Archaeology, University of Leicester*

² *Leverhulme Research Associate, School of humanities, University of Glasgow*

³ *Professor of Mediterranean Archaeology, School of humanities, University of Glasgow*

This project investigates the production of coarse wares in the Phoenician-Punic world of the western Mediterranean between the Iron Age and classical period (9th-4th c. BCE), focusing in particular on Sardinia.

It is based on the assumption that ceramic traditions are embedded in social practices and that technological study of ceramic activities may provide powerful insights into social and economic interaction. This approach allows analysis of the ways in which Nuragic and Phoenician people interacted and negotiated daily practices and identities.

The multidisciplinary research program is focused on defining local fabrics and manufacturing techniques. Work has been articulated into two main stages, with macro-level studies mostly carried out in Sardinia and micro-level analyses in Glasgow and Leicester.

Fabric definition at macro level is methodologically based on quantitative soil description. This particular methodology, which has been used in Sardinia by the Riu Mannu and Terralba projects since the 1990s, has already allowed identification of a range of fabrics in Punic west-central Sardinia.

Using these studies as a starting point, petrographic analyses are combined with EDXRF mapping-technology, which in addition to the qualitative and quantitative chemical characterization of the samples enable element image generation and comparison. Combining both analyses we can obtain a direct correspondence between thin sections and their chemical composition.

The micro-XRF is a non-destructive elemental analysis with the capability to pinpoint individual particles with diameters down to 10 µm. We can define regions of interest in the sample to complement the information gained from petrographic analysis.

These three levels of analysis (macro–micro–elemental) and the new combination of techniques enable a deeper understanding of fabrics and yield strong visual references and promising results overall.

1.5 The source of coloured early Roman tesserae and opus sectile: An experimental and geological approach

Allen, J.R.L.^{1*} and Black, S.¹

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¹*Department of Archaeology, School of Human and Environmental Sciences, University of Reading, Whiteknights, Reading, RG6 6AB.*

The Poole/Purbeck area of Dorset is well known for its decorative stone produced from coastal exposures of the Kimmeridge Clay Formation. Furthermore, these have been identified as being potential sources for *opus sectile* and tesserae of yellow and red burnt mudstone recovered from Fishbourne Roman Palace, Silchester Roman town, Caerleon fortress baths and Eccles villa. A number of key features have been identified in these materials as unique to the Kimmeridge Clay Formation namely: wave-polished faces, bioturbation, invertebrates, shelly fossils, grain size and bulk chemistry. However, it is still unknown how these materials were produced and if specific sequences within the Kimmeridge Clay Formation were targeted in order to produce these distinctively coloured materials.

We present here the results of a series of experimental burning experiments on a sequence of systematically collected rock exposures from the Kimmeridge Clay Formation, Dorset. The sequence collected from Clavell Tower through to Clavell's Hard including the Yellow Ledge unit represents the middle sequence of the Kimmeridge Clay Formation and the most likely source of materials used based on fossil evidence.

The controlled burning experiments, mineralogy and differential thermal gravimetric analyses will be presented to illustrate this type of approach in identifying potential source units from within the Kimmeridge Clay Formation. These data have significant implications for interpreting Roman tesserae and *opus sectile* production from the south coast.

This presentation replaced the talk by Allen & Black (Thursday 15:00-15:15).

1.5 The geological source of the earliest tombstones and architectural fragments from southern Britannia: A petrological and geochemical investigation of stone from Claudian Colchester.

Hayward, K.M.J.^{1,2*}

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In a province without a pre-existing tradition of fine carving and inscription in stone, where were the Romans quarrying and supplying their stone from to embellish the earliest funerary monuments and monumental architecture at centres in south-east Britannia? Was a single source responsible for the supply of stone to Colchester, London, and Silchester? Or was the whole process in fact a far more complex picture involving a mix of opportunistic and centralised quarrying operations.

In order to answer these questions limestone samples obtained from 60 first to early second century tombstones and architectural fragments were prepared and analysed using a more rigorous, considered scientific approach than before. A series of complimentary geological tests (thin-section petrography; X-Ray Diffraction; X-Ray Fluorescence and stable isotope geochemistry (carbon and oxygen)) were used to identify different limestone types. Comparison was then made with over 100 Jurassic and Tertiary outcrop samples from northern France and south-central England prepared and analysed in a similar way.

The results completely alter our understanding of where these materials were being quarried from and refute initial identification that all this material was being supplied from Bath.

Using Claudian Colchester as a case study, with specific reference to two early Roman tombstones Facilis and Longinus I will present the petrological and geochemical findings that not only show how much influence the premier early Roman centre in the province had on stone resources but begin to understand who may have been responsible for the prospecting, quarrying, supply and carving of these materials.

1.6 Iron age glass in the Netherlands: XRF-analysis of La Tene bracelets

Joas van der Laan^{1,2}, Hans Huisman^{1,3*}, Bertil van Os¹, Nico Roymans⁴, Henk Kars², Louis Swinkels⁵

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³ *Leiden University, Faculty of Archaeology, Leiden, The Netherlands*

⁴ *VU University, Archeological Centre, Amsterdam, The Netherlands*

⁵ *Valkhof Museum, Nijmegen, The Netherlands*

Glass occurs in profusion in the late Iron age in the Netherlands, after a long period when glass was rare. Some 7000 glass fragments from so-called La Tène bracelets, beads and rings are now recorded. Colors vary from blue and purple to colorless and green with yellow or white decoration.

According to one theory, the glass objects were made locally from mostly local raw materials (Roymans & Verniers 2009). Other theories imply that they were imported or made locally from imported raw materials or ingots (e.g. Henderson 1988).

We studied c. 2600 glass fragments from the Valkhof museum, Nijmegen. Their composition was analyzed using hand-held XRF, allowing quick, non-destructive measurements.

Low K and Mg contents indicates that the glass was made with soda (natron) as flux. Since the closest sources of soda are in the eastern Mediterranean, it is unlikely that the objects were made with local raw materials.

The large amounts of measurements make it possible to group the fragments confidently according to concentrations of colorants like Co, Cu and Mn and trace metals like Sr and Zr. The differences between the groups reflect differences in the type and provenance of raw materials used and in the recipes applied. The groups are similar to such groups elsewhere in Celtic Europe (e.g. Austria; Karwowski 2004). Probably, therefore, glass was traded throughout Iron Age Celtic Europe as ingots or as finished products. The glass bracelets from the Netherlands most probably were made in the Rhine region from imported raw glass.

1.7 A lead isotope provenance study of Irish Bronze Age gold artefacts using LA-ICP-MS

Standish, C. D.^{1*}, Dhuime, B.¹, Chapman, R. J.², Cahill, M.³, Hawkesworth, C. J.⁴, Pike, A. W. G.⁵.

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Europe's Neolithic – Bronze Age transition witnessed the appearance of a series of new, distinct materials that help to suggest the formation of an increasingly stratified society. One such material first seen at this time was gold, used to produce a wide range of artefacts from lunulae and discs to bracelets and gorgets. Significant concentrations of these artefacts have been found in Ireland, yet it is still unclear where the natural gold used to produce them was procured. Recognising the source locations of gold from this period is crucial for understanding the controls of its procurement, trade and exchange, and could help to explain the new social structures that arose at this time.

Here we present our results from an investigation that employs lead isotopes to provenance a set of Irish Bronze Age gold artefacts using laser ablation ICP-MS. We show that the technique of laser ablation mass spectrometry can successfully measure the lead isotope ratios of artefact samples to the required precision, that lead isotope ratios vary across Ireland and therefore allow characterisation of different gold sources, and that the lead isotope signatures of Irish artefacts are consistent with an Irish source.

1.8 Beyond provenance: Using chemical composition to create life histories for early copper-alloy objects

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Archaeological scientists have analysed the chemical composition of copper and bronze objects for over two centuries. A huge legacy database has accumulated which encompasses objects from a tremendous range of periods and regions. However, this rich dataset has been applied to an extremely narrow set of questions. Several typologies of chemical groups have been created which repeatedly address the question of regional signatures and provenance. This paper will demonstrate that a tremendous amount of useful archaeological structure has been overlooked within these copper types.

Focussing on the distinctive copper produced by the Early Bronze Age mine of Ross Island, Co. Kerry, Ireland, this paper uses chemical composition to infer life histories for individual units of metal. The differing chemical properties of arsenic, antimony, silver, copper and tin create a series of signatures of metal use. Recycling, melting in reducing or oxidising atmospheres, type of mould, smithing technique and different tin alloying methods all leave distinct composition patterns. Tracing the enrichment and depletion of elements within broad chemical typologies is a powerful tool for understanding the social and technological choices made in antiquity. Interpretation of the chemistry in this way moves us away from a simplistic concept of provenance and towards understanding how people and material interacted. Theories on the behaviour of material culture can be merged with a detailed understanding of the chemical behaviour of Bronze Age alloys, strengthening the potential of both.

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1.9 Scrapheap challenge: deriving the origin of tableware fragments from the Roman period Hallum copper alloy hoard

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In 2007, a 3rd century AD bronze hoard was found in Hallum (NL). It lay in a ditch close to a dwelling mound; the area. It contains over fourteen hundred fragments of thin-walled tableware including cauldrons and Roman wine sieves. The depot is interpreted as tinker or coppersmith's scrap metal. In an attempt to reconstruct the objects, hand-held XRF measurements were done to analyze the composition of the fragments.

The compositional data of the Hallum hoard and reference sets were plotted in histograms, scatter plots and ternary diagrams. The results show that the Hallum hoard consists of fragments from many (>100), incomplete objects. From most objects only a handful of fragments was present, making reconstruction impossible. Based on the composition, most fragments probably originate from 3rd century Westland cauldrons and Sau type Östland buckets.

The distribution of the composition of the Hallum fragments matches the distribution in reference data containing Roman objects. Therefore - although Hallum lies outside the Roman empire - most of the fragments are probably of Roman origin. It is, however, unclear whether the objects passed the frontier as complete, functional objects or as scrap metal.

The distribution of compositional values in scatterplots may suggest that the level of recycling in this type of copper alloy objects (i.e. thin-walled tableware) is low.

1.10 *In Situ* Preservation of Wetland Heritage: Hydrological and Chemical Change in the Burial Environment of the Somerset Levels, UK

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Keywords: In Situ Preservation; Monitoring; Glastonbury Lake Village; Sweet Track; Somerset Levels; Water Chemistry; Hydrology.

In situ preservation is a core strategy for the conservation and management of waterlogged remains at wetland sites. Inorganic and organic remains can however quickly become degraded, or lost entirely from the archaeological record, as a result of chemical or hydrological changes. Monitoring these parameters is therefore crucial in identifying baseline data for a site, the extent of spatial and or temporal variability, and to evaluate the potential impacts of these variables on current and future in situ preservation potential.

Since August 2009, monthly monitoring has taken place at two internationally important sites in the Somerset Levels, UK, the Iron Age site of Glastonbury Lake Village, and the southern section of the Neolithic Sweet Track bordering the Shapwick Burtle. This research aimed to identify whether a spatial, stratigraphic and analytical approach to sediment analysis, and monitoring of groundwater chemistry, redox potential, water table depth and soil moisture (using TDR), could be used to characterise the burial environment at these sites more fully, and therefore inform on current and future in situ preservation potential. Central to this strategy was the identification of the extent of spatial and temporal variability within these parameters. The water samples have been analysed using ICP-OES and anion chromatography, and the sediment samples, using particle size analysis, XRD, XRF and loss on ignition.

Observations, results and interpretations are presented here, including a discussion on possible future directions for monitoring these two sites, and how this project is expected to contribute towards in situ preservation research more widely.

2.1 The Application of Macroscopic and Biomolecular Methods of Analysis to the Study of Bovine Tuberculosis in Zooarchaeological Assemblages

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Ancient DNA (aDNA) and mycolic acid analysis have been widely applied to the study of disease in past human populations. However, the study of animal disease using both macroscopic and biomolecular methods has been impeded by disarticulated assemblages and the lack of standard recording methods for palaeopathological conditions in animal remains. At present, researchers can draw little confidence that the consistent recording of lesions, their description or their differential diagnosis will ever form a routine part of zooarchaeological analysis. This research seeks to tackle these obstacles by combining the disciplines of zooarchaeology, human osteoarchaeology and biomolecular archaeology to the study of bovine tuberculosis (bTB).

The amplification of mycobacterial DNA from archaeological bone is fraught with problems associated with degradation; a problem derived from the complex taphonomic histories associated with zooarchaeological assemblages. However, promising results using real-time PCR indicate that by targeting small template sequences associated with mycobacterial tuberculosis complex pathogens, aDNA can contribute to standard macroscopic methods by aiding in the identification of lesion specificity. In addition to this, the application of mycolic acid analysis alongside aDNA has produced encouraging results, providing a complimentary avenue of research. This multidisciplinary approach should help to create a better framework of practice for palaeopathological recording in zooarchaeology and assist in the study of zoonotic diseases amongst early human populations. Preliminary results from recent studies on both modern and archaeological faunal remains will be presented.

2.2 Ancient DNA Reveals Domestication Process: The Case of the Two-humped Camel

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During the Bronze Age, Central Asia was characterized by a number of historic-cultural innovations. The domestication of the two-humped camel has forwarded remarkable progress particularly in cultural and economic development for ancient human civilizations in the steppes of Eurasia. Due to the archaeological record, camel husbandry gained importance in the course of the 3rd millennium BC and built the basis for long-distance trade between East Asia and Europe. But beside the great economical impact of the domestic camels for the inhabitants of the Central Asian dry-zones, the evolutionary relationship between *C. bactrianus* and the extant wild two-humped camel (*Camelus ferus*) as well as time, place and motifs of the origin of domestication of these animals remain unresolved.

Therefore a 458bp hypervariable fragment of the mitochondrial DNA control region was analysed in 12 bone samples of *C. bactrianus* from Late Bronze and Early Iron Age sites of Siberia and Uzbekistan. In a subsequent population genetic analysis sequences of the aDNA-samples were compared to 122 modern domestic Bactrian camels from China and Mongolia, 8 modern domestic Bactrian camels from German and Austrian zoos, as well as to 20 modern wild camels from Mongolia. The computed intra- and interpopulation diversity-indices are inconsistent with an ancestry of the wild *C. ferus* to both, the prehistoric and the modern domestic camels. On the contrary all domestic populations show a high homogeneity. Results lead to the assumption of a single domestication centre supposed to be in Central Asia, whereas the extant wild two-humped camel is not the progenitor of the domestic *C. bactrianus*.

2.3 Mitochondrial DNA provide insights on the origins of goats, pigs, cattle and Java deer from Mauritius

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Located in the southwestern Indian Ocean, Mauritius remained unsettled until the late 16th century when Dutch sailors officially claimed the island and introduced a number of plants and animals. Among the latter, goats (*Capra hircus*), pigs (*Sus scrofa*), cattle (*Bos taurus*) and Java deer (*Rusa timorensis*) are now found in abundance on the island. Little is however known of their origins. The present study aims to investigate their phylogenetic and phylogeographic origins using mitochondrial DNA (mtDNA) from 35 archaeological bone samples (11 goats, 9 deer, 6 cattle and 9 pigs) recovered from the excavation of Fort Frederik Hendrik, Mauritius.

The results have shown some correlation with historical records but have also inferred possible unrecorded introductions from other geographical areas. Documentary sources suggest a European origin of the goat. However, genetics here support a South Asian introduction. The origin of the pigs is more conclusive with all samples pointing towards a European origin, corroborating with the historical sources. The cattle appear to confirm the records with a first introduction from Madagascar. mtDNA analysis have revealed the possibility of a maternal taurine origin but have not excluded a possible paternal zebuine origin. A European cattle introduction is also supported. Finally, the Java deer have been attributed to the *Rusa* clade but due to little work conducted on this species and its sub-species, a more precise phylogenetic origin was not possible. This study shows the valuable tool that is mtDNA in reconstructing phylogenetic and phylogeographic origins of animals.

2.4 Investigating the goat domestication process using mtDNA sequences

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The spread of farming into Europe during the Neolithic is dependent on earlier developments in the Near-East. Routes of migration and exchange are important factors in the debate about how the Neolithic transition spread into Europe. Studying the genetic diversity of animal livestock can help in tracing back some of these past events. Notably, domestic goat (*Capra hircus*) did not have any wild progenitors (*Capra aegagrus*) in Europe before their arrival from the Near-East. Genetic studies on mitochondrial DNA have shown that the diversity of European domesticated goats represents a subset of that of the wild, underlining the ancestral relationship between both species. Additionally an ancient DNA study on Neolithic goat remains has suggested that a high level of genetic diversity was already present early in the Neolithic in northwestern Mediterranean sites. We used a coalescent simulation approach in order to shed light on questions of goat demography and migration around the time of their domestication. Coalescent simulations were performed under a number of reduced but plausible demographic models and the goodness of fit to observed data evaluated using Approximate Bayesian Computation. We use this to compare different models and estimate some key demographic parameters.

2.5 Stable isotope insights into domestic animal birth patterns at Bercy (Paris, France, IVth millennium BC)

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Bercy is a large prehistoric village settled on a bank of the Seine river (Paris, France). Its main occupation, attributed to the Chasséen septentrional, was dated to the very beginning of the IVth millennium BC. The domestic animal subsistence economy relied heavily on cattle husbandry, complemented by the raising of pig, sheep and goat. A stable isotope study was performed on cattle and sheep remains in order to investigate domestic animals birth patterns. Sequential sampling was conducted in tooth enamel. The measured $\delta^{18}\text{O}$ sequences were analyzed using a model mainly based on a cosine function, involving four parameters including the period of the annual cycle. Period was then used to normalize the distance from tooth crown where the key $\delta^{18}\text{O}$ values were measured, allowing direct comparison between individuals while eliminating variability in tooth size. Results suggest that sheep were lambing in mid-Spring, only slightly later than expected from what is observed nowadays in temperate Europe under similar latitude. Cattle were born over a period spanning approximately six months. This was unexpected compared with a two to three months calving period in modern free ranging cattle populations. A direct consequence of an extended calving period would be on the annual availability of cow milk, which would have covered the whole year at Bercy. This is important information in this context given that the exploitation of cattle milk by the human community was highly suspected from the demographic management of the herd on this very site.

