Bone Tool Proxy Evidence for Coiled Basketry Production in the North African Palaeolithic

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Abstract
Bone tools from Taforalt Cave constitute the largest North African Later Stone Age (LSA) bone tool technocomplex recovered to-date. Use-trace analyses show that the small, pointed forms which dominate the assemblage show microtopographic patterning consistent with ethnographic bone tools used to make coiled basketry. The presence of coiled basketry likely scaffolded emergent cultural forms reflected in increased sedentism, resource intensification, and greater population density at Taforalt. This study explores the relationship between coiled basketry and archaeologically co-occurring technologies. Ethnographic analogies derived from Indigenous Californian groups provide a model for how resource-specific collection, processing, storage, and preparation requirements may have been supported technologically.

Keywords

1 Introduction
Taforalt Cave (also known as Grotte des Pigeons) is an archaeological site situated in the Beni Snassen mountain range of northeastern Morocco near the Algerian border (34°48′50″ N, 2°24′14″ W). Archaeological deposits represent a well-stratified sequence from the Iberomaurusian Later Stone Age (LSA), ranging from around 23,000 to 12,600 cal BP (calibrated radiocarbon years before present) (Staff et al. 2019). The site contains a wealth of well-preserved material from the Iberomaurusian culture, including faunal remains and bone tools. Along with the depth of the deposits, this exceptional preservation has allowed researchers to examine and understand the lifeways of North African LSA people in high resolution – a valuable opportunity in the North African Palaeolithic.

In order to understand bone tools created by this culture, it is necessary to examine their wider archaeological context. Early Iberomaurusian deposits from Taforalt show ephemeral use of the cave as expected by seasonally mobile hunter-gatherer groups. These deposits are referred to as the Yellow Series and begin around 22,912–23,459 cal BP (OxA-35509; Staff et al. 2019). A marked depositional shift can be seen as the Iberomaurusians transitioned to intensive year-round occupation of the cave. These deposits are referred to as the Grey Series, with an onset at c.15,000 cal BP and persisting to 12,566–12,713 cal BP (OxA-24111; Staff et al. 2019). Iberomaurusians at Taforalt did not fit into the mobile hunter-gatherer framework broadly expected of Palaeolithic/late Pleistocene peoples, and Grey Series deposits indicate degrees of sedentism and broad-spectrum behaviour often associated with the pre-Neolithic in a Mediterranean context (Humphrey et al. 2012, 2014; Barton et al. 2019a). A recently published overview and synthesis of finds from the 2003–2020 field seasons explores a number of themes related to emergent sedentism and cultural changes associated with this shift (Barton et al. 2019a). These changes manifest both behaviourally and technologically.

Behaviourally, a major cultural development commensurate with the Grey Series occupation of the cave is funerary behaviour in the form of on-site burials (Humphrey et al. 2012, 2014, 2019). Another is the development of seasonally-organised resource procurement. While Ammotragus lervia (Barbary sheep) remained the main animal hunted in both the Yellow and Grey Series, there is a marked differentiation and expansion in the use of plant resources beginning in the Grey Series (Barton et al. 2019c; Morales 2019). These include a dramatic increase in the harvesting of locally available edible plants such as acorns, pine nuts, wild pulses, and fruits (Carrión Marco et al. 2018; Carrión Marco 2019; Morales 2018, 2019), and
also in non-edible esparto grass, which was collected and brought to the site in great quantities (Humphrey et al. 2014; Morales 2019). Land snails were also collected and eaten in very large numbers, and Grey Series middens are estimated to have contained up to 60 million snail shells (Barton et al. 2019c; Taylor & Bell 2019).

At the same time, a number of new technologies appear in the Grey Series deposits. Grindstones are first attested to in these levels, and some were used to process colou- rants, while others were likely used to process acorns, nuts or other plant materials (Barton et al. 2019b). Also evident are a wealth of non-local limestone rocks, apparently selected and transported into the cave. Evidence shows these rocks were repeatedly heated, indicating that the Iberomaurusians had an advanced understanding of the thermal properties of limestone, as well as suggesting their use in boiling or roasting in cooking (Barton et al. 2019c; Collcutt 2019a). Tantalisingly, deliberately shaped and sometimes fired bits of clay are evident through the Grey Series though evidence for developed forms of pottery is wholly absent (Barton & Collcutt 2019).

Lithics have often served as a proxy for cultural development among Palaeolithic peoples. However, there is no marked difference in microlithic bladelet technology at Taforalt between the Yellow and Grey series (Hogue & Barton 2019; Hogue & Bouzzougar 2019). This conserva- tism in lithic production may be related to the continued reliance on A. lervia (Barbary sheep) as the main animal food resource, but also implies that the wide-scale changes evident in the Grey Series must have been enabled and scaffolded by other technological forms (Desmond et al. 2018; Barton et al. 2019c).

The emergent diversification in and large-scale harvest- ing of seasonally available food resources likely entailed perishable food processing and storage technologies, enabling that such food surpluses “would have constituted a vital element of risk management” in year-round occu- pation of the site (Barton et al. 2019c: 534). The presence of food collection, processing, and storage tools made from organic materials (such as leather, wood, and plant fibres) are inferred rather than observed directly (Humphrey et al. 2014; Morales et al. 2015; Desmond et al. 2018; Barton et al. 2019c; Desmond 2019). By modifying and expanding craft- ing practises (such as leatherworking or weaving), it would have been relatively easy for Iberomaurusians in the Grey Series to scale up production or create new forms as neces- sary (Desmond et al. 2018).

Finally, bone tools exist in great numbers within the Grey Series. These are present in the earliest Grey Series levels, and at least one bone tool was deliberately included in an early human burial on-site (Desmond et al. 2018). ZooMS analysis shows that the Iberomaurusians strategically selected less common taxa for bone tool construction from the onset of Grey Series sedimenta- tion (Desmond et al. 2018). Though bone tools are more numerous in later Grey Series levels, tool forms remain consistent even from the earliest Grey Series levels, and advanced taxa selection strategies were already in place at the beginning of reduced itinerary among the Iberomaurusians (Desmond et al. 2018; Desmond 2019). This indicates that whatever tasks the bone tools were used to perform were already within the technological capacities of the Iberomaurusians before the shift to sedentism, and that these tasks expanded in importance during the Grey Series occupation of the cave (Desmond et al. 2018).

