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ZooMS identification of bone tools from the North African Later Stone Age

Abigail Desmond[a,*], Nick Barton[a], Abdeljalil Bouzouggar[b], Katerina Douka[c,d], Philippe Fernandez[e], Louise Humphrey[f], Jacob Morales[g], Elaine Turner[h], Michael Buckley[i]

[a] University of Oxford, Institute of Archaeology, 36 Beaumont St, Oxford, OX1 2PG, United Kingdom
[b] L'Institut National des Sciences de L'Archéologie et Du Patrimoine (I.N.S.A.P), Rabat, Morocco
[c] Research Laboratory for Archaeology and the History of Art, University of Oxford, 1 South Parks Road, Oxford, OX1 3TG, United Kingdom
[d] Max Planck Institute for the Science of Human History, Department of Archaeology, Kahlaische, Straße 10 07745, Jena, Germany
[e] Aix Marseille Univ., CNRS, Minist. Culture, LAMPEA, UMR 7269, 5 Rue Du Château de, L'Horloge, Aix-en-Provence, France
[f] Natural History Museum London, Department of Earth Sciences, Cromwell Road, London, SW7 5BD, United Kingdom
[g] Department of Historical Sciences, University of Las Palmas de Gran Canaria, Pérez Del Toro 1, Las Palmas de Gran Canaria, 35003, Spain
[h] MONREPOS Archaeological Research Centre and Museum for Human Behavioural Evolution, RZGM, Schloß Monrepos, 56567, Neuwied, Germany
[i] School of Earth and Environmental Sciences, Manchester Institute of Biotechnology, Princess St, Manchester, M1 7DN, United Kingdom

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ABSTRACT

This study applies peptide mass fingerprinting (also known as 'ZooMS') to bone tools from the North African Palaeolithic, as the first stage in a research programme aimed at understanding distinct phases within a bone tool *chaîne opératoire*. We report on the largest collection of bone tools from the North African Later Stone Age (LSA), from the cave site of Taforalt (Grotte des Pigeons) in eastern Morocco. Their appearance at this site from c. 15,000 cal BP appears to coincide with other changes in human behaviour which led to increased sedentism, cemetery use, and intensive exploitation of certain food resources. As such, bone tools can provide insights into how such broad-scale cultural renegotiations may have been brokered technologically, independent of the lithic record. Here, we explore initial raw material selection and manufacture strategies through use of ZooMS, a technique that permits identification of specific animals from very small bone samples. We found that ZooMS is highly suitable for use on the Taforalt material, and that bone tool morphology and construction tracks closely with the original animal from which a tool was made. Our results indicate that the Iberomaurusian occupants of Taforalt embedded bone tools within culturally-mediated technological strategies, potentially involving other perishable materials.

1. Introduction

Bone tools are recurring elements of the modern human archaeological record, particularly from the Late Pleistocene onwards. They differ from the ubiquitous stone tool record in that they articulate more closely with human subsistence behaviour, being made from many of the same animals used for food and clothing. As such, tracking bone tools through their complete life history reveals otherwise inaccessible parts of the interlinked cultural system present at a site. Here, we present the first modern study of bone tools from the Later Stone Age site of Taforalt, focusing on the identification of the animal species exploited by the site's occupants.

A historical focus on Palaeolithic stone technologies has often led to bone tools being described cursorily, or using functionally-eponymous descriptions. For example, pointed tools are often classed merely as 'points,' or as 'awls' or 'spear-tips', without recourse to use-wear analyses (Allen et al., 2016; Bradfield, 2016; Desmond, 2017; Pargeter et al., 2016; Soffer, 2004). At many archaeological sites, the loss of perishable crafted forms has likely contributed to the miscategorization of bone tools that had been used to produce such items (Chomko, 1975; Soffer, 2004; Stone, 2015). Tools used in Palaeolithic craft production have generally either been classed erroneously (often as weapons), or as having indeterminate or enigmatic functions (Bradfield, 2016; Soffer, 2004).