2.6 Seasonality of birth and diet in pigs, from tooth enamel sequential isotope analysis ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$): a case study on the Celtic site of Levroux Les Arènes (France)

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Pig birth seasonality or food supply remain difficult to assess with conventional archaeozoological methods.

A pilot study involving sequential sampling of mandibular teeth (I1, I2, C, M2 and M3) for stable carbon and oxygen isotope analyses of enamel bioapatite, was performed on modern domestic pigs with known history, including Corsican traditional free-ranging pigs. Results show that birth seasonality can be investigated on incisors, while male evergrowing canines provide a high-resolution record of particular interest to investigate seasonality of diet.

The protocol was applied to the archaeological assemblage of Levroux Les Arènes (Indre, France), founded at the beginning of the second century BC. Previous studies on pig herd management at this site had lead to the hypotheses of two farrowing seasons for domestic pigs, which would have been raised inside the settlement, possibly fed on refuses of human food production. Results from the stable isotope study are in accordance with two farrowings per year. However, they also suggest that most of the sampled pigs were raised outside the village, with possible consumption of beechnuts and acorns during autumn in some cases. The diversity of diet patterns might reflect the diversity of herding strategies or opportunistic behaviour of domestic pigs kept under extensive conditions. Alternatively, it could be explained by trading between Levroux and the surrounding farms.

2.7 Autonomous uptake of dairying as a subsistence strategy in the Libyan Sahara in the fifth and sixth millennium BP

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In Africa, unlike the Neolithic of Europe and the Near East, a reliance on cattle, sheep and goats emerged as a widespread way of life long before the first evidence for domesticated plants or settled village farming communities. In the Libyan Sahara the Takarkori Rock Shelter contains archaeological deposits of exceptional preservation, yielding evidence of human occupation over the interval 8300-4000 years BP (Biagetti and di Lernia 2007). This was a period of dramatic climate and environmental change, which marked a change from a long wet, humid phase in the early to middle Holocene to arid conditions at 5.9 to 5.6 kyr cal BP (Brooks 2006, Cremaschi 2002). In addition to morphological plant and animal remains excavations have yielded appreciable numbers of potsherds.

This paper will present results of an investigation of organic residues preserved in the fabric of these unglazed pottery vessels. Following solvent extraction gas chromatography (GC) and GC-mass spectrometry (GC-MS) have been used to determine the identities and distributions of plant and animal lipids in the archaeological ceramics from Takarkori, and other sites in the region. GC-combustion-isotope ratio MS (GC-C-IRMS) was applied to determine stable carbon isotope compositions ($\delta^{13}\text{C}$ values) of fatty acids to identify animal fats, including milk fat. Previous studies have confirmed an independent cattle domestication event in Africa (Hanotte *et al.*, 2002) and these data therefore provide clear biomolecular/isotopic evidence for an autonomous uptake of dairying practices as a subsistence strategy in the Libyan Sahara in the fifth and sixth millennium BP.

2.8 ‘He maketh me to lie down in green pastures: he leadeth me beside the still waters’? The contribution made by sheep and shepherds to Central Anatolian herding decisions in the later Neolithic; the use of dental microwear and oxygen isotope analysis

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Sheep evolved to inhabit a particular niche, where their breeding behaviour is in synchrony with seasonal environmental resources. Domestication offers the opportunity for manipulation and, in early herding societies, limited adjustments – to resource provisioning, birth seasonality, herd-partitioning and movement – might have emerged as a result of interplay of environmental and social pressures. The task is to investigate innovative practices in prehistoric contexts.

Shepherding requires, first and foremost, detailed knowledge of sheep ethology and seasonal graze availability. The zoological and agricultural sciences, in conjunction with indigenous knowledge, offer a model of sheep seasonal behaviour; environmental sciences model palaeoenvironmental evidence to suggest a likely herding taskscape.

The evidential dataset presented here is highly contextual with tight temporal resolution. Oxygen isotope analysis of tooth enamel offers an insight into birth seasonality and into the ensuing herding environment. From the same tooth, dental microwear gives evidence of seasonal diet just before death. In combination, these data allow interpretation of aspects of the seasonal management of breeding, fallow and slaughter herd-parts.

The case-study is the late pre-ceramic and ceramic settlement of Çatalhöyük in Central Anatolia (7400–6200 cal. BC). Data is taken from 72 sheep teeth from secure contexts, selected to elucidate any manipulation in sheep behaviour during the duration of the settlement.

2.9 Cattle congregations? An investigation of cattle movement in Late Neolithic southern Britain

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Strontium isotope analysis of tooth enamel has suggested that cattle travelled from a diversity of locations to the Late Neolithic site of Durrington Walls (Viner *et al.* 2010). During a relatively short period of use, cattle were brought to the site from non-chalk areas and in some cases must have traversed hundreds of km. Such a massive undertaking suggests a strong motivation was acting on the people that gathered at the site, along with their animals, for feasting events.

Although it provided a glimpse of the mobility of cattle during the Late Neolithic, the pilot study was limited by its small size (13 specimens) and its focus on a single site. This paper will present the results of further investigation into the movement of cattle onto the chalkland during the Late Neolithic. Using strontium and oxygen isotope analysis a further 75 teeth, almost the entire sample of cattle third molars from Durrington Walls, have been analysed. In addition, the investigation was extended to include a small amount of contemporary material from Stonehenge and the West Kennet palisade enclosure. The local versus non-local origin of cattle at the sites studied will be discussed, along with the possible geographical area of origin and the distances covered in order for them to reach the area.

This research is funded by a grant from the AHRC and is being undertaken as part of the Feeding Stonehenge project.

2.10 Tracking the Iron Age nomads of the Altai region: isotopic analyses of horse tooth enamel from funerary barrows

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The ephemeral nature of pastoral nomadism leaves few traces in the archaeological record with which to study the functioning of these communities. Although the Iron Age peoples of the Altai region did not build permanent settlements, they did construct kurgans (funerary barrows), which on occasion include depositions of horses. As horse teeth grow, enamel records isotope compositions related to water and food consumed during the period of its mineralization as a continuous record covering several years. Carbon, oxygen and strontium isotope compositions provide information on diet, seasonality of the climate, and movements. This paper discusses results of a project to explore the movements and social connections of these nomadic groups through such isotopic analyses of tooth enamel from horse burials excavated from first millennium BC funerary barrows. The sites considered here are Tsengel Khairkhan and Baga Turgen Gol in the Mongolian Altai. The isotopic results from these sites contribute new data on the movement of horses within the landscape, which deliver new insights into the social and economic lives of these Iron Age nomadic communities.

2.11 Silence of the Lambs – Reconstructing the Pilgrimage Economy of Jerusalem during the Early Roman Period

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During the Early Roman Period (between the reign of King Herod and the destruction of the temple; 130 B.C. – A.D. 70) Jerusalem established itself as a major urban centre due to the importance of its temple to Jewish ritual practice. Historical and religious texts that postdate this period emphasize the importance of large-scale pilgrimage to the temple economy. Few archaeological remains, however, have been recovered to support the texts. This study fills the gap in the material evidence by reconstructing the impact of pilgrimage on Jerusalem's economy during the Early Roman Period using the isotopic values of goat and sheep remains. The carbon and nitrogen isotope ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) values of sheep and goat bone collagen from Jerusalem's city dump were used to reconstruct the environmental origins of animals consumed in the city. Due to the steep climatic gradient between Mediterranean and desert environments in the southern Levant, it is possible to differentiate local versus imported herd animals and the environments in which the animals foraged. Using a conservative estimate, no less than 30% of the goat and sheep consumed in the city during the early Roman Period were imported from desert regions beyond the province of Judea. To the contrary, almost no animals were brought to Jerusalem directly by pilgrims from major Jewish concentrations in the mesic Mediterranean upper Galilee. The isotopic data suggest that large-scale inter-provincial importation of animals into the city was used to meet pilgrimage needs and supported the local economy.

2.12 Animal Husbandry in New World Colonial Fishing Stations: Insights from Stable Isotope Analyses

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The island of Newfoundland, on the east coast of Canada, was seasonally visited and settled by cod fishermen from various European nations after the 16th century and onwards. Animal products were an important dietary component for sea farers involved in these transatlantic enterprises. Traditional archaeozoological analyses from early fisheries have illuminated several aspects of livestock and meat product use from early European contexts in Newfoundland. However, these cannot provide information on animal feeding practices and have a limited capacity for distinguishing between animals husbanded on the island versus those raised in Europe and transported overseas as live or barrelled products. Here, we present a substantial stable carbon and nitrogen isotope data set collected from the bone collagen of domestic and wild fauna (n= 150) excavated from a seasonal French and a permanent English fishing station in Newfoundland. This information is used to identify transatlantic animal husbandry practices. Our results indicate differing approaches to the provisioning of animal products between French and English cod fishing operations (and seasonal vs. permanent settlements) and allow for the identification of transatlantic origin of certain livestock species.

3.1 Can we establish a robust relationship for oxygen isotopes between the phosphate and structural carbonate components of human teeth?

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It is now accepted that human tooth enamel preserves life signals through the oxygen isotopes contained within. In this presentation we demonstrate that oxygen isotope ratios in the structural carbonate ($\delta^{18}\text{O}_\text{C}$) component of enamel are robustly preserved by comparison with phosphate oxygen ($\delta^{18}\text{O}_\text{P}$) derived from the same archaeological samples. The $\delta^{18}\text{O}$ analysis of the phosphate oxygen fraction of bioapatite has been favoured in the past because of its relative abundance and molecular stability compared to $\delta^{18}\text{O}$ analysis of structural carbonate. However, this study establishes a direct relationship between phosphate and carbonate derived oxygen for humans and provides a conversion equation between data derived from either source. We also establish the maximum errors for using the new conversion equation and extend these to calculate errors encountered in determining drinking water $\delta^{18}\text{O}$ for use in archaeological and environmental studies. During the course of the study we have tested the robustness of the analytical procedures employed for carbonate analysis (in terms of the effect of reaction time, reproducibility of standards and duplicate samples), the effect of acetic acid leaching of material, and have also investigated within tooth heterogeneity. This is the first comprehensive study of the relationship of oxygen isotopes between the ionic forms of oxygen (phosphate oxygen and structural carbonate) in archaeological human dental enamel.

3.2 Did they stay or did they go? Finding answers on mobility and diet in the Bronze Age Western Eurasian steppes using isotope analyses

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What was life like in the Western Eurasian steppes in the Early Bronze Age? The answers to this question were investigated in a three year PhD project within the wide-framed *Topoi* research cluster at the Freie Universität Berlin. To reconstruct mobility patterns and palaeodiet of the Eneolithic and Early Bronze Age Steppe cultures we applied isotope analyses on samples from about 30 sites in the Northern and Western Pontic regions. The use of strontium and oxygen isotope analyses helped to answer questions on the mobility of single individuals and small groups. The geological homogeneity of large parts of the steppes made it difficult to draw conclusions about small-scale seasonal mobility. However, strong correlations between strontium and oxygen isotope ratios propose different points of origin or seasonal mobility for a number of individuals.

A small number of sites located in different regions of the study area were also sampled for carbon and nitrogen isotope analyses in order to get more information about the Early Bronze Age people's diet in the steppes and steppe-like regions. Although the number of samples was small, there are obvious correlations between the results of different stable isotopes. Here we will present some of our results, which significantly contributed to answering the question posed at the beginning of this project.

3.3 Pioneering agricultural contact across the Eurasian steppe: phylogeographic signals in broomcorn millet (*Panicum miliaceum*)

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Broomcorn millet (*Panicum miliaceum*) is one of the world's earliest domesticated crops. This millet species was a staple cereal of the north China centre of agricultural origins, where evidence from macrofossils, phytoliths and stable isotopes has shown that it was cultivated from at least 10,000 cal BP. Broomcorn millet remains are also known from a number of pre-7000 cal BP sites in eastern Europe, making this the earliest crop plant to show a pan-Eurasian distribution. We used microsatellite markers to investigate the phylogeography of 98 broomcorn millet landraces spanning a range from central Europe in the west to Japan in the east. Our data show a strong phylogeographic signal with a marked east-west split. The genetic differentiation observed could potentially reflect either independent domestications in China and eastern Europe, or a founder effect in westward spread stemming from a single centre of origin in northern China. We discuss these hypotheses in respect of the fine detail of the phylogeographic patterns observed and the quality of the existing archaeobotanical record. Our results provide evidence for pioneering cross-continental contact across the semi-arid steppes and Central Asia, perhaps along the routes that later became the Silk Roads. This agricultural contact predates evidence of trade in material goods by around 4 millennia.

3.4 A biomolecular study into the lifeways and genetics of prehistoric human populations from Newfoundland

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The island of Newfoundland is situated on the northeastern edge of North America and has evidence of human occupation for over 7,500 years. Of the numerous archaeological defined indigenous groups from Newfoundland, the Beothuk (or 'Red Indians') were the last to occupy the island and yet they remain one of the most enigmatic. What is known of Beothuk lifeways has been largely acquired from historic accounts of interactions with early European settlers, and there is little direct evidence for their diet, subsistence strategies, and their genetic relationships with other native North Americans. Here we present results of an on-going multi-disciplinary investigation into the lifeways and genetic makeup of the Beothuk using biomolecular methods of isotope and aDNA analyses. These results will be discussed and put into context with other prehistoric native groups in the region.

3.5 Diversity in the LBK: using isotopic analysis to investigate lifeways and regional variation in the early Neolithic

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The use of archaeological science is at its most powerful when it is carefully integrated with the archaeological evidence. Following this approach, in September 2008, a three year project was started between the Universities of Cardiff, Durham and Oxford, entitled '*The first farmers in central Europe: diversity in LBK lifeways*' and funded by the *Arts and Humanities Research Council UK*. This project is investigating a range of different isotopes (carbon, nitrogen, strontium, calcium and oxygen) from both humans and animals, with the aim of incorporating the results with a detailed consideration of their archaeological context. The main objectives are therefore to use the isotopic results to explore patterns of diet, health and movement and hence to facilitate the investigation of diverse lifeways in the central LBK. This early Neolithic culture has previously been studied either as a monolithic entity or considered in a large number of detailed regional investigations, but rarely does research cross the regional or national boundaries of Europe. In this paper, we will present the stable isotope results from the project, examining regional variance in the human and animal data.

3.6 6000 years of migration and 15 years of measurements- what do we know about human movement across Britain?

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Over the last ten years about 650 samples of human tooth enamel have been analysed for strontium and oxygen isotopes at the NERC Isotope Geosciences Laboratory (NIGL). This makes it possible to look at isotope variation within and across Britain, characterize trends and assess the possibility of defining limits for British data sets. We present a comparison of direct measurements of enamel with proxy populations to assess the validity of the proxies, consider the possible cause of asymmetry in the Sr concentration data with Britain, and compare the probability of a British childhood origin for certain groups of individuals.

3.7 Towards the construction of a strontium isotope map of the world: Application to archaeological science

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Strontium isotope ratios have been used in archaeology for sourcing artefacts as well as human and animal populations over many decades and continue to be an important source of information. Integral to this approach is the comparison of strontium isotopes in human and/or animal remains with geological sources. In order to facilitate such studies a number of publications over the past decade have sought to produce a strontium isotope map for comparison to archaeological remains. Beard and Johnson (2000) produced the first integrated map for the USA based on a numerical analysis of rocks of known ages, whilst other maps focusing on more specific regions have been compiled for the UK (Montgomery et al., 2006; 2007; Evans et al., 2009) and parts of Europe (e.g. Hoogewerff et al., 2001). However, there has not been a systematic study investigating strontium isotopes in geological materials across the globe to consider how the applications of these data could be appropriate for archaeological science.

We present here a compilation of multiple datasets of materials analysed for strontium isotopes from which regional and global maps of strontium isotope distribution have been produced. We also present a simple model for mineral weathering to produce strontium isotope compositions for soils. We also introduce a revised model for strontium isotopes in seawater through time and consider the application for precipitated materials from seawater (such as carbonates).

These data have significant implications for a new methodological approach in Archaeological Science to enable the production of a global strontium isotope map.

4.1 Dietary adaptations in the Middle and Upper Palaeolithic of Eastern Iberia

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Isotopic analysis carried out in Neanderthals from cold environments indicate that in all cases Neanderthals were top-level carnivores and obtained mainly all dietary protein from large herbivores. In contrast, isotopic evidence from European Upper Palaeolithic modern humans portrays a wider range of dietary protein resources, including evidence of partial marine and freshwater consumption. We report here on the direct isotopic evidence for Neanderthal and Palaeolithic modern human diets in Eastern Iberia from Cova Negra, Abric del Salt, Cova del Parpalló and Cueva de Nerja. Our results confirm that the top-predator model is also applicable to Neanderthals that lived in more temperate southern areas, although not as rigid as seen on northern Neanderthals, and that Palaeolithic modern humans from the Mediterranean are definitely intensively exploiting and consuming marine resources. A clear isotopic dietary shift is hence described for Eastern Iberia between the Middle and Upper Palaeolithic.