2 Materials and Methods

To date, 743 bone tools have been excavated from Iberomau- rian levels at Taforalt (Desmond 2019). These include 704 bone tools excavated by Abbé Jean Roche in the 1950s, of which 160 are housed in the collections of the Rabat Archaeological Museum; the other 543 are reported (Roche 1963), but their current location is unknown. A further 40 bone tools were excavated between 2003 and 2016 within the current project, bringing the number of tools available for study to 700. Even though this subset represents less than half of the total number of bone tools found at Taforalt, it remains the largest known collection of North African LSA bone tools (Desmond 2019).

Size, shape, and feature-based analyses performed on this subset (n = 200) show that the most common bone tool form is a small, slender, pointed tool, constituting up to 65% of the total tools available for study (Fig. 1, Desmond 2019). These tools average 71.6 mm in length and 8.65 mm in width. Most tools displayed a greater degree of smoothing and/or rounding to the tool base than unmodi- fied taphonomic controls from the same or neighbouring archaeological contexts (Desmond 2019: 410). The average point tip size is 1.26 mm, and no tools were found to have diagnostic impact fracturing (Letourneux & Pétillon 2008; Bradfield & Brand 2013). Rather, rounding and polish of the point tip was visible on 46% of pointed tools. Together, these data suggest bone tool use and curation patterns inconsistent with being used in forceful impact activi- ties (e.g., as chisels, gouges, prises, etc.) or as weaponry (Desmond 2019). Such small, slender points dominate the bone tool assemblage throughout the Iberomaurusian deposits, and are the focus of this study.
Excavation data from the missing 543 tools shows that more than 60% were excavated from the front and middle interior of the cave, indicating concentrations in the best-lit areas on site (Desmond 2019). Pointed tools are particularly abundant in these areas, with 75.2% of pointed tools found in the front and middle interior of the cave. A small area representing perhaps the brightest area of the cave (Cav/Niveau C en avant, see Barton et al. 2019a) alone yielded 66 pointed bone tools. The distribution of bone tools (and pointed forms in particular) is further indicative of their use in everyday crafting processes, taking place on site in daylight ‘workshop’ areas, as small, pointed forms are concentrated in the best-lit areas of the cave, and occur less frequently in the rear of the cave (Desmond 2019). Use-wear analysis (or tribological analysis, which considers the interaction of surfaces in motion) considers the tool as a whole and the relationship of microscopic patterns on different parts of the tool to one another (LeMoine 1994). A tool which is used repeatedly for a specific purpose will exhibit microscopic changes to surfaces which come into contact for example with the material being worked or the human hand if the tool is held (Campana 1989; LeMoine 1994; Soffer 2004; Van Gijn 2005; Stone 2009; Struckmeyer 2011). By analysing the wear patterns which develop during use in experimental scenarios, researchers have been able to define and differentiate patterns associated with different osseous tool functions (Desmond et al. 2021). This approach allows for a more scientifically coherent assessment of use than morphological descriptions alone. Use-wear studies have come to dominate how many archaeological bone tool industries are interpreted, and there is a growing recognition that typo-functional categorisations based on whole tool morphology (i.e., shape and size) are often found wanting (Chomko 1975; Olsen 1979; LeMoine 1994; Griffiths & Bonsall 2001; Soffer 2004; Gates St-Pierre 2007; Stone 2009; Bradfield 2012, 2014; Antonites et al. 2016; Arrighi et al. 2016; Akhmetgaleeva 2017; Desmond 2017, 2019; Medina et al. 2018). Indeed, use wear-based reassessments of Upper Palaeolithic European bone and antler tool collections have shown that articles classified variously as sagies, shaft straighteners, batons de commandment, and enigmatic/art objects retain use-traces commensurate with the production of perishable crafts (Soffer et al. 2001; Soffer 2004; Stone 2011). The nature of microtopographic wear patterns on these tools suggests that perishable crafting was taking place at a wider scale than initially appreciated by Palaeolithic archaeologists (Dobres 1995; Soffer et al. 2001; Soffer 2004; Desmond et al. 2021).

To understand the processes that led to an industrial emphasis on small, thin pointed tools at Taforalt, a representative sample of 21 tools was selected. Only complete or relatively complete (after Desmond 2019) tools with good preservation (i.e., not weathered/friable) and minimal taphonomic alteration (e.g., concretions, burning) were chosen for analysis. The Iberomaurusian tools from Taforalt were analysed in collections at the Rabat Archaeological Museum and at the Institut National des Sciences de l’Archéologie et du Patrimoine (INSAP) in Rabat, Morocco. The tools were photographed using a Nikon D7000 camera and examined and imaged with a DinoLite (AM313T) digital microscope at 20–50× and 230× magnification.

In order to understand how these tools were used, it is necessary to compare the location and nature of use-wear patterning found on them to use-wear patterning on bone tools with known functions. Rather than using experimentally produced bone tools as the basis for comparative use-wear analysis, we have chosen to examine tools from ethnographic museum collections. Provided an ethnographic collection is both reliably and explicitly documented, these tools afford a comprehensive model for actualistic use-wear development which can circumvent many problems or simplifications associated with experimental studies alone (Olsen 1979; Legrand & Radi 2008; Stone 2009, 2011; Struckmeyer 2011; Keddie 2012; Langley et al. 2016). While some handling and curation of artefacts may be expected to occur in a museum setting, any use-traces developed through these processes (apart from serious changes such as the application of lacquer etc.) would generally not be extensive. Ethnographic tools are not a scientific approximation of certain use conditions, but rather objects repeatedly used and curated in dynamic everyday life scenarios by expert craftspeople.

Since Palaeolithic cultures cannot be assumed to have a direct ancestral relationship to any modern groups, comparative materials were chosen from groups with environmental and potentially cultural parallels to Palaeolithic North Africa. Metal tools are generally used in modern Moroccan and North African esparto crafting, so we must look further afield for appropriate ethnographic analogies. In order to be useful, ethnographic analogies must be, at least in part, site specific; that is, meaningfully congruent with the specific archaeological site and culture from which the archaeological bone tools were recovered.
(Binford 1962, 1978; Wylie 1985; Stone 2011). Morales et al. (2015) note widespread similarities between Palaeolithic North African Iberomaurusian and Capsian cultures and some Indigenous Californian cultures, specifically in terms of climate, emergent sedentism, and in the intensive use of pine nuts and acorns as food resources. For this reason, bone tools created and used by indigenous groups including Klamath Lake, Modoc, Yurok, Hupa, Pomo, Yokut, Eastern Miwok, Maidu, and Cahuilla peoples were analysed at UC Berkeley’s Phoebe A. Hearst Museum of Anthropology (PAHMA).