Equifinality—multiple processes leading to a similar outcome—is a problem when bone tools are ascribed use-categories based on gross morphology alone (*e.g.*, Premo, 2010, Rogers, 2000). Historic and ethnographic records show that tools of different shapes and sizes, constructed from different materials, have been used to perform the same technical function. Similarly, nearly identical-looking tools can be used in completely different ways by different communities, or even within the same community over time. Furthermore, a single tool may

* Corresponding author. Hertford College, Catte Street, Oxford, OX1 3BW, United Kingdom.
E-mail address: abigail.desmond@arch.ox.ac.uk (A. Desmond).

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have been used for a number of different purposes synchronously. For example, a long, thin, gracile tool may make an excellent ad-hoc toothpick, or be used to pierce a snail shell. In the absence of organic materials on which a tool may have been used, and in view of issues of eponymous-tool categorization and equifinality, it is necessary to develop a multi-method research programme aimed at disentangling bone tool form and function.

As part of this programme, we aim to identify and interrogate different stages within a tool's 'life history.' One model for doing so is the *chaîne opératoire*; as applied to bone tools, this includes understanding the tools' initial material selection and formation strategies, through use and curation, to eventual deposition (*e.g.*, Bar-Yosef et al., 1992, Henshilwood et al., 2001, etc.). This approach maintains a dynamic focus on tools as objects of use, providing a discursive and relational approach to material culture in the Iberomaurusian, wherein tasks and technologies together form a mutually constitutive culture of material and practice. This approach requires us to contextualise bone tools in a site- and culture-specific way, and to consider them alongside other lines of evidence with which they co-occur archaeologically.

1.1. Species identification by ZooMS/Peptide mass fingerprinting

This study uses ZooMS, or **Zoo**archaeology by **M**ass **S**pectrometry, to gain insights into initial taxon selection as the first stage in a bone tool *chaîne opératoire*. ZooMS has a number of advantages when compared with other biomolecular identification techniques, as it can work on Palaeolithic bone material from warm, arid environments, requires minimally invasive sampling, and is less expensive and labor intensive than, for example, DNA sequencing. The results can indicate degrees of industrial maturity, by revealing indiscriminate or strategic taxa selection for the production of specific tool types, as well as iterative stages through time. ZooMS data can also serve as a platform for investigating stages of an object's *chaîne opératoire*, such as use-wear and depositional relationships. For the former, use-wear correspondences among types created from specific taxa may indicate whether tools were constructed to a preconceived specification in order to effect particular tasks. ZooMS may also help identify ideological relationships with particular taxa; for example, if tools created from particular taxa are repeatedly associated with burials or other meaningful features.

Because ZooMS uses collagen peptides as the basic unit of analysis, this circumvents many of the preservation issues that can limit and constrain DNA extractions. For example, ZooMS can work on material recovered from hot, arid climates (*e.g.*, Harvey et al., 2016), because over time minerals encase, preserve, and prevent the collapse of the collagen fibrils used in ZooMS identifications. As collagen becomes entrapped in this mineral matrix, collagen peptides gain a heightened resistance to high temperatures and other deleterious long-term burial processes (San Antonio et al., 2011). When a bone or bone tool is archaeologically recovered, the collagen peptides can be extracted and high throughput mass spectrometry used to accurately determine the animal taxa (Hounslow et al., 2013, Von Holstein et al., 2014). ZooMS also minimizes the need for destructive analysis with good project designs dictating that any such sampling be as minimally invasive as possible. ZooMS meets these criteria, as very small sample sizes (as small as 5 mg from modern material) have yielded tenable results. Finally, lab-based scientific analyses are often constrained by 'real-world' considerations such as labour and materials costs. ZooMS costs and working hours are significantly lower than those associated with DNA analysis, allowing for more rapid analysis of a greater volume of material (*e.g.*, Buckley et al., 2016, Brown et al., 2016).