4.2 The exception that proves the rule: an isotopic investigation on the role of marine resources in the diets of early Holocene Mediterranean humans (Grotta dell'Uzzo, NW Sicily)

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The role of marine resources in the diets of early Holocene humans living in the Mediterranean Basin has still not been fully clarified. Here, we present the results of carbon and nitrogen isotope analyses undertaken on human and animal bone collagen from skeletal remains recovered at Grotta dell'Uzzo in NW Sicily to investigate this research question. Excavations at this site unearthed burials containing remains of thirteen hunter-gatherers, as well as isolated human bones from Mesolithic and Neolithic deposits. The isotope analyses on the skeletal remains from Grotta dell'Uzzo suggest that the main source of dietary protein for the humans in question was the meat of terrestrial mammals, in line with palaeodietary reconstructions based on faunal remains. Marine resources constituted a significant proportion (up to around one third) of the diet during the so-called Mesolithic-Neolithic transition phase, when the last hunter-gatherers of NW Sicily consumed not only shellfish and fish, as in other phases of the Holocene, but, importantly, also the meat of stranded cetaceans. In the early Neolithic, a period characterized by a mixed economy based on hunting, gathering, fishing, herding and farming, the contribution of marine resources to human diets declined progressively. Intriguing isotopic evidence for the introduction of domesticated animals to NW Sicily directly from the eastern Mediterranean will also be presented, throwing new light on the spread of the Neolithic in the central and western Mediterranean.

This research was supported by a Marie Curie Intra-European Fellowship within the 7th European Community Framework Programme, grant number PIEF-GA-2008-219965, and by the Max Planck Society.

4.3 Re-interpreting the Jomon-Yayoi Transition Using Stable Carbon and Nitrogen Isotopic Evidence

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Transitions to agriculture mark a paradigm shift in the lifestyle of a population. Debates surround the nature of the Japanese transition to farming; was it gradual or revolutionary? This study uses stable carbon and nitrogen isotope analysis of human and faunal bone collagen to examine the potential for dietary change over the Jomon-Yayoi transition in western Japan. This transition represents the shift from the complex hunter-fisher-gatherer Jomon period (14,500-800 B.C), to the full establishment of rice agriculture during the Yayoi period (800BC-300AD). Archaeologically, this shift was accompanied by new pottery, tools, iron, bronze, new settlement patterns, religion, and language, and spread over nearly all of Japan in less than 300 years. Although archaeobotanical evidence for domesticated rice and millet predates the transition, these scattered and infrequent finds are interpreted as the results of casual exploitation by hunter-gatherers. Despite the existence of narratives which support a "Neolithic Revolution" and other models which highlight continuity between the periods, the mechanism of the introduction of agriculture to Japan is still unclear. This new data will elucidate dietary aspects of the Jomon-Yayoi transition directly from the human remains with the aim to determine the mechanism for this transition. This project was funded by the University of Cambridge, Darwin College (Cambridge) and the Japan Foundation.

4.4 Diachronic reconstructions of hunter-gatherer diets in prehistoric Western Alaska through the stable isotope analysis of permafrost-preserved hair

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Recent excavations have unearthed the remains of a well-preserved prehistoric Yup'ik Inuit village close to Quinhagak, Alaska. This Thule-era site (650±40 cal BP) includes permafrost-preserved house-floors with *in situ* artefacts and tools, and an extensive bioarchaeological assemblage including animal bone, fur, and human hair. Preliminary investigation of another Western Alaskan site at Nash Harbour, Nunivak, has also yielded a rich organic assemblage including earlier Norton-age human hair and animal remains (1750±40 cal BP). These finds represent a unique opportunity to investigate pre-contact Alaskan subsistence strategies and diet, and explore the relationship between Norton and Thule cultures. Here, we present stable isotope $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ data from a pilot study of human hair from the two sites, providing a direct measure of diet; specifically, the trophic level of protein consumed and the relative contribution of marine and terrestrial protein in the diet. Isotope data from contemporary marine and terrestrial fauna at the sites provide a 'baseline' for the interpretation of human stable isotope data. The preliminary isotope data suggest a heavier reliance on marine mammal protein amongst the earlier Norton group, and the greater inclusion of terrestrial animal protein amongst the later Thule group and/or the increased consumption of lower trophic level marine foods. This analysis provides evidence for a potential dietary shift amongst Western Alaska's early Inuit groups, and has implications for our understanding of human adaptation in the Arctic, and regional and temporal variation in early Inuit subsistence.

4.5 La Isla Bonita? Diversity and Specialisation in Insular Environments

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The rich archaeological resource of the Outer Hebrides has been the subject of ongoing archaeological science research for over twenty years. Over this time bioarchaeology has come of age and what began as a traditional examination of artefacts and ecofacts has expanded to embrace new technologies. Islands and coasts are of particular relevance to debates on the nature of human animal relationship over time. These sites provide a rich archaeological resource with excellent preservation and evidence for continuous human occupation from the Mesolithic onwards. As the subject of relatively recent research excavations they have also been subjected to modern excavation strategies with excellent recovery and stratigraphic control.

This paper will examine the themes of diversity and specialisation in insular environments. The range of species exploited throughout time is much higher than on mainland British sites, hunting of marine and terrestrial animals, fishing and foraging remain essential components of the human lifeways up to the present day. This paper presents a synthetic analysis of the traditional assessments of diet (e.g. zooarchaeology) in tandem with both human and faunal isotopic evidence and pottery residue analysis to fully explore the nature of insular diets. There is also evidence for the specialisation of animal exploitation (both domestic and wild) in terms of their introduction and management, and new results from aDNA will be presented. Finally - at death as in life - bioarchaeological analyses have provided new insights into insular burial practises for both humans and animals.

4.6 *The fish without a signal.*

Can stable isotopes document diet changes in historical human populations from Belgium?

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For Belgium, changes in both freshwater and marine fish consumption during historical times are well documented by archaeozoological research. An assessment of the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ signals of the most common animal food sources (local freshwater fish, North-Atlantic marine fish species and local terrestrial, domesticated mammals) suggests that the proven changes in fish consumption should be reflected by shifts in the stable isotope values of the human skeletal remains from archaeological sites dating from early medieval to postmedieval times. However, on a macro-level (comparing sites from the whole of Belgium) diachronic trends seems difficult to ascertain. Nevertheless, a case study on a micro-level (dealing with a single site: a mixed lay and monastic population from the postmedieval Carmelite friary burial grounds at Aalst) shows that a differentiation of the diet in terms of animal protein input can clearly be traced within a population. Why then is such differentiation invisible on a wider scale? Are we dealing with problems of sample resolution or are more fundamental issues at stake regarding our interpretational approach? The paper will present an overview of the stable isotope data available from animal and human bones from early medieval to postmedieval Belgian sites and will confront them with the archaeozoological record for the same periods and locations.

4.7 Testing collagen amino acid stable isotope dietary proxies using animal feeding experiments, reference organisms and archaeological populations

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Archaeological and palaeoecological investigations are drawing increasingly on the stable isotope compositions of the hard and soft tissue remains of fossil organisms to reconstruct a wide range of aspects of dietary behaviour and ecosystem characteristics. Collagen is one of the major biomolecules targeted due to its structural importance and widespread survival in the fossil record. While determinations of whole collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values have been highly informative of palaeodietary preferences and habitat palaeoecology, in order to properly understand the stable carbon and nitrogen isotope signatures (and indeed of other isotopes) investigations have to be performed of the isotopic compositions of the building block amino acids that comprise the complex collagen macromolecule. Where this has been undertaken sources of variation have been revealed and new proxies recognised (Hare *et al.* 1991; Howland *et al.* 2003; Corr *et al.* 2005; Jim *et al.* 2006).

One such proxy is the $\Delta^{13}\text{C}_{\text{Glycine-phenylalanine}}$ proxy carried by collagen revealed during investigations of high marine protein consuming humans from the Western Cape region of South Africa (Corr *et al.* 2005). We have now tested this proxy extensively by analysing collagen amino acids isolated from (i) a wide range of modern *comparanda*, (ii) tissues from an animal feeding experiment using pigs as digestive analogues for humans, and (iii) archaeological humans from Europe. The amino acid $\delta^{13}\text{C}$ values, determined directly from collagen hydrolysates by LC-IRMS, confirm the wide utility of the $\Delta^{13}\text{C}_{\text{Glycine-phenylalanine}}$ proxy for detecting the consumption of marine resources.

4.8 Investigating archaeological bone collagen at the amino acid level using liquid chromatography-isotope ratio mass spectrometry

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Archaeological bone 'collagen' plays an important role in the field of archaeological science as it is the substrate of choice for isotopic analysis for palaeodietary investigations and for radiocarbon dating of bone.

Diagenetic factors (and methodological variations) have the potential to bias the nature of the 'collagen' extract and the interpretations made from them. It is to be expected that diagenesis will be evident as changes in the amino acid content of the 'collagen' extract and might cause isotopic fractionation.

We will present results of a study where we have analysed collagen at the amino acid level, extracted from bones with a range of diagenetic types (i.e. varying levels of collagen preservation/with and without microbial attack). Hydrolysed collagen extracts were analysed using liquid chromatography-isotope ratio mass spectrometry (LC-IRMS), which provides quantification and carbon isotopic analysis of the constituent amino acid fractions of the collagen. Furthermore, each collagen extract was ultrafiltered to produce a range of size fractions and each fraction was investigated. We will discuss the results and interpret them in terms of collagen preservation, methodological considerations and how they impact on isotopic analysis of bone collagen.

4.9 Keratin degradation and multi light stable isotope analysis of archaeological wool samples

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The production and international trade of raw wool and wool textiles was of central economic importance to Britain in the later medieval period (1200-1500AD). An analytical method to establish the origin of finds of cloth, cordage and wool from waterlogged deposits would complement the art-historical/structural analyses developed in the 20th century.

Mammalian hair fibres consist of several hundred keratin proteins, which decay at different rates under burial conditions. The application of multi light stable isotope analysis of carbon, nitrogen and (un-exchangeable) hydrogen, which has been used to identify provenance in studies of modern sheep tissues (Camin F *et al* (2007) *Analytical and Bioanalytical Chemistry* **389**:309-20, Hedges REM *et al* (2005) *Rapid Communications in Mass Spectrometry* **19**(22):3187-91), must therefore consider the effect of taphonomic change on amino acid content and hence isotope ratios. This contrasts strongly with analysis of the protein fraction of bone, essentially a single-protein system with a catastrophic degradation profile (Dobberstein R *et al* (2009) *Archaeological and Anthropological Sciences* **1**:31-42).

This presentation will cover the protein structure and amino acid composition of wool fibres. Composition and isotope data from experimentally buried and laboratory-degraded wool textiles will be presented. Isotope results from analysis of medieval wool textiles from Iceland and Britain will be considered for evidence of trade. A number of methodological features of the determination of hydrogen isotope ratios of proteins will be discussed.

4.10 Quantitative and Qualitative Investigations of Lipid Residues in Modern Luo pottery from Lake Victoria, Kenya: Implications for Archaeology

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Molecular and isotopic investigations of lipid residues preserved in association with ancient pottery vessels have grown in sophistication over the last two decades. Understanding how much and where organic matter is taken up into pottery vessels during use has been supported by experimental studies but very little work has been undertaken on ceramic containers used in modern communities. One advantage of studying ethnographic pottery is that the lipid profile is likely to show a more representative and possibly more complex picture of actual pottery use in the past since the vessels are likely to have longer use-lives reflecting many more food preparation episodes than is feasible in laboratory-based experimental scenarios.

Our aim is to explore whether lipid analysis of modern pottery from ethnographic contexts can aid the detection of dietary components in lipid residues from archaeological ceramics. The pottery selected has been used over relatively long periods of time (years) and, as far as informants report, for repeatedly cooking the same foodstuffs. Working with samples that have not been subject to burial enables us to explore how much lipid is absorbed during use, where the lipid is absorbed in the vessel and the degree to which lipid biomarker and bulk carbon and nitrogen isotope determinations can pinpoint specific foods associated with specific pots. In addition the presence and fate of non-lipid food components can also be evaluated from the data obtained. The implications for archaeological interpretation of pottery vessel use are addressed.

4.11 Investigation on the influence of C₄ plants on the isotopic composition of adipose and dairy fats

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The pottery excavated from archaeological sites contain biomolecular information relating to food processing and storage, most commonly in the form of lipids, preserved in the porous clay wall, or in carbonised matter adhering to the pottery surface (Evershed 2008). Such information can be accessed using chromatographic, spectrometric and, more recently, isotopic methods, to infer the source of the degraded fats that dominate lipid assemblages. The fatty acyl lipid distributions and their isotope compositions ($\Delta^{13}\text{C}$ proxy) enable distinctions to be drawn between domestic ruminant and non-ruminant, and adipose and dairy fats (Evershed *et al.* 1999; Copley *et al.* 2003). Thus, the study of potsherds in this way can provide important insights into the economy and management of domesticated animals within a site or region (Dudd and Evershed 1998; Copley *et al.* 2005; Evershed *et al.* 2008). As C₄ plants (e.g. maize) were mainly introduced to Europe after the discovery of Americas, the diet of European prehistoric animals would mainly have consisted of C₃ plants. Thus, up to now, research has focused on animals raised on C₃ plants. Extensive samplings of adipose and dairy fats from UK animals raised on a restricted C₃ diet and of fats from Eurasian Steppe animals were carried out by Dudd (1999) and Stear (2008), respectively. This presentation extends the investigation of molecular and isotopic compositions of lipids and carbohydrates from C₄ plants and of lipids from adipose and dairy fats of animals raised on mixed C₃/C₄ diets, in order to confirm that the $\Delta^{13}\text{C}$ proxy still holds in mixed C₃/C₄ environments, e.g. in prehistoric Africa.

5.1 Unraveling the complexity of the Austronesian expansion and dispersal

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The peopling of Oceania over the last three millennia marked the culmination of a global colonization process that began when humans left Africa. Several models, which attempt to explain the origins and dispersal of Austronesian farmers through ISEA into Oceania have been proposed, all of which rely upon traditional lines of evidence (material culture, linguistics and modern human genetics). Several models that describe the origins of the Lapita cultural complex (the immediate ancestors of the Polynesians and many other Oceanic cultures) focus on a single and complete cultural and biological package moving from Taiwan to the Pacific. These contrast with others that claim the origins of Lapita to be found across broader regions of mainland Asia and even ISEA.

Because pigs are intimately linked with human dispersal history, the primary aim of our project is to test the 'Out of Taiwan' model as an explanation for the Austronesian origins and their dispersal into the Pacific using domesticated animals as proxies. Methodologically, we will combine two techniques: geometric morphometrics and ancient DNA. By exploring both dental morphologies and genetic signatures (mitochondrial and nuclear DNA) from modern material and archaeological collections from Southern coastal China, mainland South East Asia, Taiwan and ISEA we will be able to correlate data in the same specimens across two different levels of biological organization. Though our project is in its early stages, I will present preliminary data how both tooth shape and genetic data is shedding new light on the origins of the pigs in Austronesian.

5.2 Identifying Chemical Markers for Anomalous Radiocarbon Dates from Surface Organic Residues

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Surface residues recovered on archaeological pottery have become a valuable source of samples for radiocarbon dating. The use of Bayesian statistics for chronological modelling has highlighted how important it is that items being dated are not residual within the archaeological context from which they are recovered. Pottery residues from groups of refitting sherds are therefore particularly desirable, alongside other sources of dates.

However it has been discovered that pottery residues are more likely to return anomalous results, when included in Bayesian models, than other sample types. Approximately 15% of the measured ages are non-reproducible between laboratories and are statistically inconsistent with the other information included in the models. Dates that are both too old and too young are encountered. There does not appear to be a correlation between the anomalous ages and laboratories or methods of sample pre-treatment. It appears therefore that there is some form of contamination present in a proportion of the dated residues.

Rigorous chemical characterisation of a range of relatively abundant residues is being undertaken at the molecular level in order to identify the chemical features of residues that will return an anomalous radiocarbon date. Analyses focus primarily on the use of pyrolysis-gas chromatography/mass spectrometry (py-GC/MS), alongside other techniques, such as Fourier transform infrared spectroscopy (FTIR), organic elemental analysis (C/H/N) and solid state cross-polarisation magic angle spinning nuclear magnetic resonance spectroscopy (CP/MAS NMR), providing complementary composition information. The results of this study will be presented with a view to identifying a pre-treatment to remove the contamination or an appropriate screening process to eliminate residues likely to return anomalous radiocarbon dates.

This presentation replaced the talk by Kirke et al. (Saturday 14:15–14:30)

5.2 Tracing economic patterns from the Neolithic to the Late Norse period on Shetland through the application of lipid biomarker and compound specific stable isotope proxies to organic residues preserved in pottery.

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The analysis of absorbed residues preserved in pottery offers the opportunity to identify processing of particular commodities in vessels in antiquity. Although the original fatty acid composition of many commodities may be altered due to the loss of more unstable components, the stable carbon isotope signature of the more persistent fatty acids is preserved over millennia and may be exploited as a means of distinguishing fats of different origins. Further, more stable products, such as vicinal diols and ω -(*o*-alkylphenyl)alkanoic acids, may arise via the degradation of unsaturated components, which preserve the carbon chain length of the original fatty acid components (Hansel et al. 2004; Craig et al. 2007; Evershed 2008; Evershed et al. 2008; Hansel & Evershed 2009). Whilst these products are often present in only very low concentrations, operating the GC/MS in selected ion monitoring mode enhances the sensitivity of the instrument significantly, and has the potential to reveal these biomarkers at concentrations that would otherwise be undetectable. Thus, by employing these stable isotope and highly sensitive lipid biomarker proxies to pottery residues, the detection of products characterised by high abundances of highly labile components, such as marine fats and oils, becomes possible.