In order to avoid selection bias, a ‘control group’ of bone tools was selected and analysed from PAHMA and the Pitt Rivers Museum at the University of Oxford. These artefacts included ethnographic bone tools made and used among geographically and culturally disparate peoples in Alaska, Arizona, New Mexico, Montana, Indonesia, Guatemala, Sudan, India, Algeria, Australia, Melanesia, and New Guinea.

Ethnographic tools were selected for analysis only if they had detailed provenance records, which were broken down into three main categories: location/culture/time period, function, and, when possible, articulation and product. In this way, tools were selected which had not only known uses/functions (i.e., basketry awl), but also known articulations (i.e., vegetal/hide/wood) and, when possible, recorded details of the specific artefacts produced (i.e., used to make moccasins, coiled baskets, etc.). Ethnographic tools selected for analysis included arrowheads, marrow spoons, hide and skin scrapers, leather awls (for piercing), flensing tools, lithic retouchers, woodworking polishers, netting needles, wedges, knife sharpeners, woodworking gouges, matting needles, tule mashers and splitters, woodworking finishing tools, leather creasers, mesh-measures, bark strippers, sap gathering tools, netting shuttles, knot slippers (marlinspikes), warp-lifters, crocheting needles, sweet potato-, tuber- and pandanu-measures, bark strippers, sap gathering tools, netting shuttles, or knotslippers displayed use-wear patterning consistent with that found on the Taforalt subset. This use-wear patterning was also found to be visually inconsistent with and distinct from damage as a result of bioturbation and/or rodent/carnivore gnawing, by comparison with unmodified bone from Taforalt at INSAP and bone tools with chattermarks and grinding striations at PAHMA.

These traces were observed to be distinct from examples of chattermarks which are related to lithic shaping of the tool (Fig. 2A) and are inconsistent with striations associated with axial grinding as a tool formation strategy (Newcomer 1974; Campana 1989). This use-wear patterning was also found to be visually inconsistent with and distinct from damage as a result of bioturbation and/or rodent/carnivore gnawing, by comparison with unmodified weathered (Fig. 2B) and gnawed bone from the same or adjacent contexts at Taforalt. The nature of the Grey Series deposits from which the tools were excavated precludes many other kinds of taphonomic alteration (Collcutt 2019a), and taphonomic scenarios inconsistent with the nature of the deposits were not considered (e.g., water or wind dispersal/transport, trampling, extensive sedimentary abrasion or rockfall, ice movement, volcanic activity, digestive etching, etc. [Lyman 1987; Fisher 1995]). None of the ethnographic tools used as arrowheads, marrow spoons, hide and skin scrapers (Fig. 2C), leather awls, flensing tools, lithic retouchers (Fig. 2E), woodworking polishers, netting needles, wedges, knife sharpeners, woodworking gouges, matting needles, woodworking finishing tools (Fig. 2F), leather creasers (Fig. 2D), mesh-measures, bark strippers, sap gathering tools, netting shuttles, or knotslippers displayed use-wear patterning consistent with that found on the Taforalt subset.

Figure 2 provides some examples of functional use-wear incommensurate with the patterns found on this subset of Taforalt tools. These include an invasive, glossy polish on the point tip of a bone tool used in hide-scraping (Fig. 2C), non-invasive smoothing with crushing and pitting to the point tip of a bone tool used in creasing leather (Fig. 2D), randomly oriented scratches, gouges, divots, and the formation of smoothed-over chipped platforms on a bone tool used as a lithic retoucher (Fig. 2E), and a roughened surface with areas of high polish occurring at highest topographies of a bone tool used in woodworking finishing (Fig. 2F). For more examples of use-traces incommensurate with those found on this Taforalt subset, please see Desmond et al. (2021).

The small, thin, pointed tools from Taforalt displayed an overwhelming similarity in use-trace patterning to...
a specific subset of ethnographic basketry tools. These consistencies in patterning are borne out by a review of experimental bone tool research (Table 1), wherein descriptions of basketry and plant working use-trace development match those observed in this study. These use-traces consist of rounding and polish to the tools’ tips and bases, smoothing and/or polish extending along the shaft of the tool, and specific microwear patterning consisting of short, shallow, parallel striations beginning at or slightly below the point tip (Table 1, Fig. 5 A–D).

The patterning described here is a synchronic compression of use-traces which develop at different diachronic stages of use within a tool’s life history, or chaîne opératoire. Specifically, chaîne opératoire refers to the operational sequence from raw material selection, tool construction, tool use, and eventual deposition (Bar-Yosef et al. 1992; Leroi-Gourhan 1993, 2009; Henshilwood et al. 2001; Desmond et al. 2018). As with any archaeological technology represented in sufficient numbers, bone tools at Taforalt are representative of different stages in these processes.
objects’ chaîne opératoire. Because lithic scraping was the bone tool formation strategy used at Taforalt, one would expect to see some lesser used tools retaining clear longitudinal lithic striations (Fig. 3, Table 2: Initial basketry use-trace stage) (Campana 1989: 31; Desmond 2019).

Conversely, tools recovered at a more advanced chaîne opératoire stage appear smoothed, and such smoothing occurs atop and obliterates any lithic formation striations. In cases where the tool has been used for a long enough duration to sufficiently homogenise the tool’s surface, a glossy polish can be seen covering the entire tip and shaft of the tool (Fig. 4, Table 2: Advanced basketry use-trace stage). This kind of polish formation is consistent with basketry processes in which working portions of the tool are repeatedly abraded against silicate-rich vegetal material (Table 1), which over time homogenises the bone surface topography (Campana 1989; Legrand & Radi 2008).

As a result, tools which are most diagnostic of basketry use-wear are those in an intermediate use-stage within their chaîne opératoire (Fig. 5, Table 2). These tools have been used long enough to have developed microtopographic changes where they came into contact with the worked plant material, but not so long that all surface features have been homogenised and obliterated through continuous abrasion (Table 2: Intermediate basketry use-trace stage). While it is possible that these patterns represent different crafting processes and/or materials worked, this seems unlikely for the following reasons.

First, ethnographic basketry tools show similar chaîne opératoire use-trace development among tools used for the same purpose (e.g., Figs. 3 and 4). Second, chaîne opératoire stages are largely heuristic, and exist on a continuum rather than as discrete categories. Tools with features ‘between stages’ exist in both the Taforalt subset and among the ethnographic basketry tools. Finally, granular inclusions (such as pigments) which could cause different abrasive patterns are present in similar volumes on tools at all chaîne opératoire stages (Fig. 7, discussed later). It is therefore suggested that this differential patterning is representative of a chaîne opératoire use-wear continuum rather than evidence for different uses.