1.2. Taforalt

The cave site of Taforalt (34° 48′ 50″ N, 2° 24′ 14" W) is located in the Oujda region of northeastern Morocco, approximately 40 km from the Mediterranean coast (Fig. 1). This site has yielded the largest collection of bone tools from the North African Later Stone Age (Iberomaurusian), providing a unique opportunity for insight into the archaeological culture that produced them. To date, more than 500 bone tools have been recovered from Iberomaurusian levels at Taforalt, 200 of which are currently available for study. The Iberomaurusian first appeared in North Africa around 25,000 cal BP (Hogue and Barton, 2016) and may have continued into the Holocene after 11,600 cal BP (Barton et al., 2008). At Taforalt, the bone tools first appear in Iberomaurusian deposits dating from c. 15,000 cal BP, which coincided with major changes in human behaviour at the site linked to dietary shifts and likely a reduction of group mobility (Humphrey et al., 2014). They are one of a number of novel social and technological behaviors that appear at Taforalt against a background of climatic changes at the beginning of Greenland Interstadial GI-1e (Rodrigo-Gámiz et al., 2011; Barton et al., 2013). This phase of the Iberomaurusian is also marked by a major change in sedimentation within the cave (hereafter 'Grey Series' levels) that, in the area where the tools were recovered, began to accumulate between 15,190 and 14,830 cal BP (Barton et al., 2013).

Rather than a significant change in cultural material, the onset of Grey Series sedimentation may mark a subtle behavioural transition that led to an early form of sedentism, intensification in the exploitation of specific food resources and the first examples of funerary activity (Humphrey et al., 2012, 2014). Of the 200 available tools, 40 were excavated since 2003, of which 38 were recovered from the earliest burial deposit located in the Sector 10 alcove at the rear of the cave. All tools analysed here were among those recovered from grey ashy deposits in Sector 10 which correspond with the onset of Grey Series sedimentation. The remainder of the tools were excavated during the mid-20th century; between 90 and 160 of these were excavated from related Iberomaurusian burial areas (Necropolis I [NI] and Necropolis II [NII]) by Abbé Jean Roche in the 1950s (Desmond, 2017; Roche, 1963). Overall morphologies and repetition of specific tool features are similar between the tools excavated by Roche and those found in Sector 10, indicating that these are members of a continuous Iberomaurusian bone tool industry (Desmond, 2017, Desmond forthcoming).

While Iberomaurusian stone tools have been relatively well-documented (Lubell, 2001, Hogue, 2014, Hogue and Barton, 2016, McBurney, 1967, etc.), no modern study has been made of bone tools from the Iberomaurusian, either from Taforalt or elsewhere. Stone or lithic tools are the most taphonomically robust components of the archaeological record, in contrast to organic materials, such as wood, bone, skins, and vegetal remains. Because of their durability and ubiquity, stone tools have served as de-facto benchmarks for defining cultural entities, and even as indices for human species (Bordes, 1950, Debénath and Dibble, 2015, Hoffecker, 2011, Kuhn and Zwyns, 2014, etc.). However, reliance on a single aspect of material culture cannot typify a culture's entire technological strategy. This is especially true when examining the evolution of technologies through time, and during wide-scale cultural renegotiations. Lithics may also show conservatism across cultural thresholds; it has yet to be determined whether wood, bone, and other perishable material forms may allow more plastic responses to short-term environmental, demographic, or cultural pressures. Bone tool studies therefore permit a broader understanding of how the Iberomaurusians negotiated changes in both external forces such as palaeoclimatic processes, and internal forces such as increased sedentism, burial as an emergent ritual practice with respect to the dead, and resource intensification.

1.3. Aims

Although ZooMS has been applied to much more recent bone implements (*e.g.,* Viking combs; Von Holstein et al., 2014), the present study is the first to apply it to Palaeolithic bone tools, and as such we created a nested set of aims that explore the power of this technique. First, we aimed to identify the taxa from which each sampled bone tool was made, to the genus or species level if possible. Second, we aimed to