Our current research has encompassed the investigation of residues from ~ 1000 sherds dating from the earliest Neolithic through to the Viking/Norse period at coastal and island locations, as a means of tracing economic and subsistence strategies and the fluctuating importance of marine products. Here we present findings from one of our island locations (Shetland), from which we have investigated residues from 90 sherds representing four sites, spanning the Neolithic to the Late Norse period. The combination of lipid biomarker data with stable carbon isotope proxies, to which we have added an extensive new body of reference data that represents likely exploited marine species, has revealed a predominantly ruminant-derived economy with a strong emphasis on dairy products in the Neolithic. Marine products appear unimportant before the Iron Age, whilst appearing to be the dominant resource processed in pottery by the Late Norse period.

5.3 Reconstructing past water availability using plant carbon and nitrogen stable isotopes: (im)possibilities of the method

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Stable isotope ratios of archaeological plant remains have been used to reconstruct past water availability, both as rainfall and related anthropogenic practices such as irrigation. The use of the method is based on the relationship between plant carbon stable isotopes and water availability as attested in modern crops. Because the method is potentially very valuable but its application to archaeological samples is relatively new, this research seeks to improve its empirical basis and test the suitability of archaeological samples.

Experimentally grown cereals were used to assess the relationship between water availability, other environmental variables, and the crops' stable isotope ratios. Wheat, barley and sorghum were grown at five different irrigation regimes at three different sites in Jordan for up to three years. Results indicate a relationship between water availability and carbon stable isotope ratios of wheat and barley grains, but one that is site-specific. No relationship between nitrogen stable isotope ratios and water availability was found, but significant differences in nitrogen stable isotope ratios were present between sites.

Grains were experimentally charred, which appeared to alter plant isotope ratios in a few cases, but these can be corrected for. In addition, samples were buried at sites in the UK and Jordan and retrieved after up to two years. Preliminary results indicate that burial of up to 18 months does not alter isotopic ratios in any systematic manner. This paper will thus argue that the method can be applied to archaeological samples for reconstruction of past water availability, but with limitations.

See linked poster #20.

5.4 Crop watering in Neolithic and Bronze Age Western Asia: the stable carbon isotope approach

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The provisioning of crops with sufficient water was central to the agricultural practices and economic strategies of early farming communities, particularly in regions where water was the primary limiting factor on crop production. In Western Asia the management and distribution of water resources has played a major role in socio-politics and settlement patterns. The water status of ancient crops offers a window through which agricultural water management practices can be investigated, and for over a decade the stable carbon isotope analysis of charred, macroscopic crop remains has been identified as a means of inferring the water status of ancient crops. The doctoral research discussed in this presentation aimed to validate, refine and apply the stable carbon isotope approach. The presentation will briefly outline the results of the experimental aspects of the research, followed by a discussion of the archaeological findings. The focus is on the prevalence and nature of irrigation in the Neolithic and Bronze Age of Western Asia, but the importance of hand watering techniques, garden cultivation methods, site locations, and the preferential treatment of different crops will also be discussed.

See linked posters #5, 21, 55.

5.5 Plants in palaeodiet: incorporating crop stable isotope ratios in dietary reconstruction

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In palaeodietary studies, the $\delta^{15}\text{N}$ values of plant dietary components are normally inferred from local herbivore values or assumed to be similar to generalised values for vegetation in relevant climatic zones. The lack of data pertaining directly to plant food has resulted in considerable uncertainty in palaeodiet studies, such as in estimation of the relative importance of plant and animal food in C3 terrestrial diets.

The Crop Isotope Project has demonstrated the potentially radical effect of manuring practices on $\delta^{15}\text{N}$ values in modern cereals and pulses, assessed the effects of charring on these values and developed cleaning procedures for the analysis of charred archaeological crop remains. We also conducted a large-scale isotopic study of ancient charred crop remains and (where available) collagen of associated fauna and humans from a series of Neolithic sites across Europe. We are thus able to include the actual isotopic values of major plant dietary components in palaeodietary interpretations and models. We present case studies to demonstrate the usefulness of crop $\delta^{15}\text{N}$ values from in palaeodietary studies.

See linked posters #5, 21, 55.

5.6 Seeing Through Walls: Çatalhöyük

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Pulsed terahertz imaging provides a non-invasive, non-contact, non-destructive method for determining the internal structure of optically opaque materials. Penetration depths of up to 1 cm are achievable in materials such as plaster, wood and clay in the reflection configuration. It is the combination of these properties that make this technology ideal for probing the construction and life histories of archaeological artefacts. One particular area of interest is the imaging of obscured wall paintings. Ultrafast pulses (less than one millionth of one millionth of a second in duration) penetrate the covering plaster and are reflected from internal paint layers. Spectral analysis of these reflected pulses provides information to differentiate obscured pigments, making the reconstruction of the obscured painting possible.

This technique is demonstrated by identifying the presence of sub-surface paint layers in samples of wall plaster from the archaeological site at Çatalhöyük, where the presence of Neolithic wall paintings was identified in 1963. Current methods to locate and visualize these works are, time consuming and destructive. Using a specifically designed post processing algorithm, the presence and approximate depth of sub-surface layers can be calculated. Additional spectral measurements of pigment samples from the site show differentiation between ochre based colours in the terahertz frequency range. This research demonstrates that pulsed terahertz imaging can be used to identify the location of obscured mural paintings and shows the potential for imaging in full, obscured Neolithic paintings at Çatalhöyük.

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5.7 Modelling the spread of Aurignacian material culture: Were the first modern humans in Europe ethno-linguistically structured?

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A high degree of structuring is seen in the spatial distribution of symbolic artefact types associated with the Aurignacian culture in Upper Paleolithic Europe, particularly the degree of sharing of ornament types. Multivariate analyses of these distributions have been interpreted as indicating ethno-linguistic differentiation, although simpler explanations such as isolation-by-distance have not been formally discounted. In this study we have developed a spatiotemporally explicit cultural transmission simulation model that generates expectations of a range of spatial statistics describing the distribution of shared ornament types. We compare these simulated spatial statistics to those observed in the archaeological record for Aurignacian Europe – using Approximate Bayesian Computation – in order to test and compare a range of hypotheses concerning group interaction dynamics for the period. Among the set of hypotheses examined, we include ones where material culture does or does not drive inter-group conflict.

6.1 Vikings, post-Vikings, and Volcanic Ash: Using tephrochronology to understand the relationship between environmental change and human settlement at Vatnsfjörður, Iceland

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In archaeology, it is crucial to establish accurate and precise chronologies before we can understand causation and correlation relationships between human settlement patterns and environmental change. Tephrochronology, which uses volcanic ash (tephra) layers to date stratigraphy, is a powerful chronological tool for archaeology and environmental science. Its ability to link archaeological and environmental sequences using tephra isochrones combined with the high level of precision possible from historically-recorded eruptions, eliminates much of the chronological uncertainty that other methods, such as radiocarbon dates, present.

Here I will present tephrochronologies from environmental and archaeological sequences from Vatnsfjörður, which is a landscape project combined with a multi-phase archaeological site in northwestern Iceland. Vatnsfjörður began as a large, high-status farm mentioned in the sagas, but it had dwindled to a small homestead by the early 20th century. In order to understand the relationship between environmental changes of the Little Ice Age, and the changes in fortune at Vatnsfjörður, I present a number of correlations of tephra layers from a lacustrine core, a peat core, and the archaeological site to known Icelandic eruptions. These provide absolute dates for the sequences, which are then used to interpret the relationship between environmental change over the past 1200 years and patterns of human settlement at the site.

6.2 Holocene Hydrological and Vegetation Changes in Ombrotrophic Bogs in Central Ireland: Implications for our Understanding of Climate History and Human Activities

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The results of a palaeoenvironmental study of an ombrotrophic raised bog (Littleton Bog, Co. Tipperary) are presented. The multi-proxy approach adopted utilises a combination of stable isotope (^{13}C and ^2H), plant macrofossil, pollen and testate amoebae analyses. The stable isotope data from *Sphagnum* plant macrofossils show a cyclical variation in ^{13}C and ^2H suggesting wetter and drier cycles from 800BC through to AD400. There are apparent lags in the responses of different proxies: the ^2H curve suggests a cooling trend until c.700BC, whilst the ^{13}C curve shows a consistent trend towards wetter conditions until c.550BC and vegetation communities, reflected in pollen and plant macrofossil data, indicate a stable bog surface until c.650BC after which wetter conditions are indicated. A warming phase indicated by ^2H at c.200-80BC is followed by dry conditions indicated by ^{13}C between c.100-86BC and by the plant macrofossils c.100-70BC. These proxies do, however, indicate a synchronous warm/dry shift at c.AD200. These data may also correspond to changes in the archaeology recovered from Littleton Bog: there appears to be a change in construction style between the Late Bronze Age and Early Iron Age trackways on the one hand and Late Iron Age platforms on the other. The construction of a stone and timber trackway in the Late Bronze Age is associated with stable and dry conditions, whilst the Late Iron Age platforms seem to be associated with more variable bog surface conditions. Littleton Bog, therefore, contains a sensitive and dynamic record of Holocene environmental change linked to a complex history of human activities.

6.3 Investigations into Late Quaternary Climate Change and Human Behaviour in North Africa: Isotopic Analysis of Mammalian Tooth Enamel

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Haua Fteah, in northeast Libya, provides one of the longest records of human occupation in North Africa, dating back to ~200 ka. During this time period the archaeological record shows significant changes in human behaviour, occurring against a backdrop of high climate variability. This has led to suggestions that climatic change was a driving force behind human behavioural developments. However, a direct link between climate and human populations remains to be established, in part due to a lack of climatological records that can be correlated with the archaeological record. The faunal assemblage from Haua Fteah provides the means to establish such a link.

Faunal material from an archaeological context can be directly related to human activity (thorough cut marks, burning, etc), while the isotopic analysis of such material can be used as a palaeoclimatic proxy. The $\delta^{18}\text{O}$ of mammalian teeth and bones is linked to the $\delta^{18}\text{O}$ of local meteoric water because mineralisation occurs in equilibrium with body water (at a constant temperature), and the $\delta^{18}\text{O}$ of the body water is determined by the water and vegetation an animal consumes, which in turn reflect the isotopic composition of local precipitation.

This paper presents palaeoclimatic interpretations from the isotopic analysis of *Ammotragus* (Barbary sheep) tooth enamel from Haua Fteah, from the most recent ~80ka. Patterns of climatic variability are discussed in relation to the archaeological record.

6.4 AMH and the Dansgaard-Oeschger events in northern Europe: an investigation using oxygen isotopes of faunal remains

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The initial colonisation of Europe by anatomically modern humans 50-20kya took place during a period of rapid, large-magnitude oscillations in climate known as the Dansgaard-Oeschger (D-O) cycles. Twelve such oscillations took place between 50-20kya, which have been associated with large fluctuations in mean annual temperature in the Greenland ice cores and periodic cooling to levels similar to those experienced during the coldest part of the last glacial cycle c.20kya. How these fluctuations affected climates and environments visited by early hunter-gatherers in continental Europe remains uncertain, however.

This presentation reports the results of an investigation into the human response to these D-O events at archaeological occupation sites in two focal study regions of Moravia (Czech Republic and south Poland) and the Kostenki site cluster (Russian Plain). Oxygen isotope analysis of mammoth (*Mammuthus primigenius*), horse (*Equus* sp.) and fox (*Vulpes vulpes* and *Alopex lagopus*) at 22 assemblages from 14 sites across the two regions are presented, including the Pavlovian "megasites" of Dolní Věstonice, Pavlov I, Milovice I, and Předmostí, and the early (>39kya) human occupation assemblages from Kostenki XIV (layers 4a and 4b). The climatic signal from the oxygen isotope data is interpreted in relation to palaeo-temperature at the time that humans occupied these sites, and the implications of the temperature differences between D-O interstadial and D-O stadial events is discussed.

6.5 Comparing isotope ecology across the Middle Palaeolithic - Upper Palaeolithic transition at St Cesaire, France

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The nature of the transition from Neandertals with Mousterian traditions and Upper Palaeolithic modern humans about 40- 30 Ka remains controversial. It has been suggested that they occupied distinct niches in Western Europe, as indicated by associated faunal assemblages. For instance one suggestion is that modern humans specialised on reindeer-hunting along major migration routes, whereas Neandertals remained dependent on more opportunistic exploitation of fauna. However, new understanding of the chronology of the transition suggests that sharp, high amplitude changes in glacial climates could also explain some faunal distinctions. We report here on the results of an isotope study of enamel from three species, Bos, Equus and Rangifer, sampled from the well-dated site of St Cesaire. It forms part of a larger study that is re-examining the chronology, subsistence strategies and ecology of Neandertals and early modern humans in sites over the transitional period from Mousterian to evolved Aurignacian assemblages. Oxygen isotope data, although generally offset from each other, show little in the way of patterned shifts through the sequence, suggesting either that the isotopic composition of precipitation differed little through these climate episodes, or that this approach lacks the required sensitivity to detect them. There is some evidence that carbon isotopes do change however, and carbon and oxygen isotope data together indicate niche differences between the species throughout the sequence. This is hardly surprising except that according to this data Rangifer niches varied and in some periods there is little evidence for a reliance on ¹³C-enriched lichens.

6.6 Earthworm secreted calcium carbonate – a new palaeothermometer?

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The chemical composition of calcium carbonate (CaCO_3) skeletons produced by a range of aquatic and terrestrial organisms has been proven to be a useful tool in palaeoenvironmental reconstructions. Oxygen isotope ($\delta^{18}\text{O}$) values are generally found to be in equilibrium with the environment, solely depending on oxygen isotopic composition of ambient water and temperature. Thus the oxygen isotope compositions of carbonates can be used to determine palaeotemperatures. Stable carbon isotope ($\delta^{13}\text{C}$) values of biogenic CaCO_3 are generally the result of mixing of different C sources ingested by the animal, and can shed light on ecological variables like vegetation composition and food sources.

Although they do not form skeletons, many earthworm species are true biomineralising animals, secreting millimeter-scale granules of calcium carbonate (CaCO_3). These granules are readily found in archaeological finds and buried soils. We are currently investigating the utility of stable isotope compositions of earthworm secreted calcite granules linked to the dating of single granules via U-Th dating for reconstructing past environments at sites of archaeological interest.

We have carried out experiments in which earthworms have been cultured under different temperature and CO_2 conditions. The granules have been collected and their carbon and oxygen isotopic signatures measured. We have used this information to determine the source of the carbon in the granules and also how the oxygen isotope signatures of the granules vary with temperature. This represents the first step in producing a much needed new terrestrial proxy for the reconstruction of past environments in archaeological and geological contexts.

6.7 Investigating the late-glacial climate warming and the Magdalenian re-colonization of the Northwest Europe

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The timing of the re-colonization of northwest Europe after the Last Glacial Maximum has been the focus of much research. Some researchers have suggested that the re-colonization occurred prior to the late-glacial abrupt climate warming. Thus non-climatic factors, most probably social developments, enabled humans to adapt better to the prevailing cold conditions, and hence to re-migrate into the region prior to any significant improvement in climate. Other researchers have suggested, however, that the rapid climate warming observed in the Greenland ice-cores (Greenland interstadial-1e) and the re-colonization of northwest Europe occurred synchronously and that the abrupt climate change triggered an equally abrupt and widespread response in human development at that time.

Linking ice-core and regional climate records to the evidence for human re-colonisation is challenging thus there is a need to develop high-resolution palaeoclimatic reconstructions, local to archaeological re-colonisation sites. We aim to reconstruct the climatic conditions during the Magdalenian occupation of Northwest Europe through isotope analysis of animal skeletal remains that have been humanly modified (e.g. cut marked, worked or smashed) and thus are directly linked to human activity. The results of oxygen isotope analysis of horse teeth and hydrogen isotope analysis of horse bone collagen will be presented. Preliminary results mimic climate records from the Greenland Ice-cores although the onset of climate warming appears to vary spatially. This suggests that major climate changes during the Late Glacial were time transgressive across Europe, and between Europe and Greenland.

6.8 Early Holocene Rapid Climate Change and Vegetation Succession at the Mesolithic-Neolithic Transition in the Central-Western Mediterranean

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The paper will summarise the findings from recent palaeoenvironmental investigations in the Ligurian Apennines (Italy) and Corsican Alps (France), combined with archaeological records from the central-western Mediterranean. The investigations at Lago Riane (Liguria) and Lac de Creno (Corsica) indicate aridification between ~8500-8000 cal yrs BP, with an extreme event recorded at ~8200 cal yrs BP. This was succeeded by the onset of wetter climatic conditions until ~7800 cal yrs BP. These rapid climate change events interfered with natural vegetation succession and the hydrology of mires, and were characterised initially by a decline and then expansion of drought intolerant plant taxa (e.g. *Abies*), and fluctuating water levels, respectively. The multi-proxy records, based on radiocarbon dating, stable isotope analysis of *Sphagnum* plant macrofossils and pollen stratigraphy, provide the first unequivocal evidence for the '8.2 event' in this part of the central-western Mediterranean. They suggest that wetter climatic conditions inferred for parts of Europe at this time did not characterise Liguria or Corsica. The Late Mesolithic – Early Neolithic transition (~8200-7800 cal yrs BP) therefore witnessed a major climatic change from drier to wetter conditions, which may have acted as an important forcing factor for the introduction of farming into lowland, coastal areas.