Use-traces diagnostic of basketry production in an intermediate use-trace stage occur in the form of small, short, shallow, parallel, clustered transverse striations, generally originating at and/or below the point tip (Griffits 2001; Soffer 2004; Legrand & Radi 2008; Stone 2009; Buc 2011; Campana & Crabtree 2018; Medina et al. 2018). These are visible at 20–50× magnification, and their specific locations on the tool, direction, orientation, and density are consistent between a subset of ethnographic basketry tools and the pointed tools from Taforalt (Fig. 4). These correspondences remained consistent at 230× magnification. Specifically, both the Taforalt tools and some basketry tools exhibited short, clustered, parallel striations occurring just below point-tip (Fig. 5 A–B) and overlapping transverse striations occurring on the tool shaft just

**Figure 3** Early chaîne opératoire stages showing longitudinal lithic striations on small, thin pointed tools from Taforalt, at 20× magnification

**Table 2** Use-wear indicative of chaîne opératoire stages in silicate-rich basketry crafting

<table>
<thead>
<tr>
<th>Initial basketry use-trace stage</th>
<th>Intermediate basketry use-trace stage</th>
<th>Advanced basketry use-trace stage</th>
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<tbody>
<tr>
<td>Initial lithic formation striations visible; these appear as longitudinal scoring along the entire surface to the tool, parallel to the tool’s axis.</td>
<td>Short, clustered parallel or overlapping transverse striations occurring at tool’s point tip or just back from point tip along tool’s shaft. Rounding and polish begin to develop on the tool’s tip, shaft and base.</td>
<td>High degree of smoothing and polish to tool, rounding of tool tip, smoothing of tool base where it is held in the hand.</td>
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Figure 4  Consistencies in highly smoothed surfaces on ethnographic basketry tools (A, C) and on bone tools from Taforalt (B, D) at 20× magnification.

Figure 5  Correspondences between basketry use-wear at 20–50× magnification on ethnographic bone tools used to make coiled baskets (A, C, E, and G) and on bone tools from Taforalt (B, D, F, and H).
Emergent features of this Taforalt tool subset include the presence of pigment on most of the tools analysed. Pigments were found embedded within fossa, in crevices, on tools' tips and bases, and within use-wear striations. Colourant was always found to occur beneath all other matrices (Fig. 7), indicating that colourant on tools was not the result of a passive accumulation or post-depositional transfer. Whether these pigments were used specifically to colour baskets or had some other purpose at Taforalt, the presence of colourants deeply ingrained in some use-traces indicates that at least some of the worked material (i.e., grasses/basketry) came into direct contact with pigments.

Pigment colours include ochre in reds, purples and oranges, as well as a striking silvery grey ‘glittery’ mineral pigment. This has yet to be formally identified but is consistent with manuports consisting of lead and galena found elsewhere on site (Collcutt 2019b).

4 Discussion

Given congruences in use-wear with a consistent subset of Indigenous Californian ethnographic basketry tools, and the lack of similarity in use-wear with all other tool types investigated, it is probable that small, thin, pointed tools found at Taforalt were likely used to create basketry. Since use-traces on Taforalt tools are a match with some, but not all, Indigenous Californian basketry tools, it is necessary to determine what factors explain these correspondences and differences. To begin with, basketry making among Indigenous Californian groups was not a monolithic practice but rather incredibly diverse, with a number of different ‘technocomplexes’ or regional traditions of similarity in practice (Kroeber 1905, 1908; Bates & Bernstein 1982; Jordan & Shennan 2003). Because these areas of practice are relatively well documented, it is possible to track what kind of basketry was being made in each ethnographic region, and which plant materials were favoured for use. It must be noted that tribal entities as conceived by anthropologists do not always have
a basis in Indigenous concepts of relatedness, and for the sake of clarity and reproducibility, this study retains the spelling and wording under which the artefact or cultural group was recorded in the relevant museum collections or literature. Where possible the Indigenous names for plants and objects have been listed alongside their Latin taxonomic or English counterparts. Finally, because ethnographic materials studied here originated in the late 19th and early 20th centuries the past tense is used for the sake of consistency but should not be taken to imply that basket making or other Indigenous cultural practices are things of the past (Bates & Bernstein 1982).

Among all tools examined in this study, use-traces on tools from Taforalt are nearly identical to those found on basketry tools produced by Cahuilla, Eastern Miwok, and an unnamed central Californian people (Fig. 8, Cahuilla ‘wish’ [Mason 1988] and Miwok ‘tculla’ [Barrett & Gifford 1953]) (Table 3). Though Cahuilla and Eastern Miwok tools represented only a small subset (n = 15) of those analysed in this study, these tools were used specifically to create single- and three-rod coiled baskets, which likely accounts for the relative homogeneity in use-trace development. These consistent correspondences in use-wear track with coiled basketry as a production complex among southern and central Californian groups (Mason 1988; Kroeber 1905).

Some groups created both coiled and twined basketry forms, such as the Pomo peoples of central California. A number of Pomo coiled basketry awls were examined, and though these showed some similarity in use-traces to the Taforalt tools, the use-trace correspondences were not as precise as those found on Cahuilla, Miwok, and the central Californian basketry tools. This is likely because Pomo peoples produced baskets using not only single- and three-rod coiling, but also splint-foundation, two-stem foundation, four-stem foundation, and half-hitch coiling techniques, as well as seven forms of twined basket techniques (Mason 1988). Performing a wider variety of basketry techniques with these awls caused different and more complex use-wear patterns to develop on the tools, when compared to the Taforalt tools and ethnographic tools used in only one or two techniques.