6.9 Prehistoric salt production and the palaeoenvironmental record: a case study from the Seille Valley, Eastern France

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The Seille Valley in Eastern France was a leading European salt production centre during the Iron Age, with estimated annual production peaking at thousands to tens of thousands of tonnes. Natural salt springs enabled production to flourish at this inland site and the archaeological record bears testament to the enormous scale of this activity. Three million m³ of "briquetage" debris comprising discarded fragments of clay salt moulds and furnaces were dumped on the floodplain, resulting in the creation of artificial islands up to 12m thick and 500m long. Rapid and continuous alluviation took place from at least the Mid-Bronze Age onwards (coincident with regional climatic change), resulting in extremely well preserved sedimentary archives. Sedimentology, palynology and geochronology have been integrated within ongoing archaeological research in order to reconstruct and elucidate the human-environment relationship of salt production in the Seille Valley. Alluvial and archaeological records have been successfully dated using optically stimulated luminescence and radiocarbon techniques, thereby providing a robust chronological framework. The results suggest that the development of this industry had a major impact on the hydrological regime of the valley and its sedimentological history, with evidence for accelerated alluviation arising from floodplain erosion at salt production sites and modification of the local fluvial regime due to briquetage accumulation on the floodplain. This research provides an important insight into the environmental implications of early industrial activities, in addition to advancing knowledge about the Holocene palaeoenvironmental and social history of a previously poorly studied region of France.

6.10 Biometry and Climate Change in Norse Greenland: The Effect of Climate on the Size and Shape of Domestic Mammals

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The Norse settlement in Greenland is of particular interest due to its short lived nature and the apparent influence of climate on its initial success and eventual demise. Climatic deterioration occurring during the 14th and 15th Centuries towards the end of the Norse Settlement in Greenland and its possible effects on the size and shape of domestic mammal (sheep and goat) bones is investigated in this paper. Both biogeographical and nutritional factors affect the size and shape of mammal bones and the availability of both pasture and hay for fodder would have been negatively influenced by a deterioration in climatic conditions. Bone size and shape from two sites in Norse Greenland are examined; Gården under Sandet in the Western Settlement and Ø34 in the Eastern Settlement. The results seem to indicate a negative impact on bone growth both as a direct result of decreased temperature and as a result of a reduction in vegetation productivity and hence animal nutrition. Reduction in bone size would also indicate a relatively greater decrease in overall body mass meaning that muscle and fat tissues available for human consumption would be greatly reduced resulting in an extremely detrimental effect on the human population.

Poster Abstracts

1. Reviewing 1930s field notes of Muge shellmiddens (Portugal): insights on early modern archaeology

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CEAUCP/CAM- Group Prehistoric Territories and Spaces

The mesolithic shell middens of Muge (central Portugal) were discovered in 1863. Thenceforward they are considered major Portuguese archaeological sites on which investigation is continuously carried out by several teams for about 150 years (continuing today).

The archaeological works were directed in the 1930s by Mendes Corrêa supported by a small team of disciples among which stands out Rui de Serpa Pinto (died in 1933, aged 25). Mendes Correa's work of which we have unpublished documentation will be studied under a master's thesis. The documentation consists of handwritten notes of fieldwork, bibliographic notes, photographic pictures, travel records, and more.

In 1932 Rui de Serpa Pinto travelled to England and France for nearly a month and a half. A draft of a report to send to the former Board of Education justifies his absence. In London attends and presents two largely appreciated communications in the I International Congress of Prehistoric and Protohistoric Sciences where he met Reygasse, Bosch-Gimpera, Reginald Smith, among others.

We believe on the basis of coeval documentation that field work methodology applied in the diggings of Muge by Mendes Corrêa team was influenced by new concepts introduced by Rui de Serpa Pinto. The contacts he made mainly in England are of extreme importance for the analysis of history and development of Portuguese archaeology in early twentieth century.

2. A methodology to determine age in sheep *Ovis aries* from dental development using x-radiography and its application to archaeological material

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Observing stages of tooth development can provide a relatively accurate method of estimating the age-at-death of an animal. Subjecting mandibles to x-radiography allows tooth development to be observed inside the mandible and such a technique can be applied to archaeological material using a scoring system to create mortality profiles of high resolution. Currently, methodologies exist for examining tooth development in red, roe and fallow deer, and wild boar, which have previously been used to study hunting strategies and periods of seasonal habitation on prehistoric sites. None, however, have been developed for sheep - animals crucial to the economies of most farming societies.

This paper gives details of a project aimed at examining dentition in modern sheep of known age-at-death, providing the opportunity to develop a methodology for estimating age from archaeological sheep mandibles through tooth development. This scheme has been tested on archaeological specimens from Iron Age and Romano-British sites in a region of West Sussex. The initial results of this work are presented here and discussed in terms of seasonal slaughter of the domestic stock populations, problems in analysis, and directions for the future of the method.

3. IR Microspectroscopy of Archaeological Materials from the Neolithic Near East

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The Neolithic was a significant point in human development, with the domestication of crops and animals and the emergence of the first permanent settlements. The study of thin sections through architectural sequences is therefore of great interest in any study of a Neolithic settlement, such as at the archaeological sites of Çatalhöyük (7400-6000 BC) in Turkey, and Tappeh Sheikh-e Abad (9800-7600 BC) and Tappeh Jani (~8200 BC) in Iran. These thin sections are ideal for reflectance analysis by IR Microspectroscopy, containing materials such as fine plaster sequences from walls and floors. Individual layers are often around 20–40 micrometres in thickness, as well as crushed and consolidated, making it difficult to source the raw materials or understand the technology using bulk chemical analysis or optical microscopy alone. Similarly the use and nature of pigments such as ochre found in wall paintings within these sequences and the presence of coprolites from the detection of phosphate can be investigated. There are several advantages to the use of the instrument at Diamond in micro-infrared imaging analysis, including lower frequency studies and the improved signal to noise ratio on spectra recorded from smaller areas.

4. 'Aesthetics and Earth-building: Identifying 'Clean' and 'Dirty' Spaces within Buildings at Calleva Atrebatum.'

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Micromorphology was carried out on internal deposits within early Roman timber and earthen-walled structures (c. 70-80 AD – c. 125-150 AD) at *Calleva Atrebatum*, the Roman town at Silchester, Hants, UK. The use of mud-render being used to cover earthen floors has been identified. This particular render was coloured with a glauconite pigment as has also been identified in wall plasters from Silchester (Dr. Paul Hatherly pers. comm.). Both earth-based decorative floor-renders and earthen floors themselves are currently unrecorded in studies of Roman architecture. Through the classification of archaeological deposit types, 'clean' and 'dirty' spaces have been identified. 'Clean' spaces were associated with the annex (room 1) in Early Roman Timber (ERT) Building 1 which had an *Opus signinum* floor and ERT Building 5 where the rendered-finished earthen floor was laid. 'Dirty' spaces were identified by poor maintenance which enabled the build up of dump deposits, accumulations and compacted trample in ERT Building 1 and ERT Building 5. Calcareous plaster floors such as *Opus signinum* and coloured mud-rendered floors appear to have been considered to have greater prestige than simpler earthen floors in the early Roman period in Britain. *Opus signinum* was generally considered more of a functional material than of high status on the Continent and in Britain in the later Roman period.

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5. Investigating the nature of early farming through archaeobotanical crop $\delta^{15}\text{N}$ values

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Given its labour demands and 'slow-release' character, manuring is a useful index of relations between farmers and their land in a long-term perspective. Here we apply insights gained from a large-scale isotopic study of modern cereals and pulses in Europe and south-west Asia grown under a range of experimental and 'traditional' manuring regimes to the interpretation of archaeobotanical crop $\delta^{15}\text{N}$ values. Our aim is to address questions surrounding the nature of early farming, such as: to what extent were Neolithic cultivation and herding functionally integrated, and how much did the basic character of early farming vary between sites, regions and phases? We assess the potential and limitations of crop $\delta^{15}\text{N}$ values for the inference of land use practices through a series of archaeological case studies.

6. An Investigation into the Relationship Between Bone Diagenesis and Funerary Rite

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When human or animal remains are buried, the bones are frequently exposed to attack from invading microorganisms and physico-chemical reactions. The microorganisms mostly comprise bacteria that originate from the body's putrefying organs. Funerary rites such as embalming, dismemberment and secondary burial are sometimes difficult to identify archaeologically. However, these processes affect the abundance of bacteria and the accessibility of the bone substrate, thereby altering the mode of biogenic attack. Patterns of bone diagenesis may therefore aid the identification of particular mortuary treatments. At the Bronze Age site of Cladh Hallan (South Uist, Scotland) the arrested biogenic decay observed in the articulated human bone thin sections was used to argue that the bodies had been mummified. Thus far, seventeen sets of remains from five Bronze Age British sites have been sampled and analysed using thin section light microscopy. All of the remains were excavated from similar burial contexts, providing some control for environmental variation in diagenesis. Preliminary observations suggest that disarticulated remains invariably demonstrate excellent histological preservation, which is consistent with what is normally observed in butchered animal bones. This similarity leads to the tentative suggestion that the disarticulated Bronze Age human remains were either dismembered or exposed on the ground surface until they had skeletonised. The histological preservation of articulated and partially articulated Bronze Age human remains is much more variable suggesting that these bodies may have been subject to diverse funerary treatments. Further analysis involving more samples should refine these conclusions and aid the identification of specific funerary rites.

7. Investigating the Exploitation of Tropical Plant Resins Through GC-MS Analysis: Ethnographic and Archaeological Applications

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Resin is an organic substance that preserves well in a number of situations. As organic remains are often rare at archaeological sites, particularly those in tropical climates, resins can offer a wealth of information if they are successfully identified, collected and scientifically analysed. Analysis of both modern and archaeological resins from Borneo by gas chromatography-mass spectrometry (GC-MS) demonstrated the potential of identifying the botanical sources of plant resins to high taxonomical levels (Bradshaw 2009). Such resolute identification allows the observation of patterns of exploitation and use of resins in the past. Results from the Borneo resins suggest that specific resins were deliberately selected for different uses in prehistoric Sarawak. The likelihood that similar technological choices would have been made in other tropical areas, such as Oceania and tropical Australia, is to be investigated through the analysis of a collection of resinous materials from a range of artefacts housed in the Pitt-Rivers Museum, Oxford. Current research is funded by NERC.

8. Life in an Extreme Environment: An Isotopic Investigation into Seasonal Resource Use in the Lower Ica Valley, Peru

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The lower Ica Valley, though today largely an unpopulated and arid desert, is rich in archaeological remains of settlement and irrigated field systems spanning approximately 2000 years from the Early Horizon (500 B.C.) to the Spanish Conquest. This research aims to understand how subsistence strategies, influenced by both biological and social factors, evolved during this period using isotopic analysis of human tissues. Previous archaeobotanical work suggests that a gradual transformation took place as natural and anthropogenic changes took their toll on the environment. Additionally, repeated cultural transitions provided social impetus for economic based changes.

Isotopic dietary information obtained from mummified human remains has been used to investigate three main transitions: a) the Late Ocucaje to Early Nasca cultural transition (c. 200 B.C. - 200 A.D.); b) the Late Nasca to Wari transition (c. 800 - 1000 A.D.) during which there was a gradual collapse of the desert ecosystem; and c) the transition from the Wari to the regionally developed Ica-Chincha period (1000 - 1400 A.D.).

Results from the isotopic analysis of bone collagen show the diet of each period to be subtly different, with a range of resources potentially being exploited. Several explanations can be put forward indicating that the subsistence strategies cannot be simply defined as 'hunter-gatherer' or 'agriculturalist'. Isotopic analysis of hair samples is used here to explore seasonal resource use in each of these cultures in an attempt to tease out information about the mixed economies employed by these populations.

9. Shellmiddens as a landmark: visibility studies on the Mesolithic of Muge valley (Central Portugal)

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It is now broadly accepted that, starting sometime in early Holocene times, the organization of the landscape became more and more complex, leading the so-called enculturating landscapes (Zvelebil 2003) and to the concept of constructing landscapes during the Mesolithic (Driscoll, 2009).

In this context, recent studies on the Mesolithic shellmiddens of the Muge valley indicate that these sites must have had, by their size and structural complexity, a major impact on the landscape, as a consequence of a new level of spatial cognitive perception. In fact, this perception seems to be well mirrored on site location patterns, with the distance between sites not resulting from physical landscape characteristics but from a clear anthropogenic decision.

This paper focuses on the use of geospatial techniques to analyze visibility as a determinant of Mesolithic settlement patterns in the Muge valley. Simple and cumulative viewshed analyses were undertaken to explore the cognitive behaviour of the Mesolithic communities concerning visibility factors between settlement locations and the surrounding landscape.

10. Science and Archaeology at Silchester

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Science@Silchester is a large multi-disciplinary project which involves scientists from both within the University of Reading and from other institutions (e.g. the Natural History Museum and the University of Leicester). The project fits within the Town Life project run by the Department of Archaeology at the University of Reading and seeks to complement the archaeological excavation using a broad spectrum of science based techniques. As well as the vital links between Earth Sciences and Archaeology which have been strengthened through work with micropalaeontologists we have also been involved in projects with the departments of chemistry, food science and physics.

The ultimate aim of this research is to characterise the evolving use of space through time at Insula IX using a variety of science based techniques. A large part of the work involves the analysis of soil chemistry using x-ray fluorescence (both laboratory based and portable). We also use micromorphology, phytolith analysis, infra-red microscopy, micro x-ray diffraction, geological thin-sections (for provenancing work), isotope analysis and Raman spectroscopy.

This presentation will illustrate some of our recent research highlights and outline our plans for the future of Science@Silchester.

11. The story in the floors: using geochemistry to aid in the understanding of the use of space at Insula IX Silchester

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Although prima facie evidence for non-ferrous metal working in the form of slag, crucibles, moulds, etc is present at the Roman town of Calleva Atrebatum at Silchester Hampshire, UK it has not yet been stratigraphically associated with *in-situ* hearths; this can make the location of metal working difficult to determine. This in turn raises the further question of the range of function of hearths in this urban context. The opportunity for undertaking an extensive survey of soil-material analysis of successive phases of House 1 presented itself in 2002-3 (Cook *et al.*, 2005). Since that preliminary sampling we have continued to collect samples from occupation deposits across the excavation we now have eight seasons worth of data. Using x-ray fluorescence (XRF) we have been able to distinguish between probable industrial and domestic hearths based on elemental concentrations (Cook *et al.*, 2010); for example locally elevated metal concentrations, in particular of copper, show evidence for the probable working of copper alloys at Silchester. The results presented here show the potential of this kind of sampling in aiding the interpretation of the use of space not only within the lateral variation across the excavation but also through time as the story of human occupation at Insula IX evolves.

12. Teotihuacán, the greatest of Mesoamerican cities: An organic residue analysis approach

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Teotihuacán, the first important metropolis of Mesoamerica, was a success story in world urbanism. However, it is clear that its inhabitants faced significant challenges, economic, social, and political, in sustaining such a dense urban society (Cowgill, 1997). Absorbed organic residue analysis, which has been successful in answering archaeological questions relating ancient diet and agriculture in other parts of the world, offers opportunities to add an important new dimension to the intensive work that has been undertaken in Teotihuacán in the recent years.

This first attempt at absorbed organic residue analysis from utilitarian 'cooking' pottery in Mexico aims to provide baseline information for food acquisition, processing and consumption at Teotihuacán. Such information will be very helpful in understanding analogous activities at other contemporaneous and later New World urban centres, as it is possible that the people of Teotihuacán pioneered the broader range of subsistence strategies characteristic of other metropolises. This paper will present the results of parallel chemical investigations of organic residues from archaeological ceramics and modern *comparanda* of the biological materials likely have been processed therein.

13. Turning their backs on the sea? New evidence for Neolithic diet in Britain from organic residues in pottery vessels

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The Neolithic period in Britain is widely regarded to herald a sudden and profound shift in economy and diet, prompted by the arrival of farmers in one or more episodes of colonisation. The economy was dominated by terrestrial domesticates and crops, with limited archaeological evidence for wild resources. Combined with evidence from bulk collagen stable isotope measurements of human bone collagen, it would seem that at coastal sites, Neolithic peoples were avoiding locally-available aquatic resources in favour of domesticated animals and crops and as such, 'turning their backs on the sea' (Schulting & Richards, 2002). However, aquatic resources can be discriminated against taphonomically in the archaeological record and furthermore it is now acknowledged that collagen bulk isotope data can fail to detect low or sporadic contributions of marine protein (Hedges, 2004).

The analysis of absorbed residues preserved in pottery offers the opportunity to identify processing of particular commodities in vessels in antiquity. Although long-chain highly unsaturated fatty acids characteristic of aquatic organisms are susceptible to rapid oxidation and loss, more stable products have been identified that are diagnostic of the original polyunsaturated components (Hansel et al. 2004; Evershed et al. 2008; Hansel & Evershed, 2009). Although these tend to be present in low concentrations, operating the GC/MS in selected ion monitoring mode enhances the sensitivity of the instrument significantly, and has the potential to reveal these biomarkers at concentrations that would otherwise be undetectable. We have extracted residues from ~ 1000 sherds from coastal sites dating from the earliest Neolithic through to the Viking/Norse period. The findings demonstrate that whilst marine product processing in pottery is predictably most intensive by the Viking/Norse period, marine-derived biomarkers can also be identified in residues from Neolithic vessels, indicating that 'wild' resources were not, in fact, wholly abandoned.

14. Application of portable X-ray fluorescence (XRF) to soft-stone artefacts: evaluating economic and socio-political networks in Bahrain and Cyprus

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Current doctoral research, close to completion, is developing a cross-cultural, community-based approach to study the nature of trade, incorporating scientific materials analysis to evaluate models of economic and socio-political networks. Networks in the trading hubs of Early Bronze Age Bahrain (*Dilmun*) and Late Bronze Age Cyprus (*Alashiya*) are being examined. This research is comparing the sites of Qala'at al-Bahrain and Saar, Bahrain, and Enkomi and Maroni, Cyprus. These sites demonstrate substantial evidence for metalworking and trade. Their rich excavation and publication record is being used to conduct detailed contextual analysis of site layout, distribution of seals, weights and craft production, to compare engagement in economic and socio-political networks by different communities and sectors within them.

That particular communities may have developed specific socio-economic relationships is suggested by results of destructive bulk X-ray diffraction (XRD) mineralogical analysis (Kohl *et al.* 1979), identifying variation in soft-stone circulating around Persian Gulf sites. Non-destructive portable X-ray fluorescence (XRF) analysis of trace elements in soft-stone artefacts from the four sites has been used to identify distribution of materials and possible source groups. This research is examining variability in the iconography and geochemistry of soft-stone artefacts from household, workshop, temple and funerary contexts at the four centres, examining interaction across socio-political, economic and ideological spheres. This poster presents the integrated methodological approach being applied, and the implication of results for the use of portable XRF in answering social questions.

15. Stable isotope analysis of diet in early and late, Pagan and Christian, Anglo Saxon Sussex, UK

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This study presents a unique opportunity to reconstruct the diet of an early Anglo-Saxon pagan cemetery, Rookery Hill, which is closely associated with a nearby late Anglo-Saxon Christian cemetery, St Andrew Church, Bishopstone. The aim of this project is to determine if the development from a pagan to a Christian religion at these sites is reflected in a change in animal and plant based protein intake.

Stable isotope ratios ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) were reconstructed from bone collagen taken from 20 Rookery Hill individuals using standard methods. Skeletally complete individuals were selected. Bone samples (2-4g) were taken from either the cranium or pelvis, which were also used to estimate the age and biological sex of the individual. Samples from Bishopstone were from a previously published report.

Preliminary results suggest that the inhabitants of Rookery Hill were eating proteins that were mostly from herbivore and terrestrial plants. In contrast, Bishopstone, showed $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values significantly higher, suggesting inhabitants were eating animal proteins that were from omnivores, and carnivores. Despite the zooarchaeological evidence, which included small quantities of fish bone (molluscs were more abundant) at Rookery Hill in contrast to Bishopstone which produced a large and varied assemblage dominated by marine species, neither group were consuming fish or shell fish on a daily basis. Cultural factors such as status and burial location will be considered in the interpretation of the isotopic data.

16. A Molecular Approach to the Neanderthal Extinction

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It is unknown as to the extent that the arrival of modern humans into Europe (~ 40-30 kyr BP), or the unstable climate throughout Marine Isotope Stage 3 leading up to the Last Glacial Maximum led to Neanderthal extinction at ~30 kyr BP. However it is possible to determine this by reconstructing a demographic model for the Neanderthals thus illustrating how their demography changes alongside a chronology. One method that has become popular recently that is able to do this is the software programme BEAST (Bayesian Evolutionary Sampling Trees). If it is possible to reconstruct the changing Neanderthal demography over time, then it becomes possible to identify the timing of the event(s) that had the most impact on the Neanderthal population. Unfortunately, there is not a sufficient quantity of Neanderthal genetic data or information for input. This thesis addresses the question what is required for the Neanderthal data for input into BEAST with the aim of assessing the feasibility of obtaining a demographic model for the Neanderthals. This thesis has involved quantitative analyses on how much genetic data should be input, an examination on the importance of accurate prior information, and an evaluation into whether BEAST can recover a demographic signal from a suitable amount of Neanderthal data. The results from these analyses highlighted key issues that have been applied to the Neanderthals in order to examine the feasibility of obtaining the demographic model.

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17. Trace element and stable isotope analyses of *Orytolagus cuniculus*, the British wild rabbit: Testing a new methodological approach for geographical spatial discrimination

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The ability to accurately reconstruct the movement of mammals using isotopic markers in biological materials is well established, and commonly utilised for analysing animal migration and diet. Such studies primarily focus upon predictable spatial fractionation of stable isotopes, in particular $\delta^{18}\text{O}$ and δD incorporated into mammalian fur, bones and teeth, which provide geographical markers. Isotopes of carbon and nitrogen ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) are particularly relevant for identifying dietary habits, which can also show a degree of geographical specificity.

Whilst these techniques aid the interpretation of large mammal migration, small mammals with limited geographical ranges present significant opportunities to advance these methodologies further, as these species are unlikely to migrate across the distances required to encounter variety in their isotopic environment. Trace elemental analysis has also shown promise in terms of geographical spatial discrimination, both in conjunction with isotopic methods and independently. Elemental profiles in soils are related to parent material, and uptake into plants represents a route into the food chain, potentially facilitating the development of a location-specific elemental fingerprint capable of incorporation into mammalian body tissues.

We present here multivariate statistical analyses of elemental and isotopic profiles from soil, vegetation and modern rabbit body tissues (bones, teeth and fur) from two geographically distinctive sites in the southern UK. The data discriminates the small mammal populations into regional groups with ca. 90 – 100% statistical accuracy. Elemental concentrations of particular value appear linked to underlying geologies. These data have significant implications for a new methodological approach in Archaeological Science.

18. Phytolith Analysis: Pits, Wells and associated Slumps from the Roman Town of Silchester

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Two detailed phytolith studies have been carried out in 2009 and 2010 from the Roman town of Silchester. The primary study was carried out on a series of pits and slumps spanning both Period 1; c. AD 40/50-c.AD 70/80 and Period 2; c.AD 70/80-c. AD 125/150 of Roman occupation. The second study was carried out on an Iron Age well and its associated slumps. Thirteen samples were taken from a range of four pits and slumps from the Roman occupation and ten samples were taken at intervals throughout Iron Age well and its associated slumps. Phytolith analysis was employed to examine whether phytoliths survived in these contexts and to determine what they could tell us about the paleoenvironment, the presence of cereals and crop processing.

The Iron Age well samples contained husk multi-cells that can be positively identified to genus level (*Tritium*, *Hordeum*, *Avena*, *Aegilops* and *Phragmites*). The Roman pits also produced *Tritium*, *Hordeum* and *Cyperaceae*. This phytolith assessment demonstrates that the preservation of the phytoliths from the Iron Age deposits in this well is more than sufficient to provide evidence for environmental proxies, crop processing and cereal identification. The pit and slump contexts sampled during period 1 and period 2 of Roman occupation indicate a dominance of monocots (grasses and sedges) over dicots (shrubs and trees). The presence of both pooid and panicoid grasses indicate the presence of cereals and an assemblage of associated weeds.

19. Meat-eating in chimpanzees: the isotopic ecology of a primary rainforest

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There is no general consensus regarding the diet of early humans with paleoanthropologists differing on whether hunting, and associated meat-eating, or plant foods played a larger role in shaping hominin evolution. Investigations into the diets of *Pan*, our closest living relatives, can potentially shed light on this issue. Variation in diet amongst different chimpanzee communities, and amongst male and female chimpanzees of the same group is frequently reported. This study is the first to employ ¹³C and ¹⁵N stable isotope analysis to investigate the isotopic ecology of a West African primary rainforest habitat, and to determine if behavioural observations of hunting and meat-eating correlate with protein-associated $\delta^{15}\text{N}$ values. 118 hair samples representing 38 identified chimpanzees from Taï National Park, Côte d'Ivoire were analysed, along with corresponding behavioural data gathered over a 10 year period and sympatric flora and fauna. The flora and fauna of Taï National Park displays a large range of variability in both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values. A significant difference in adult male and female chimpanzee $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values was found with males being marginally less depleted in $\delta^{13}\text{C}$, and significantly more enriched in $\delta^{15}\text{N}$, compared to females. The results of this study provide baseline isotopic data for a tropical rainforest habitat environment and support previous hypotheses that male Taï chimpanzees consume more meat compared to females who are more insectivorous.

20. Suitability of archaeobotanical samples for carbon and nitrogen stable isotope analyses

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Carbon stable isotope ratios of archaeological plant remains have been used to reconstruct past water availability and, to a much lesser extent, nitrogen stable isotope ratios have been measured in order to reconstruct crop management practices. As archaeobotanical remains will often be preserved in a charred state and will have been buried for a long time, it is important to assess possible charring and diagenetic effects on plant isotopic composition, in order to assess the suitability of archaeobotanical samples for the application of stable isotope analyses.

Experimental charring and burial experiments were therefore conducted, as part of a study aimed at investigating and improving the empirical basis of the use of carbon and nitrogen isotope analysis of cereals for the reconstruction of water availability.

Wheat, barley and sorghum grains were charred at temperatures from 200-700°C in both oxygen-rich and oxygen-poor atmospheres. It appeared that in some cases the isotopic composition was altered, but these can be corrected for. In addition, samples of wheat and barley were buried at three sites in Jordan and two in the UK and retrieved after up to two years. In this time period their isotopic ratios appeared not to have changed in any systematic way.

Based on these results, it can be concluded that archaeobotanical samples are suitable for carbon and nitrogen stable isotope analyses, although care should be taken to pick up on any possible alterations as a result of charring.

21. Investigating the impact of manuring on $\delta^{15}\text{N}$ values in cereals and pulses and potential for archaeobotanical analysis

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We present results of a broad investigation into the impact of animal manure application on $\delta^{15}\text{N}$ values in modern crops with a view to refining the reconstruction of crop husbandry practice and palaeodietary studies. We summarize the effect of manuring on $\delta^{15}\text{N}$ values in a range of Old World seed crops (cereals and pulses), under variable manuring levels/regimes and at a series of locations extending from northwest Europe to the eastern Mediterranean. The results of the modern studies, which include both agricultural experiments and 'traditional' farming regimes, demonstrate that intensive manuring can radically increase cereal $\delta^{15}\text{N}$ values, the degree of impact depending on level and frequency of manure application; conversely, the impact on $\delta^{15}\text{N}$ values in pulses, which fix atmospheric nitrogen, is generally slight. Reliable interpretation of archaeobotanical crop $\delta^{15}\text{N}$ values depends not only on understanding how arable land use and other ecological factors affect nitrogen isotope ratios, but also on assessment of the effects of charring and other diagenetic variables. We summarise modern experimental work on the effect of charring and cleaning procedures adapted from radiocarbon pre-treatments. Together with the results of the modern manuring studies, these observations form the basis for interpretation of archaeobotanical crop $\delta^{15}\text{N}$ values as evidence of land use and, together with stable nitrogen and carbon isotope analyses of associated faunal and human remains, palaeodiet.

22. Locating new Mesolithic sites in the Tagus Valley (Portugal): a contribution from GIS

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A predictive model was created using Geographic Information Systems (GIS), based on the analysis of location parameters relevant to the human occupation of a small tributary (Ribeira de Muge) of the Tagus River during the Atlantic period (c. 7500-5000 BP), and on the correlation between the past and today's landscape. Three main goals were taken into account: (1) identify potential new sites, (2) develop an inter-site spatial analysis, both as single entities – microspatial scale – and as part of a settlement network – macrospatial scale; and (3) contribute to the dissemination of GIS in archaeological research. The analysis was only carried out in Ribeira de Muge, one of the tributaries of the Tagus River, and the results seem very significant, since they present positive values in the order of 73%. Eight of the eleven identified areas have lithic artifacts and faunal remains on the surface. Only two locations (ID15 and ID20), representing a universe of 19%, could be confirmed as Mesolithic sites.

23. Predicting mechanical loading in the human spine using micro-CT.

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Bipedal posture and locomotion in humans results in large compressive forces being exerted on the lumbar spine. These stresses are usually transmitted through the vertebral bodies and intervertebral disc between them. However disc degeneration may lead to a proportion of the load being transferred through the neural arches (NA), specifically the apophyseal joints. Robson-Brown *et al* (2008) have previously examined the extent of load-bearing by the NA in elderly cadaveric specimens. They found increased NA load to be strongly associated with cartilage and bone degeneration, particularly when the load resisted by the NA is above 50% of the overall compressive load applied.

Here, a subset of the apophyseal facets used in the 2008 study are submitted to micro-CT in order to analyse the effect of varying degrees of NA loading on the internal bioarchitecture of the joints. Changes in the trabeculae and cortical bone are observed in response to known ages and NA loading profiles. We are currently using micro-CT to ascertain if the same patterns can be found in the apophyseal joint facets of a medieval population from Taunton. The results of this will allow us to consider if the degree of degeneration observed both within and on the surface of apophyseal joints can be used as a marker of mechanical loading in life.

24. Dietary and social transitions in the Amazon: an isotopic approach

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In the past thirty years only a few studies using stable carbon and nitrogen isotope have been conducted on Amazonian archaeological bone material (van der Merwe *et al* 1981; van der Merwe 1982; Roosevelt 1989, 2000), and for that matter the results obtained for this region are still insufficient to draw broad interpretations on the dietary pattern, resource domestication and the consequences agriculture can have on population mobility. Archaeological and historical evidence shows that the Amazon was occupied by large stratified groups, possibly chiefdoms, by the time of contact (1500 AD). In order to maintain such large sedentary populations these groups had to rely on highly efficient resource production and environmental management, probably based on exogenous crops such as maize and manioc. The ways in which these populations reached this point of social organization is still highly debated and many believe it started around 2000BC with the widespread appearance of ceramist groups. By using stable isotope analysis in a large sample of human and faunal bone samples from different sites in the Amazon occupied for the past 4000 years it is possible to identify dietary variations in the given time that could indicate a change of subsistence patterns and a possible reliance on agriculture. Also, carbon stable isotopes can indicate if, when and how relevant maize domestication was in different areas throughout the Amazon, making it possible to push forward the current discussions regarding the origins of the Amazonian formative period.

25. Conformity in Diversity: Isotopic investigations of breastfeeding practices during the Iron Age on Öland

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The duration of breastfeeding is a strong determinant of infant health, but the timing of both the onset and cessation of weaning varies significantly in the human species. It is thought that this variability arose as an evolutionary adaptation that enabled breastfeeding practices to be altered in accordance with the differing costs and benefits of weaning in different environmental contexts. Breastfeeding practices are, however, often dictated by cultural norms rather than biological needs, leading to poor health outcomes for infants.

In this study stable isotopic methods (carbon, nitrogen and sulphur) were used to investigate infant feeding practices in two prehistoric populations from the island of Öland, Sweden. One population dated to the Roman Iron Age and almost all the individuals in this population had survived the earliest years of life. The second population dated from the Late Iron Age and consisted mostly of infants who died before the age of six months. It was anticipated that different breastfeeding practices might have contributed to the different mortality profiles at the two sites. The results, however, did not reveal any differences in breastfeeding practices between the two populations, but did show that there was substantial diversity in practice within each population. The level of diversity suggests that there was no single idealised model of infant feeding at either site. That the same diversity was seen at both sites may nonetheless reflect a shared infant feeding ideology, but one that emphasised fluidity and flexibility rather than a single rigid ideal.

26. The strange case of 60 frothy beads: Analyzing bronze age glass from the Netherlands

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During the excavation of a late prehistoric urnfield near Zutphen (NL), a rich late bronze age burial was found to contain c. 60 simple small blue-green glass beads and two blue *ringaugenperlen*. This made this a very special find, as up till now bronze age glass was only known from two locations (totaling c. a dozen beads). The simple beads are currently being investigated to determine origin and properties.

Preliminary results of the chemical analyses (hand-held XRF) show that the glass was made using soda as a flux. This is remarkable, since the closest known glass production centre (Fratessina, Italy) produced mixed alkali glasses at this time (Angelini et al. 2004, Tite and Shortland 2008). The raw materials therefore probably originate from the eastern Mediterranean.

Study by microscope, electron microscope and micro-CT showed that the glass objects contain a vast amount of air bubbles, making up an estimated 50% of the total volume of the object. This gives the glass an almost frothy structure. Moreover, the glass mass contained a large number of fine metal particles and some mineral inclusions. This gives the impression that this glass is of lower quality than is usual for glass imported as ingots from the eastern mediteranean glass production centers. The inclusion of metal fragments and minerals are even reminiscent of faience.

Tentatively we may suppose that these glass beads were made using frits or other raw materials meant for faience – originating from the eastern Mediteranean - to produce low-quality glass objects in northwestern Europe.

27. The Swifterbant tilled field

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The Middle Neolithic Swifterbant sites (c. 4300 to 4000 cal BC) are located on levees of a former freshwater tidal system. While they have traditionally been interpreted to be occupation sites for seasonal herding, hunting and gathering, recent studies suggest the area in fact have been used for crop cultivation (Cappers & Raemaekers 2008; Huisman et al. 2009).

Typical sites consist of a thick layer of black material that may be up to c. 1 m thick, intercalated between fluvial or fresh-water tidal deposits. These layers are commonly rich in fragments of pottery, bone and flint. Micromorphological study at one site (S4) showed that the groundmass in this layer consists almost exclusively of carbonized plant remains and phytoliths. The layers may therefore be better interpreted as midden-like deposits.

Detailed archaeological and micromorphological investigations at two sites (S2 and S4) yielded evidence for tillage. At S4, careful excavation made it possible to recognize a regular pattern of clods of earth, indicating tillage by some form of hand tool. A detailed follow-up micromorphological study indicated that at the S4 site, at least six phases of tillage alternated with phases of flooding and of deposition of waste material on the same spot.

These results have given a new image of the land use and subsistence in the Swifterbant area during the Middle Neolithic: Rather than extensive seasonal activities related to herding, hunting and gathering, the area was probably used intensively for a mixed subsistence in which tillage and crops played a major role.