Finally, there were no use-trace correspondences evident between the Taforalt tools and tools used to make twined baskets. These include bone basketry tools used by northwestern Californian, Pacific Northwestern and Alaskan groups who exclusively created twined baskets (Kroeber 1905; Merrill 1923). This suggests that use-wear on Taforalt tools corresponds not with ‘basket making’ in general, but only with use-wear developed through a limited number of coiled basketry techniques, and are potentially specific to single- and three-rod coiling. In
Table 3: Ethnographic basketry tools which best correspond with Taforalt use-wear

<table>
<thead>
<tr>
<th>Tool number</th>
<th>PAHMA catalogue information</th>
<th>Culture</th>
<th>Baskets produced</th>
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<tbody>
<tr>
<td>1–11115 Fig. 8F</td>
<td>‘Basketry awl of deer leg bone.’</td>
<td>Cahuilla</td>
<td>Coiled Basketry (Mason 1988: 423)</td>
</tr>
<tr>
<td>1–10125 Fig. 8A</td>
<td>‘Used in [basketry] sewing and weaving. With a sharp point. This is made from the proximal end of posterior cannon bone (fused metatarsal) of Odocoileus (deer). Split from foreleg of deer and polished off.’</td>
<td>Eastern Miwok</td>
<td>Single- or three-rod coiling (Kroeber 1922: 264; Barrett &amp; Gifford 1953: 90), Plate XXXIX (Barrett &amp; Gifford 1953)</td>
</tr>
<tr>
<td>1–11028</td>
<td>‘Basketry awl of deer leg bone.’</td>
<td>Cahuilla</td>
<td>Coiled Basketry (Mason 1988: 423)</td>
</tr>
<tr>
<td>1–10072 Fig. 8E</td>
<td>‘Old sharp pointed bone [basketry] awl.’</td>
<td>Eastern Miwok</td>
<td>Single- or three-rod coiling (Kroeber 1922: 264; Barrett &amp; Gifford 1953: 90), Plate XXXIX (Barrett &amp; Gifford 1953)</td>
</tr>
<tr>
<td>1–11097</td>
<td>‘Basketry awl of deer leg bone.’</td>
<td>Cahuilla</td>
<td>Coiled Basketry (Mason 1988: 423)</td>
</tr>
<tr>
<td>1–10241 Fig. 8B</td>
<td>‘Used in [basketry] sewing and weaving. Native name: “tculla”.’</td>
<td>Eastern Miwok</td>
<td>Single- or three-rod coiling (Kroeber 1922: 264; Barrett &amp; Gifford 1953: 90), Plate XXXIX (Barrett &amp; Gifford 1953)</td>
</tr>
<tr>
<td>1–216989 Fig. 8D</td>
<td>‘Bone, tip broken. Made of deer cannon bone, polished. Used in making coiled basketry.’</td>
<td>California</td>
<td>Coiled basketry (catalogued provenance, Kroeber 1922: 274)</td>
</tr>
<tr>
<td>1–216991 Fig. 8C</td>
<td>‘Bone, tip intact, unfinished at handle end with dried residue attached. Used in making coiled basketry.’</td>
<td>Central California</td>
<td>Coiled basketry (catalogued provenance, Kroeber 1922: 274)</td>
</tr>
</tbody>
</table>
Cahuilla basketry, *Epicampes rigens*, *Muhlenbergia rigens* (deer grass, Cahuilla ‘suulemt’), or *Washingtonia filifera* (palm) was used for the weft, and either *Juncus robustus*, *Juncus lesenerii* (rushes, Cahuilla ‘seily’) or *Rhus tribolata* (sumac) was used for the coils (Mason 1988; Kroeber 1908; Lando & Modesto 1977; Pearlstein et al. 2008). Basket making among the Cahuilla was traditionally performed by girls and women, and a description of the coiling process follows:

The basket is begun at the center of the bottom, the thickness of the coil of grass depending upon the size of basket to be made. A bone pricker [awl, Fig. 8F] is used. The coil is begun by laying one end of the filament [weft] upon the bunch of grass and taking a few wraps about it to hold it down. This is bent double, and the sewing progresses by catching the filament [weft] over the bunch of grass through the coil of the sewing filament made at the last turn.

*Mason 1988: 424*

In Miwok basketry, the method of production is single- or three-rod coiling (Kroeber 1922; Barrett & Gifford 1953). Preferential coil materials were *Epicampes rigens* (deer grass) and *Rhus tribolata* (sumac, Miwok ‘ta’ma’), and *Cercis occidentalis* (rebud, Miwok ‘tapātapa’) was generally used for the weft (Barrett & Gifford 1953). Basket weaving was also done by women, and coiled basket making proceeded as follows:

These various materials were manipulated and woven with the hands. The only tool was the bone awl [Fig. 8 A, B, and E] which was used to pierce the finished part of the basket, to make an opening through which to pass the sewing material ... The starting knot [Miwok ‘sayu’] in many coiled baskets is a small, tightly bound coil of fine maple or sedge splints, or of the leaf of *Iris hartwegii* [Miwok ‘yotowina’]. These must be very fine to permit bending at a very sharp curve.

*Barrett & Gifford 1953: 86*

Correspondingly, the use-traces which develop on the bone tools (evident in the form of parallel and crossing linear striations [Fig. 6 A–D]) show the direction of movement of the tool when in use. These traces develop on the portion of the tool (the tip and shaft) which is repeatedly coming into abrasive contact with the coils as the weft is sewn through the coils of grass or rushes. Use-traces indicative of this gesture develop transversely or diagonal to the tools’ shaft, depending on the angle of the tool as it is pushed through the coils (Fig. 6). In Cahuilla basketry the coil direction is clockwise (from left to right), except in the case of small, globular baskets which are coiled counterclockwise (Kroeber 1938). Miwok peoples likewise used both clockwise and counterclockwise coiling techniques (Barrett & Gifford 1953), which may account for the presence of overlapping transverse striations (Fig. 6 C–D).

In addition to use-wear patterning, Cahuilla, Miwok, and Taforalt tools show analogous chaîne opératoire use-trace development. Specifically, later stage tools exhibit highly polished surfaces as a result of repeated abrasion as the tool passes tightly through the silicate-rich basketry coils (Fig. 4) (Legrand & Radi 2008). Use-wear in the form of rounding to the tools’ point tips has been observed to be beneficial in the creation of coiled basketry (Fig. 4 C–D, Fig. 5 A–B). Pointed bone tools with slightly rounded tips were able to effectively split the basketry coils in order to insert the weft without splitting the fibres, an advantage over sharply pointed or metal tools (Mason 1988; Campana 1989). Matches in use-trace patterning on small, thin, pointed tools at Taforalt are therefore interpreted as diagnostic of the production of coiled basketry using silicate-rich plants in the coils, and potentially as a result of both clockwise and counterclockwise coiling.

ZooMS research into preferential bone tool raw material selection at Taforalt has shown that these tools (and by extension, their products) were embedded within long-term culturally mediated strategies (Desmond et al. 2018). In order to understand these cultural strategies in a holistic way, it is necessary to examine how the use of coiled baskets interdigitates with other lines of archaeological evidence at Taforalt. Basketry, alongside other technologies, appears to have facilitated an intensification in specific food resources among the Iberomaurusians. Here, ethnographic analogy is used to understand how different cultures used similar technologies to collect and process the same resources which were important at Taforalt. Finally, we will consider how basketry could have connected with emergent cultural forms, such as increased population size and craft specialisation.