28. Exploring seasonal dietary variability in a Late Pleistocene mammalian ecosystem using trace element ratios from high-resolution LA-ICPMS

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Incremental chemical sampling of mammalian tooth enamel allows an understanding of seasonal palaeoclimate, as well as palaeodietary and migratory behaviour, due to the sequential enamel formation process. However, uncertainties concerning the temporal resolution achievable using the conventional intra-tooth sampling method have been identified (Montgomery et al., 2010, *Environmental Archaeology*). It has been demonstrated that during the complex two-stage enamel formation process, the chemical input signal is mixed, resulting in a time-averaged and attenuated signal. This study evaluates the potential for extracting a high-resolution trace element signal from mammalian tooth enamel that is least affected by the complex temporal and spatial aspects of amelogenesis, and is closely associated with the incremental growth lines secreted during matrix formation. This is achieved by targeting the highly mineralised innermost enamel layer that lies parallel to the enamel-dentine junction (EDJ), using laser-ablation inductively-coupled-plasma mass spectrometry (LA-ICPMS). Recent research suggests that the innermost enamel layer, which is highly mineralised during matrix formation, may preserve a high percentage of the original chemical signal (Tafforeau et al., 2007, *Palaeo3*). This is because during maturation, the increase in mineralisation of the innermost layer is far less than for any other enamel layer, thereby reducing potential overprinting of the original chemical signal. Sr/Ca and Ba/Ca ratios, which are proxies for trophic level and palaeodiet, are used to explore dietary behaviour and seasonal variation of a range of Late Pleistocene mammalian species from Kent's Cavern in Devon at a time of considerable climatic complexity.

29. Interpreting isotopes in the North Atlantic Islands

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The coastal communities of North Atlantic Islands have always had access to a rich and diverse resource base. Reconstructing the changing relationship between these populations and the sea represents a complex enigma for archaeologists. Stable carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) isotope analysis of human remains has been employed in an attempt to understand marine food consumption in specific time periods in the North Atlantic Islands. Valid interpretation of human isotope results relies on a detailed knowledge of typical values for the major species being consumed by humans and an understanding of background environmental carbon and nitrogen levels. Carbon and nitrogen values vary depending on the time period and geographical location in question as a result of environmental and climatic factors. To date North Atlantic island isotopic research has mainly centred on human values, with little emphasis on the analysis of faunal samples, which are integral to the valid interpretation of human results.

This paper presents data from detailed sampling of a wide variety of different species in the North Atlantic Islands from the Neolithic to the Norse period. Nuances in carbon and nitrogen fluctuations provide an effective baseline for a more comprehensive understanding of human results. These models show interesting dietary behaviour amongst certain species, with evidence of non human consumption of marine resources. Isotopic evidence from bird remains provides an insight into migratory behaviour, and seasonality of this resource. Faunal isotopic evidence provides a much more detailed outlook on human and animal dietary behaviour in the North Atlantic Islands.

This research was funded by the Natural Environment research Council (NERC)

30. Evaluating archaeobotanical N-isotope measurement as an indicator of prehistoric farming practice: the impact of charring on cereal $\delta^{15}\text{N}$ values

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The use of animal manure has experimentally been shown to affect plant N-isotopic signatures ($^{15}\text{N}/^{14}\text{N}$). Isotopic analysis of archaeological grains is therefore potentially a promising new methodological tool to reveal the beginning and onset of prehistoric manuring practice in a more direct and detailed way than archaeologically possible. Evidence of manure affecting the plant N-isotopic signature is, however, based on studies of fresh plant material. As prehistoric grains generally are preserved and found in a charred state, it remains to be seen if the isotope ratio is affected by charring. The main hypothesis of this study is that charring does not disturb the isotopic signature in cereal grains substantially. A range of controlled experiments has been carried out in order to test this hypothesis. The results of this study indicate that the degree of distortion caused by charring is negligible, especially within the range of optimal charring conditions.

The isotope analysis for this study was supported by a grant from Carlsberg Fondet.

31. Technology based evolution? A biometric test of the effects of handsize versus tool form on efficiency in an experimental cutting task

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The use of stone tools opened a novel adaptive niche for hominins. Hence, it has been hypothesised that biomechanical adaptations evolved to maximise efficiency when using such tools. Here, we test experimentally whether biometric variation influences the efficiency of simple cutting tools (n= 60 participants). Grip strength (dynamometer) and handsize (length) were measured in each participant. 30 participants used flint flakes, while the other 30 used small (unhafted) steel blades. It was ensured that mean handsize and strength in each participant group was not significantly different ($\alpha=.05$) to investigate the effect of tool variation. The task required cutting through a 10mm hessian rope, with efficiency being measured using “number of cutting strokes required” and “total time taken”.

Consistent with previous biometric work, handsize and grip strength were significantly correlated ($r=.679$, $p < 0.001$). Hence, only correlations between handsize and cutting efficiency were tested, since handsize is more directly amenable to study in the fossil record. Both efficiency measures were significantly correlated with handsize (Time taken: $r = .273$ $p = .037$; Stroke count: $r = .389$, $p = .02$). However, no significant differences were found between flake and blade groups in terms of mean efficiency. We stress that our results do not imply that tool form has no impact on tool efficiency, but rather that – all things being equal – biometric variation has a significant influence on efficiency variation when using simple cutting tools. These results demonstrate empirically, that biomechanical parameters related to efficiency may plausibly have been subject to selection in stone tool-using hominins.

32. Defining what it is to be local: Interpreting differences in stable isotope signatures from a lost medieval village, East Lothian, Scotland

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Studies of British medieval society often focus on identifying migrants (such as the Vikings). To be useful, isotope studies need to understand 'local' population variation before any 'exotics' can be assessed. This study examines strontium, oxygen, nitrogen, carbon and sulphur isotopes from a population buried at Auldhame, East Lothian, Scotland. The site, containing up to 260 burials, is close to the coast and underlain by Carboniferous limestone. The population has Sr isotope values in the range 0.7082-0.7085, suggesting a predominantly static population with two outliers (likely spending their childhood in a more radiogenic setting, possibly the Southern Uplands or Perthshire/Aberdeenshire). The $\delta^{18}\text{O}$ data from the same individuals are normally distributed with $\delta^{18}\text{O}=17.4 \pm 1.1\text{‰}$ (2σ , $n=18$), converting to a drinking water equivalent value of -7.6‰ which is consistent with local drinking water. One individual has a local Sr isotope value but an unusually high $\delta^{18}\text{O}$ value, more typical of Mediterranean climates. The combined Sr and O data suggest most of the individuals are from the Lothian area, allowing us to examine variation within a truly local population. The dietary isotopes are compared with data from medieval populations situated in Northern England and fit the model of a fish-rich diet (Muldner and Richard 2005). More interestingly, C and N isotope values are elevated in females, which could indicate societal differences in diet such as the relative proportions of meat and fish. However, we conclude it is more likely to be due to increased physiological stress associated with prolonged periods of pregnancy/breastfeeding.

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33. Can *Triticum urartu* be identified by pollen analysis? Its importance for origins of the agriculture

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Triticum urartu, a wild wheat species, has only recently been discovered because the plant phenology does not allow distinguishing it easily from Einkorn wheat (*T. boeoticum* subsp. *thaudar*), although a clear DNA separation exists between the 2 species. Both are wild two-grained forms and both could potentially be the relatives of a cultivated two-grained form that is extinct. Archaeobotanical evidence indicates the presence of one of these two-grained forms as a wild cereal from the Late Pleistocene in Syria; but it is impossible to distinguish kernels from these two wheats in archaeological sites. Moreover, a domesticated two-grained cereal in Syria, Turkey and, even, into Neolithic Europe has been identified. This implies that besides the one-grained einkorn domestication, a two-grained einkorn domestication occurred. Even so, the 2 species require slightly different growing habitats, and it is likely that Urartu played an important role in dryer areas like N Syria, where natural occurrence of wild Einkorn is questionable. This confusion needs to be solved.

Here we present a microscope study on acetolysed pollen grains of 14 wheat accessions of Urartu, wild and domesticated Einkorns with well-established genotypes in order to identify criteria to distinguish *T. urartu* from other wheats (*T. boeoticum* subsp. *thaudar*, *T. boeoticum* subsp. *aegilopoides*, *T. monococcum*). Preliminary results indicate that grain diameter is not a good way to separate species, but SEM and phase contrast give good results that could potentially be applicable to both taxonomy and archaeo-palynology respectively.

34. Lying Through Your Teeth, Strontium Uptake in Archaeological Enamel

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The strontium isotope methodology is becoming increasingly popular for studying mobility and migrations in archaeological populations. However, the development of the technique over the last 30 years has been complicated by the effects of diagenetic contamination. Although bone was initially the primary material for isotope analysis it has since been comprehensively proven to be susceptible to diagenetic alteration.

As a result of its increased resistance to diagenetic alteration relative to bone, tooth enamel has become the primary sample material for strontium isotope analysis. Nonetheless, its absolute resistance to diagenetic alteration has never been comprehensively tested. Fundamentally tooth enamel is the same mineral (carbonated hydroxyapatite) as bone and is in contact with the same burial environment so why should it be completely immune to diagenesis?

This research focuses on identification of diagenetic strontium in archaeological enamel of different ages. The project aims to use samples where *a priori* assumptions about the biogenic and diagenetic strontium isotope ratios can be made. By doing this it is possible to be more accurately assess diagenetic alteration. The primary materials for the study are marine mammals recovered from terrestrial archaeological contexts, together with terrestrial mammals buried by marine transgressions.

The study considers that contamination in archaeological enamel may not be equal across the entire thickness which may be consistent with a model of diffusion with simultaneous adsorption or reaction. To assess this, the project will use LA-ICP-MS which has the high spatial resolution necessary to work across the few millimetre thicknesses typical of most enamel.

35. Dietary Change in Roman Galicia: First stable isotope evidence from NW Spain

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The growing number of carbon and nitrogen stable isotope investigations on Roman-period populations over recent years have begun to reveal the stark dietary differences that existed between different regions of the Roman Empire. Here, we present the first palaeodietary data from the Northwest Iberian Peninsula, the Roman necropolis of A Lanzada on the Galician coast. The human sample comprises 56 individuals, including 6 subadults, and is compared with 31 faunal data, including a number of marine fish. The analyses revealed a mixed marine-terrestrial diet with a contribution from C4-plants (probably millet) to the diet of the animals and possibly also to the human diet. There were no intra-population differences between the sexes and different age-groups; however, there is clear evidence for significant intensification of marine resource use in the Late compared to the Early Roman period, with a shift in average human $\delta^{13}\text{C}$ values from -16.7‰ to -14.8‰ . We consider a number of possible explanations, including political, religious and environmental change that impacted on the economic and dietary choices of the population of A Lanzada.

36. Extending the Potential of Zooarchaeological Data: New Approaches to Reconstructing Depositional Histories through Taphonomic Analysis

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This paper investigates the potential of a holistic approach to faunal analysis for reconstructing depositional histories, particularly at sites with obscured or unobservable stratigraphy.

The development of new scientific techniques has substantially enhanced the information that can be gained from animal bones. Unsurprisingly animals remain at the centre of research on faunal material, but the osseous remains themselves have untapped potential for gaining new insights into the archaeological record, particularly for the reconstruction of depositional histories. Bones represent the optimal archaeological resource for reconstructing the taphonomic trajectories of deposits, as they are resistant enough to decay to survive in abundance (depending on depositional environment), but also soft and malleable to the degree that they can be altered by a range of processes, thereby taking an imprint of their taphonomic history. Fewer processes are traceable on ceramics and the few taphonomic indices which are frequently analysed have uncertain or varied aetiologies.

This paper presents a pilot study into the use of bone taphonomy for reconstructing complex depositional histories. Firstly the susceptibility of different species and elements to taphonomic changes was assessed and this information then used to interpret the characteristics of a single deposit. By employing simple statistical approaches, differences in the taphonomic signatures of layers were revealed. These were indicative of various patterns in the treatment of skeletal material and revealed sequences of deposition, hiatus and disturbance. Analysis focused on various taphonomic indices including weathering, gnawing, trampling, and fracture character and demonstrates the largely unexploited potential that taphonomic datasets have.

37. Time and Genes – The Early Neolithic in the Mediterranean Basin

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In recent years archaeologists have been demonstrating a growing interest in the application of quantitative analyses to data, in broad temporal and geographical scales, using archaeological dates as proxies to the presence and distribution of populations as well as their dispersals and expansions in a given spatial reality (Gkiasta et al 2003, Van Andel et al 2003).

Within this approach our project expects to: 1) create a chrono-archaeological database of all Early Neolithic settlements in North Africa and Mediterranean Europe, obeying to archaeological quality criteria; 2) establish collaborations with other researchers in order to perform new dating, from both published and unpublished sites; 3) perform calibration of all radiocarbon dates using OxCal program; 4) apply multivariate statistical analyses to data, such as PCA, and plot results in synthetic maps; 5) integrate and compare the obtained results with the ones displayed by current studies in Population Genetics.

This will allow us to evaluate some hypotheses about the Neolithic diffusion along the Mediterranean Basin including North African information that has been largely misrepresented in these kinds of studies.

This project is funded by the Fundação para a Ciência e a Tecnologia, Ministry of Science, Technology and Higher Education, Portugal, grant SFRH/BD/44089/2008.

38. From bread to bratwurst? Problems in interpreting dietary differences in Roman and Medieval Italy

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This paper presents a summary of carbon and nitrogen isotopic analyses of human and animal collagen from central Italy during the first millennium AD. The degree of cultural continuity, including food practices, is an important question for this period of enormous social, political and economic change. The historical and economic evidence suggests a change in diet occurred because the abandonment of trade routes, depopulation and the migration of new groups from central Italy increased the amount of livestock and pastoral land available. The question of whether the peasantry actually consumed more animal meat during the early middle ages is an ideal candidate for using stable isotope analysis.

This study has three outcomes. First, it demonstrates the variety of Roman diet in Italy with a variable, elevated $\delta^{15}\text{N}$ and largely terrestrial $\delta^{13}\text{C}$. Secondly, it shows a reduction in dietary diversity in early medieval Byzantine-controlled Italy, with lower $\delta^{15}\text{N}$ and no evidence for an increase in animal meat consumption. Some data suggest the pattern may be different in Lombard-controlled areas.

Thirdly, it raises questions about the interpretation of bulk collagen stable isotope results for dietary reconstruction. Identical data can represent multiple diet types and the most likely scenario is usually chosen based on external evidence, often simply confirming *a priori* assumptions. A diet potentially low in protein could introduce further uncertainty. We discuss how the dietary interpretation could be improved using single amino acid $\delta^{13}\text{C}$ analysis to provide an independent discrimination between similar dietary categories.

This research is funded by a doctoral fellowship from the Social Sciences and Humanities Research Council of Canada and by a studentship from the School of Archaeology, University of Oxford. Additional support comes from the Meyerstein fund, School of Archaeology, Oxford, and the Waldren Fund, Linacre College, Oxford.

39. The bones of the matter

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From earliest times, people have used the hard skeletal tissues of other animals, such as bone, ivory, horn and feather, as raw material, to create almost everything from simple tools to subtle and evocative works of art. The correct identification of the materials of cultural objects is fundamental to understanding their cultural significance, conservation needs, issues of authenticity and the underpinning of future research. Today these materials have been replaced by alloys and synthetic plastics, and animal conservation concerns have made some unavailable and unacceptable. With the passing of these raw materials, familiarity with their characteristics and properties has been lost, posing a challenge for those who work with historic and prehistoric artefacts made from them. Additionally, the working of these materials can greatly obscure their origins and this is further complicated by the decay and contamination that occurs in different archaeological environments. Cultural Objects Worked in Skeletal Hard Tissues is a three-year post-doctoral research project, funded by the AHRC/EPSRC Science and Heritage Programme, that aims, through the collation, evaluation and validation of visual criteria and analytical techniques, to refine and develop identification protocols. This paper will outline the scope of the project and report the latest developments, illustrated with examples of archaeological ivories of several species that have survived in very different states of preservation on UK sites.

40. Differences in the management of raw material in the Upper and Middle Paleolithic in SW Iberia

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Lithic assemblages are one of the most important bodies of evidence for the study of hunter-gatherers. This is due to being practically indestructible and retains a large quantity of information relating past populations, including options relating raw materials selection, transportation, reduction sequences, blank production, retouch and discard.

Our study approach Southwestern Iberian Peninsula. Geological and geographic features mark this region with strong impact on asymmetries between North and South as between coastal and inland territories. This influenced the distribution of resources through the landscape, conditioning land usage.

Concerning lithic raw materials, it offers numerous igneous, sedimentary and metamorphic rocks along with a large amount of minerals. From these, Paleolithic populations choose a narrow quantity to produce their tool-kits, which can be divided in fine and coarse grained. Previously, some researchers defended the possibility of these last being used just as substitute or a practical way to save the fine ones, especially flint. However, recent studies seem to suggest that during through all Upper Paleolithic and probably also during the final moments of Mousterian, populations developed a strategy based on combined usage of fine and coarse grained raw materials, having each one a specific porpoises, aiming hunting or domestic activities. Data pointing to this new direction came from differences recognized on raw material selection, technological patterns, blank characteristics and use-wear traces.

In this paper we present some of these results derived from just finished, on-going and recently started research projects.

Keywords: Southwestern Iberia; Paleolithic; raw material management.

41. The Paleoecology of Oasis Origin on the Arabian Peninsula (4th millennium B.C.)

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The research project focuses on examining shifting prehistoric water management strategies on the Arabian Peninsula and investigates specifically the role of mid-Holocene climatic oscillations during the mid-Holocene in the formation of an entirely new socio-economic entity- the oasis economy- at least at 3200 cal BC. So, my research project is interested in the origin of oasis phenomenon, its role and significance in the development of local to regional right up to supra-regional trade networks as well as the importance of oases in the settling of Arabian Peninsula.

Although intensive subsistence economies associated with oases are important for nomads, sedentary dwellers and the entire economical region, little is known about the oldest oases as well as of their cultural antecedents on Arabian Peninsula. The roots of first oasis settlement date back to 5000 years ago and are visible in the surprising full developed oasis economy of Hili 8 in South-East-Arabia.

This abrupt appearance of a new economy in form of oasis on Arabian Peninsula begs the question of potential progenitors or processes of development. At present there are three theories for the origin of oasis on the Arabian Peninsula. The research project is orientated towards the theory of changing climatic conditions after the Mid-Holocene climatic optimum, but will also show an interest in the thesis that first oasis cultures resulted from the onset of cooler and more arid conditions after this climatic optimum, and not as found in literature, that oases are the direct result of a Mid-Holocene climatic optimum.