A first consideration is the spatial organisation of basketry production within the cave. Given the preferential distribution of pointed bone tools in well-lighted areas of the cave, and the abundance of pointed forms recovered from the small, brightly-lit area near the northerly cave entrance (Desmond 2019), it is probable that this last area represents a ‘workshop’ for the production of coiled baskets. All recorded Indigenous Californian coiled basketry techniques involve the strategic selection of basketry materials, including extensive planning in seasonal harvesting and pre-processing (Mason 1988; Merrill 1923; Barrett &
Gifford 1953; Pearlstein et al. 2008). Once materials are collected and prepared, plants constituting the coils need to be soaked in order to be pliable enough to work into the desired shape (Merrill 1923). These conditions underscore the need for fixed, spatially organised, and well-lighted production areas, and explain the concentration of tools in corresponding areas on site. At Taforalt, the coils were likely constructed from *Stipa teccanisima* (esparto grass, Arabic ‘(h)alfa(h)’ and Amazighe ‘awri/ari/iwri’ [Barton et al. 2019c]), as inedible esparto stalks were uprooted with the root systems intact and transported into the cave in great numbers (Humphrey et al. 2014; Morales 2019). Previous to this study, esparto has been hypothesised to have served as basketry material in the North African Palaeolithic, and at Taforalt specifically (Humphrey et al. 2014; Morales et al. 2015; Carrión et al. 2018; Desmond et al. 2018; Morales 2018; Barton et al. 2019c; Gassin et al. 2020). Traditional Moroccan esparto crafting has a known history dating back to the late Pleistocene and continues into the ethnographic present (Barton et al. 2019c; Gassin et al. 2020). Esparto also has a long history as a crafting material elsewhere in the Mediterranean. Clay impressions, as well as artefacts in the form of clothes, hats, shoes, baskets, and rope crafted from esparto, have been evident since the Neolithic in Spain (Fajrado et al. 2015). Because of its high silica content, esparto would produce analogous use-traces to the polish seen in later chaîne opératoire stage tools when used as basketry coils (Maghchiche et al. 2013).

The presence of clay in the Grey Series also likely articulates with basketry production; specifically, to line baskets in order to make them waterproof (Barton & Collcutt 2019; Barton et al. 2019c). Parallel impressions of sedges or grasses are found in some clay nodules, and it is suggestive that one clay fragment was intentionally shaped into a coil (Barton & Collcutt 2019), mirroring the shape of and suited to the lining of coiled basketry. In the world archaeological record, pottery is hypothesised to have had many independent centres of development through the accidental burning of clay-lined baskets, enabling the transition from clay as a lining to a stand-alone form (Morris 1927; Brown 1989; Blinnman 1993). The presence of clay-lined baskets is suggested elsewhere in prehistoric North Africa: Early-Middle Holocene basketry fragments from Libya retain mineral traces suggestive of clay (Di Lernia et al. 2012). Above-ground clay-lined baskets have previously been suggested as storage containers at Taforalt in the absence of pit forms on site (Barton et al. 2019c). Clay-lined baskets would also have been suitable waterproof containers, and are known to have been used in hot-rock heating and cooking methods from the Pleistocene onward (Speth 2015; Shyrock & Lord Smail 2018). The presence of clay-lined baskets is further indicated by the fact that the clay fragments recovered at Taforalt were all heated and occurred alongside non-local fire-crazed limestone throughout the Grey Series (Barton & Collcutt 2019; Collcutt 2019a). In some cases ‘baked clay’ has been known to replace heated stones in some acorn-cooking processes (Heizer & Elsasser 1982; Mason 1992). However, owing to the overwhelming presence of fire-crazed rocks in Grey Series levels which would have served this purpose much more effectively, the use of clay as a heating element seems unlikely.

To date, the earliest evidence for hot-rock cooking comes from the late Aurignacian in France, and has appeared since the Upper Palaeolithic consistently in European, African, and Asian archaeological contexts (Movius 1966; Petraglia 2002; Thoms 2009). It was likely a component of early technological repertoires in the Americas as well, though modelling has suggested that less frequent use and smaller population sizes may have rendered it archaeologically invisible until the Holocene (Thoms 2009). Watertight baskets have been the preferred method for stone boiling in particular. Basketry is an ideal material for withstanding the impact of the heated stones dropped into it, by being “… a flexible fabric able to withstand repeated direct force by conforming to the force” (Nelson 2010: 243). Hot-rock cooking generally appears in cultures experiencing an intensification in broad-spectrum foraging, land-use intensification, and population packing, measured as an area’s “food-resource potential relative to its extant land-use system”; all conditions are met within the Grey Series at Taforalt (Binford 2001; Thoms 2009; 588; Barton et al. 2019a). The broad-spectrum intensification seen in Grey Series levels at Taforalt further conforms to a study of world-wide ethnographic patterns,”… when [the] percentage of time spent gathering makes up more than 30% of the total time in subsistence activities, basketry is used for stone boiling” (Nelson 2010: 246). Ethnographic techniques for waterproofing esparto baskets exist in the region surrounding Taforalt Cave, and involve flattening the leaves before weaving (Barton et al. 2019c).

Based on the evidence for basketry and hot-rock cooking at Taforalt, it is possible to investigate how these technologies could have articulated with and scaffolded an intensification in the three main resources intensified in Grey Series levels; acorns, pine nuts, and land snails.

Pine nuts and acorns are both considered ‘back-loaded’ food resources; that is to say, relatively easy to collect and store, but energetically costly to process (Tushingham & Bettinger 2013; Barton et al. 2019c). For acorns and pine nuts, parallels in cultural strategy with Indigenous Californian groups will be investigated, following Morales et al. (2015).
California’s density of hunter-gatherer populations exhibiting reduced mobility, intensification in pine nuts and acorns, and social complexity more commonly associated with agricultural groups in similar climatic settings make these groups appropriate analogies with – and effective models for – specific cultural practises and processes at Taforalt (Buonasera 2013; Morales et al. 2015). Acorns and pine nuts have been described as the two staple foods of the Cahuilla (Lando & Modesto 1977) and were also important among the Miwok (Barrett & Gifford 1953). Burden baskets were used in foraging both acorns and pine nuts among Indigenous Californian groups, including Cahuilla and Miwok peoples, and experimental studies have shown that when filled to capacity, baskets containing pine nuts and acorns were virtually identical in weight (Bettinger et al. 1997).

Pine nuts were a commonly exploited food resource among Indigenous Californian groups throughout the Holocene, and are high in polyunsaturated fat (Bettinger et al. 1997; Farris 1993; Gamble & Mattingly 2012). Among the Cahuilla specifically, Singleleaf (Pinus monophylla) and Parry pinyon pine (Pinus quadrifolia, Cahuilla ‘tevatwic’) were used as part of the ‘winter diet’ (Bean 1974; Wilke et al. 1979; McCarthy 2012). Hot-rock pine nut processing in baskets has been identified among a number of Indigenous Californian groups (Coville 1892; Gamble & Mattingly 2012). While pine nuts can be eaten raw, roasting can improve the flavour, remove the pine pitch, kill the nut embryo which enables long-term storage, and open the scales of green cones for extracting the nuts (Farris 1982; McCarthy 2012). Other segments of pine were used in various ways. Among the Miwok, uses included (but were not limited to) fuel, as a basketry material, in thatch, bedding, and floor coverings, in house coverings, for medicinal purposes, and to make pitch and mastics (Barrett & Gifford 1953). Pine pitch was used by many Indigenous Californian peoples to make baskets watertight, including the Cahuilla and Miwok (Barrett & Gifford 1953; McCarthy 2012). Ethnographic accounts from northwestern Tunisia show that pine cones were collected unripe and stored, and, when needed, the cones were sun dried or roasted in order to extract the seeds (Morales et al. 2015). The pine nuts were then ground, mixed with water, sieved, and heated at a low temperature to form a soup or broth. Empty cones were stored and used as fuel. Evidence for the same or similar collection and processing techniques is attested at Taforalt, as well as at the Early Holocene site of El Mekta in Tunisia and the Late Pleistocene site of Haoua Fteah in Morocco (Morales et al. 2015: 135–136).

The use of acorns among Indigenous Californian peoples is well documented and will be treated here only in brief. Quercus kelloggii was the preferred food acorn in all but the Northwest of California. It required an extensive logistical strategy in harvesting, transportation, drying, storage, processing, and eventual preparation into food (Mason 1992; Bettinger et al. 1997). Basketry or other woven vegetal material was involved in every stage of this process; burden baskets in collection and transportation, mats for drying, baskets or granaries for storage, grindstones and baskets for processing (sometimes including leaching, or the removal of tannic acid), and baskets for food preparation (Mason 1992; Tushingham & Bettinger 2013). One of the most common acorn food preparation methods was hot-rock cooking in watertight baskets, a method requiring constant stirring and producing an acorn ‘soup’ or ‘mush’ widespread among Indigenous Californian peoples, including the Miwok (Barrett & Gifford 1953; Mason 1992). Acorns are also a traditional North African food, and as with pine-nuts, acorns were often collected unripe from trees, stored, and then processed when needed to open the nut (Morales et al. 2015). Evidence for this same acorn collection strategy is present in Late Pleistocene and Early Holocene archaeological contexts across North Africa (Morales et al. 2015). Regional North African strategies for acorn processing include boiling, roasting, drying, storage, and refining into a flour (Morales et al. 2015). Near the modern village of Tafoughalt (next to Taforalt Cave), local informants related that unprocessed acorns could be stored in esparto baskets for six months, and processed acorns presumably have an even longer ‘shelf life’ (Barton et al. 2019c).

Land snails are not a well-attested food source in Indigenous California but continue to be a staple resource in many African and circum-Mediterranean cultures (Adeyeye et al. 2020). Snails have a high nutritional value as they are rich in protein and other essential minerals and amino acids (Adeyeye et al. 2020). When snails are collected from the local environment, as in the Grey Series at Taforalt, modern best practice dictates that they be ‘purged’ before they are consumed. Purging entails containing and feeding the snails for at least three days, enough time for them to expel any potentially toxic plants they may have consumed in the wild (Thompson 1996). This process would have necessitated containers for collecting and purging snails. In Spain, a particular esparto basketry form (known as ‘Caracolera’) was crafted for snail collection and involved the use of a stitching technique specific to this purpose (Farjado et al. 2015). Boiling snails remains the most common method of processing
to this day, and hot-rock cooking in baskets has been posited as a likely scenario for snail cooking at Taforalt (Arrebola Burgos & Álvarez Halcon 2001; Taylor & Bell 2019). Snails spoil shortly after they die, and preservation techniques such as smoking or drying are necessary to reduce the microbial load and preserve snail meat for longer periods (Adeyeye et al. 2020). In the absence of pottery containers at Taforalt, it must be assumed that collection, purging, cooking, processing (drying or smoking), and storage needs were met with the use of organic technologies. Whether from Barbary sheep or snails, the main factor in meat preservation is “keeping it sufficiently dry, a point which recalls the advantage in hanging such materials close to a more or less continuous source of heat and smoke” (Barton et al. 2019c: 535). Given the extensive evidence for burning in Grey Series levels, Taforalt Cave would certainly have met this criterion.

While use-trace patterning suggests that coiled basketry was being made, the presence of colourants suggests that pigment may have been intentionally applied to the baskets. All Indigenous Californian coiled basket forms considered here have deliberate colouration and design motifs, and vegetal materials were often selected for their colour and woven into patterns on the baskets (Mason 1988; Merrill 1923; Barrett & Gifford 1953; Pearlstein et al. 2008). Though dichotomous conceptions of ‘utility’ and ‘art’ are largely modern, the use of colourants at Taforalt shows that Iberomaurusian basket makers may have incorporated deliberate stylistic or aesthetic elements into their crafting process.

5 Conclusion

This study underscores both the usefulness of bone tools as an artefact class and the usefulness of appropriate ethnographic case studies in the interpretation of archaeological materials. First, it reiterates the validity of using a chaîne opératoire approach to bone tools. As with lithics, osseous tools can be understood using traditional artefact analyses, such as typological and whole-tool morphology studies. Unlike lithics, however, osseous tools can be subjected to tests designed for use on organic materials, such as proteomics and DNA analysis. These analyses enable an understanding of taxa raw material selection, and while they are in some ways akin to lithic proveniencing studies, they can also illustrate seasonal, ideological, and otherwise inaccessible cultural strategies. Since bone is softer than stone, its surface features more readily deform during use and develop diagnostic use-traces indicative of function (Legrand & Sidera 2007; Legrand & Radi 2008). Because of the relatively rapid deformation of bone surfaces during use, it is possible to interpret the uses of archaeological osseous tools through a comparison with diagnostic use-trace matches on ethnographic osseous tools (Desmond et al. 2021). This method has been profitably applied to bone tools from southern African, Australian, North American, and European archaeological contexts (e.g., Olsen 1979; LeMoine 1994; Soffer 2004; Stone 2009; Langley et al. 2016; Bradfield & Antonites 2018; Bradfield 2020), and the current study underscores the productivity of this line of enquiry. In particular, such comparative analyses are a useful way to obtain proxy evidence for perishable crafted forms which may not have otherwise been accounted for, or, as with Taforalt, whose presence was suggested (but not confirmed) through complementary lines of archaeological evidence (Barton et al. 2019c).