42. Dietary patterns in the mixed lay and monastic population from the postmedieval Carmelite friary burial grounds at Aalst (Flanders, Belgium), and their relationship with DISH

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Although studies on diet reconstruction using carbon and nitrogen stable isotope signatures ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) are numerous, little research is done on Belgian archaeological populations. The focus of this study is twofold. The first goal is to examine diet composition for a postmedieval mixed lay and monastic population, evaluating possible intra-population diversity by comparing carbon and nitrogen (^{13}C and ^{15}N) stable isotope data from different social, sex and age groups. The second goal of this research is the ^{13}C and ^{15}N stable isotope analysis of skeletons that display *Diffuse Idiopathic Skeletal Hyperostosis* (DISH), a condition of the vertebral column of uncertain aetiology, of which the most prevalent theory states that it is caused by a diet rich in animal protein. Stable isotope analysis is used to test whether such a high trophic level diet can indeed be linked to the prevalence of DISH.

43. Metric and morphological analysis of the human sternum: A surprisingly neglected skeletal element

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Morphological and metric analysis of the sternum was undertaken in this preliminary study to investigate its potential as an indicator of sex and population affinity. A set of 11 standard measurements was devised to record 162 sterna from males and females of European, African and Asiatic ancestry from skeletal collections at the School of Applied Sciences (Bournemouth University), the Duckworth Laboratory (University of Cambridge) and the Centre for Human Bioarchaeology (Museum of London). Statistical analyses including Pearson's chi-square, Spearman's correlation, the Kolomogorov-Smirnov test, t-test and one-way ANOVA were used to characterise differences in dimensions and morphology between and within the sexes and ancestral groups. Length of the manubrium was observed to vary according to sex, whereas width of the third sternal segment exhibits the greatest observed differences between ancestral groups. Observations on sternal measurements, indices and ratios were discussed in light of similar studies with comparable methodologies and results. The findings were compared and contrasted to Ashley's (1956b) observations and differences were found between both studies for sternal morphology of European and African individuals. For Asiatic individuals in particular, this study presents the first effort to summarise sternal morphology and metrics. Overall, relationships between sternal morphology and both ancestry and sex have been statistically proven and may be applied to practical osteological work in archaeology and anthropology. Future research on this topic, incorporating greater sample sizes, may potentially yield regression formulae for the determination of sex and ancestry, since morphological and metric differences have been established in this study.

44. Site formation processes and mining operations at the prehistoric salt mine of Hallstatt, Austria: A geoarchaeological multi-proxy approach

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During the late Bronze and Iron Age the area of Hallstatt developed into one of Europe's earliest industrial sites and became part of a continental trading network, based on the extraction of subterranean salt deposits. The prehistoric salt mine of Hallstatt presents a unique interface between social, economical and environmental agencies and patterns, together with the well known early Iron Age cemetery at the site, and therefore plays a key role in our understanding of European prehistoric societies,

During the Bronze Age a large collapse at the mine in the *Christian von Tusch shaft* sealed in former worked tunnels and preserved many archaeological features. In order to understand the exceptional and complex formation processes of the structures and activities underground, which are crucial to interpretation of the mine's operation and collapse, this research investigates the main sediment sequences on a series of scales.

Micromorphology has been chosen as principal technique to examine the microstratigraphy of selected sedimentary sequences. The study of composition, internal structure and transition zones of each stratigraphical unit provides important data on the depositional and post-depositional processes of the sediments underground and thereby sheds light on the mine's formation processes, operation, organisation and spatial concepts prior to the collapse.

The cause, sequence and chronology of the catastrophic collapse is being specifically investigated by geochemical (XRF, XRD, pH) and sedimentological (grain size) characterisation and comparison between collapse sediments from under, and potential sources above ground.

We demonstrate the usefulness of a multi-proxy approach in geoarchaeology and its potential for the application to underground mining scenarios.

45. Were dairy products important foodstuffs in prehistory or just a widely used post-firing waterproofing treatment?

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Organic residue analysis enables the investigation of organic molecules preserved in the porous fabric of prehistoric pottery in order to address the questions of food acquisition and preparation techniques, and vessel function. Dairy fats are regularly detected in pottery from a wide chronological and geographical range (Copley et al. 2003, 2005; Craig et al. 2005; Evershed et al. 2008; Outram et al. 2009), including vessels from domestic and funerary contexts. A reoccurring question is whether these dairy fats represent remnants of the post-firing waterproofing/sealing of porous pottery vessels, or are genuine residues of milk products prepared within such pots. We have addressed this question through laboratory cooking experiments, wherein replica pottery vessels were waterproofed with milk and then used to process different commodities. Vessels were then sampled, the potsherds extracted with organic solvents and the lipid extracts investigated using gas chromatography and isotope ratio mass spectrometry. Examination of the $\delta^{13}\text{C}$ values of the major saturated free fatty acids [palmitic ($\text{C}_{16:0}$) and stearic ($\text{C}_{18:0}$)] enables ruminant and non-ruminant fats, and most importantly adipose and dairy fats, to be distinguished. Previous cooking experiments have shown a cumulative lipid signature when plant and animal foodstuffs were prepared sequentially in the same vessel (Evershed 2008); this paper discusses the effects on the fatty acid carbon isotope signature of meat subsequently processed in the milk-sealed vessels.

46. Carbon Nitrogen and Strontium isotopes in the Neolithic Tavoliere (Apulia, southern Italy)

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The re-study of the human remains from the Scaloria cave in Manfredonia, in southern Italy, has forced us to question our hitherto interpretations on the use of this cave during the middle Neolithic and, in general, our idea on human occupation in the Tavoliere during the V millennium bc. This has triggered a carbon, nitrogen and strontium isotope study on a number of sites in our study area to have a better understanding of food practices and human mobility.

A complex pattern has emerged, where the isotopic signature referring to the use of specific foodstuffs and the exploitation of resources traditionally associated with Neolithic economies not always met our expectations. Human mobility and the relationship between different groups as expressed by the Sr signature has also challenged our idea of a network of sites in the Neolithic Tavoliere plain.

47. Ancient DNA analysis of Gaelic medieval human remains - The Ballyhanna Research Project

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The Ballyhanna Research project (BRP) provided an exciting opportunity for ancient DNA (aDNA) analysis to be undertaken on individuals from the medieval community at Ballyhanna, Co Donegal. This collection of human remains is one of the largest ever excavated in Ireland, therefore it was hoped that the project would add significantly to our understanding of the lives and deaths of an Irish medieval population.

Ancient DNA analysis is a relatively new area of science which has presented archaeologists with an alternative means of investigating past societies. One of the aims of the project was to develop a reliable biomolecular method for the extraction and analysis of aDNA. The recovered aDNA extract would then be analyzed to establish the sex of a number of adult and juvenile skeletons. At present, reliable sex estimates cannot be established for juveniles using standard osteological methodologies.

DNA was extracted from 50 Adult teeth after comparing the sensitivity of a number of extraction methods. Subsequently the sex of each individual was identified using Forensic based methods and the results verified in a second centre laboratory in the University of Wisconsin, Madison. Once it was determined that the molecular methods were accurate in their sexing of adults, these methods were then used to determine the sex of juveniles.

Research is also being carried out to identify whether it is possible to extract *Mycobacterium Tuberculosis* in the Ballyhanna skeletons exhibiting pathological lytic lesions which may indicate Tuberculosis disease, with assistance from Mike Taylor from University of Surrey.

48. Soil processes and post-depositional changes to charcoal

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Please insert the abstract in place of the text below. It should be no longer than 250 words, exclusive of title, author information and acknowledgements of funding support.

Charcoal is one of the most frequently recovered material remains from archaeological sites. Analysis of which aids site interpretation with respect to the human activities undertaken at sites, the palaeovegetation and palaeoclimate and land-management practices such as swaling and coppicing. On entry into soil, charcoal is subject to post-depositional (soil) processes which have the potential to alter its physico-chemical characteristics and hence any subsequent archaeological interpretations. The large surface area of charcoal means that its presence in soil also has the potential to impact on not only soil processes such as N-cycling, but the post-depositional loading and retention of archaeologically-relevant elements such as Ca, Sr, P, Zn and Cu. Soil moisture content is one of the primary controls of soil processes and water-logged soils often contain well-preserved archaeological specimens.

Using soils with contrasting lead contents, collected from a former lead mine, we have incubated fresh charcoal from birch for a period of six months under laboratory conditions in order to investigate the impact of soil moisture conditions and regimes on the post-depositional changes to charcoal structure and chemistry.

49. Agricultural development in Tongan prehistory: From strandlooper to maritime empire?

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People of the Lapita cultural complex settled the Tongan archipelago around 2900 years ago, and the islands formed the eastern limit of this first human colonisation of Remote Oceania. Over time, a complex maritime chiefdom emerged that continued this tradition of long-distance voyaging, travelling throughout Western Polynesia to gain political influence. Understanding the role of agriculture in the development of this chiefdom is vital, as the full suite of domestic plants and animals were apparently not introduced as a single package by the Lapita colonisers, indicating later introductions through trade and island contact. Additionally, the dispersed small island landscapes within the archipelago are quite unlike the islands of the Western Pacific, and would have forced revisals of agricultural practices to allow crops to be grown successfully. My research will investigate the timing and introduction of prehistoric introductions in Tonga through a study of ancient plant remains found in Lapita and post-Lapita archaeological sites around Tongatapu. A combination of micro- and macro-botanical techniques will be implemented. One primary question that the study will examine is whether early colonisers were dependent on introduced crops, or if human dispersal was fuelled predominantly by the exploitation of natural resources. The answer is important for understanding the motives for human migration into Polynesia, and the transformation of island environments and cultures over time. To gain early feedback, this poster will focus on the methodology that will be implemented, and display preliminary findings from the establishment of a comparative collection at the ANU.

50. How can 17th century bronze cannons be magnetic?

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During investigations to the cause and type of corrosion of salvaged 17th century cannons, it became apparent that some of the bronze pieces were (ferri or ferro) magnetic. A magnet would stick at the surface of, what should be, a bronze cannon. What could be causing such a phenomenon?

The hypotheses are:

- During manufacturing the mold for the cannon, an iron frame is constructed and added for strength. If this frame is close to the surface, the cannon could get magnetic.
- Iron particles or scrap could be included in the bronze melt.
- Magnetic iron minerals (magnetite, greigite) may have been formed during the stay on the seafloor.

We investigated the composition of eight 17th century cannons with hand held XRF. The results indicate that the magnetic cannons have higher iron contents than non-magnetic cannons. In addition, the tin content of the bronze was in some cases lower as was described or ordered in the 17th century. Was some iron added to the cannon in order to disguise the deficiency of tin? Material science research is currently being performed to confirm the addition of iron to the bronze cannons.

51. Late Iron Age to early Roman occupation at Calleva Atrebatum: A geoarchaeological investigation of pits and preserved floors

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The late Iron Age to early Roman periods are of major importance to our understanding of key changes in economy, social organisation and material culture, with increasing contacts with Europe and the Mediterranean world. Excavations at *Calleva Atrebatum* (Silchester) are currently uncovering occupation levels from these key transitional periods. The urban traces of these periods are best represented by pits and floors from ephemeral buildings, which are best preserved when they are slumped into the top of pits.

Multi-proxy analysis of these deposits are of critical importance to the interpretation of the early history of Silchester, and this poster will outline the research objectives to explore the development of the late Iron Age settlement.

Micromorphology will be used to classify the origin, deposition and post-depositional alteration of sediments, bio-archaeological remains and artefacts to determine anthropogenic activities associated with the floors and pits, and place them into Silchester's wider stratigraphic history. Phytolith analysis will be used to examine the presence and preservation of selected species to investigate associated activities. In addition, geochemical analysis (XRF and pH) of these features will be utilised to identify 'diagnostic' elemental signatures of materials and activities, with comparison to off-site controls and wider geochemical analysis of the site.

The nature and character of activities, indicated by these combined scientific techniques, will form the basis of intra-site comparison of late Iron Age and Early Roman features to determine the nature of urbanisation and continuity and change within Insula IX.

52. Mammoth and horse movement in the Pleistocene of Jersey: results of a pilot study using strontium isotope analysis

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Strontium isotope analysis has been used successfully to investigate animal movement in a variety of periods. Results from the analysis of Pleistocene faunas have provided evidence of long distance movement in species such as woolly mammoth (*Mammuthus primigenius*) and shorter distance movement in horses (*Equus hydruntinus*) throughout this period. Recent work has used the information provided by isotope analysis as a proxy for Neanderthal hunting and mobility practices.

This pilot study used strontium isotope analysis to investigate the movement of animals found at the Middle-Late Pleistocene cave site of La Cotte de St Brelade, Jersey. Isotope analysis of animal teeth from the site has provided information about the likely migration patterns of different prey species in the Palaeo-Channel region and has implications for Neanderthal mobility. Strontium signatures have also helped to test the hypothesis that megafaunal 'bone heaps' are evidence of a Neanderthal mass-kill site (Scott 1980).

The research was funded by a Société Jersiaise Millennium History Research Fund.

53. Global perspectives on mass fatalities in medieval London

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Ice core evidence suggests that the largest volcanic eruption of the last millennium occurred in 1258 somewhere in the tropics. According to palaeoclimate models this would have led to a significant summer cooling, possibly on a global scale, due to the stratospheric spread of a blanket of volcanic particles.

Contemporary English sources noted a cool period from February to June 1258 and a very cold winter in 1260-1261, a pattern that may reflect the aftermath of strong tropical volcanic activity. Severe summer and autumn rains led to crop failures throughout north-west Europe. In England this caused rising grain prices and famine, and increased rates of migration from the countryside to London. A great pestilence struck the city in the spring of 1259.

Mass burial pits in the medieval burial ground of St Mary Spital in East London may have been dug as a reaction to increased rates of mortality. Stratigraphic analysis and radiocarbon dating established a peak in mass burial in the mid 13th century.

Whilst famine and disease were no strangers to urban populations throughout the medieval period, it may be that the suffering in the late 1250's was part of a global scenario that originated from volcanic activity.

54. A tephrochronological framework for climate variability from the mid-late Holocene, Northern Italy

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The Holocene is punctuated by significant periods of rapid climate change (RCC), global intervals which are characterised by polar cooling, tropical aridity and major atmospheric changes. These events have had dramatic impacts on cultural groups around the globe where the ecological resources of society have responded negatively to changing climatic conditions. Although it is clear these events can have far reaching consequences, it must be noted that each event has regionally specific reactions.

The Northern Apennine region of Liguria, Italy has a good regional framework for vegetation changes throughout the Holocene but not a precise enough chronology to correlate RCC intervals with palaeoenvironmental and archaeological data. This study aims to (1) develop a precise chronological framework for environmental changes using tephrochronology, and (2) develop a new, independent climate model for the mid-late Holocene using stable isotope analysis. Tephrochronology is arguably the best chronological method for synchronising RCC events as tephra disperses over a wide geographical area creating an isochronous marker which can be used to link environmental and archaeological events. This study will represent one of the first explorations into a tephrochronological framework for Northern Italy where results, alongside new climate data, will create a better understanding of the environmental and anthropogenic response to climate change in the region.

55. Developing the stable carbon isotope method of inferring the water status of ancient crops

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Stable carbon isotope analysis has been identified as a means of reconstructing the water status of ancient crops. While plant physiologists have shown that the stable carbon isotope ratios of present-day crops relate to growing conditions, especially water status, isotopic analysis has not been widely used as a way of reconstructing the water status of crops grown in unknown conditions. Consequently, there is a lack of a consensus on how widely and reliably the isotopic analysis of charred archaeological remains can be used to reconstruct the water status of ancient crops. This research aims to establish the effectiveness of the stable carbon isotope technique, and involved the growth of modern crops in several locations across Europe and Western Asia. Issues regarding the charring, contamination and pre-treatment of archaeological crop remains are also addressed. The research shows that stable carbon isotope analysis is an effective means of inferring crop water status, but variation, which cannot be fully accounted for in the archaeological record, limits the resolution with which water status can be reconstructed. Awareness of the limitations of this type of isotopic analysis is critical to its reliable application in archaeological research.

56. A multi-disciplinary approach to subsistence at two Early Neolithic sites in Western Iran: Integrating evidence from plant macrofossils, phytoliths and dung remains from micromorphological samples

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The Early Neolithic sites of Sheikh-e Abad and Jani are situated 90km apart in the Central Zagros Mountains of Western Iran (1,425m and 1280m asl respectively). Preliminary investigation was undertaken in 2008 and initial radiocarbon determinations have produced highly significant dates with the earliest levels at Sheikh-e Abad dated to c.9,800 cal BC. Plant macrofossil studies to date at Sheikh-e Abad have indicated the presence of wild grasses, leguminous taxa, and a range of taxa common to local forest steppe including reeds and sedges. Charcoal accounts for upwards of 85% of the charred assemblage. Phytolith remains include Pooideae, Panicoideae and Chloridoiseae grasses, Barley, Wheat (the latter only from Jani) reeds and sedges. Micromorphological evidence has demonstrated the presence of faecal dung spherulites, possibly indicating *in situ* penning of animals and the utilization of dung as fuel. Deposits with omnivore and herbivore coprolites identified by micromorphology, have been subject to bimolecular analysis by GCMS (Shillito *et al.* forthcoming).

By continuing to embrace this multidisciplinary approach throughout our future studies we hope to add weight to existing findings and address a range of important issues related to human and animal subsistence at these two Early Neolithic sites in Western Iran including; the adoption of domesticated cereals, seasonality of occupation and activity, food preparation and storage, management of livestock and penning and the possible use of dung as fuel.