This study also shows the utility of interrogating broad-scale correspondences between cultures which are geographically and temporally disparate, but which display a ‘robustness of relevant similarities’ (Currie 2016). Such similarities include peoples who inhabit(ed) similar landscapes or climates, used the same food resources entailing a breadth of logistical preparation and attendant technologies, and experienced similar patterning for example in mobility or reduction of mobility, and demographic expansions and contractions. While realising that the archaeological record itself is a contemporary phenomenon, structures of inference must be based on uniformitarian principles in order to gain meaningful insight into the processes that created this record (Raab & Goodyear 1984). In other words, while the specific cultural strategies of the Iberomaurusians cannot be observed directly, it is not parsimonious to presume they would have used their technologies in vastly different ways to other cultural groups which produced these technologies in similar circumstances. However, in using ethnographic data, it is crucial to avoid pitfalls such as presupposed ancestral relationships, deterministic approaches, ‘primordialism’, and unwarranted inferential leaps (Bradfield 2014; Pargeter et al. 2016). Here, the tension between useful ethnographic analogy and cultural determinism can be bridged through a scientific analysis of bone tool topography, and how these tools and their products are embedded in specific, co-occurring technological and behavioural strategies. When analogies are scaled to the artefactual level, ethnographic materials are useful tools in investigating archaeological artefacts (Stone 2011). This is particularly true of bone and fibre artefact analysis, because
The use-wear on these objects was produced in a dynamic, day-to-day context by people who actually used these objects, which reflects not only the mechanical properties of the interacting materials, but also personal variation, developed motor skills and long-term, authentic utilization. The physical and mechanical properties of bone and fibres are not greatly affected by variation in environment, and considering a wider range of possibilities in the ethnographic record may allow the recognition of unexpected patterns on archaeological artefacts.

Stone 2009: 229

Though no one would suggest direct relationships between Iberomaurusian and Indigenous Californian cultures, striking technological and cultural parallels exist (Morales et al. 2015). These take the form of environmental and climatic similarities, an intensification in acorns and pine nuts coinciding with increased population density and reduced group mobility, and technological corollaries in the form of grindstones, hot-rock cooking, and basketry.

While it is much less secure to extend ethnographic analogies to the social and ideological, it is possible that comparable cultural processes, such as emergent role specialisation in craft production, also accompanied this shift at Taforalt. In the European Palaeolithic, gendered role specialisation has often been approached through perishable craft production, with a view to how people used these forms in constructing inter- and intra-group social identities (Dobres 1995; Stone 2009). In a number of Indigenous Californian contexts, the enhanced labour inherent in resource intensification (necessitated by collection, preparation, and processing) were absorbed primarily by women (Willoughby 1963; McGuire & Hildebrandt 1994; Buonasera 2013). For example, basketry making was the domain of women and girls among the Cahuilla and Miwok peoples, and tasks surrounding acorn and pine nut procurement and processing were mostly performed by women (Barrett & Gifford 1953; Lando & Modesto 1977). While gendered division of labour with regard to these particular resources is unclear at Taforalt, studies of femoral cross-sectional strength and robusticity indicate that both men and women were highly mobile, and gendered strategies in resource procurement are not contraindicated (DeGroote & Humphrey 2019).

Evidence for perishable crafts in symbolic or ideological processes can, however, be deduced from other lines of evidence. While the cultural or individual-specific significance of colourant on the baskets at Taforalt cannot be fully understood, it suggests that stylistic, artistic, and aesthetic conventions were in place in the North African LSA. Crafted forms also appear as a part of early funerary behaviour. In burial contexts at Taforalt, individuals 1, 2, 3, 7, 13, and 14 show skeletal articulations and positioning consistent with partial decomposition in a void, a scenario met when bodies are wrapped before burial (e.g., in woven material or animal skins) (Humphrey et al. 2019). These voids indicate that baskets or other organic materials were a part of Iberomaurusian mortuary practice, even among the earliest burials.

While the appearance of advanced perishable crafting techniques at Taforalt cannot be called precocious (with baby carriers, for example, hypothesised to date to millions of years ago [Berecz et al. 2020]), they can be understood in a rarely afforded high-resolution North African Palaeolithic context. Bone tools used in basketry crafting existed as elements in the technological repertoire of seasonally itinerant hunter-gatherer Iberomaurusians, and these technologies were scaled up and expanded on in support of changing cultural strategies. When viewed in context, it is clear that plastic, adaptive crafting processes, including the creation of coiled basketry, scaffolded (and arguably enabled) the shift to greater sedentism, resource intensification, and demographic expansion evident in the Grey Series Iberomaurusian at Taforalt.

Acknowledgements

Funding was obtained from the following sources: the Calleva Foundation, the Meyerstein research fund, and the Oxford Journal of Archaeology scholarship. I am grateful for assistance and advice from Nick Barton, Abdeljalil Bouzouggar, Louise Humphrey, Simon Collcutt, Philippe Fernandez, Jacob Morales, Elaine Turner, Alison Roberts, Natasha Johnson, Nicholas Crowe, Peter Berridge, Paul Berridge, Alison Freyne, Julia Lee-Thorp, Tom Higham, and Julius Koll. I would like to thank the Phoebe A. Hearst Museum of Anthropology, the Pitt Rivers Museum, the Ashmolean Museum, the Institut National des Sciences de l’Archéologie et du Patrimoine, the Rabat Archaeological Museum, Museum, Mustafa Mani, Habiba Atki, Ahmed Margaa, Ahmed Gharrafi, Mohammed Mansour, the Moroccan people, the Cahuilla (Ivilyuqaletem) people, the Miwok (Me-Wuk) people, the Klamath people, the Modoc people, the Yurok (O’loolekweesh ’ol) people, the Hupa (Natinixwe) people, the Pomo people, the Yokut people, the Inupiat and Yupiat peoples, the Maidu people, Julius Koll, Jane Desmond, and Rebecca Desmond.
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