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Abstract: Recent genetic studies based on the distribution of mtDNA of haplogroup U6 have led to subtly different theories regarding the arrival of modern human populations in North Africa. One proposes that groups of the proto-U6 lineage spread from the Near East to North Africa around 40-45 ka (Olivieri et al., 2006) followed by some degree of regional continuity. Another envisages a westward human migration from the Near East followed by further demographic expansion at ~22 ka centred on the Maghreb and associated with a microlithic bladelet culture known as the Iberomaurusian (Maca-Meyer et al., 2003). In evaluating these theories, we report on the results of new work on the Middle (MSA) and Later Stone (LSA) Age deposits at Taforalt Cave in Morocco. We present 54 AMS radiocarbon dates on bone and charcoals from a sequence of late MSA and LSA occupation levels of the cave. Using Bayesian modelling we show that an MSA non-Levallois flake industry was present until ~24.5 ka cal BP, followed by a gap in occupation and the subsequent appearance of an LSA Iberomaurusian industry from at least 21,160 Cal BP. The new dating offers fresh light on theories of continuity vs. replacement of populations as presented by the genetic evidence. We examine the implications of these data for interpreting the first appearance of the LSA in the Maghreb and providing comparisons with other dated early blade and bladelet industries in North Africa.

Origins of the Iberomaurusian in NW Africa: New AMS radiocarbon dating of the Middle and Later Stone Age deposits at Tatoralt Cave, Morocco.

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## Introduction

Recent phylogenetic studies of mtDNA haplogroups M1 and U6 have proposed that modern human populations in North Africa originated from groups that had migrated into this region from Southwest Asia (Maca-Meyer et al., 2003; Olivieri et al., 2006; Gonzalez et al., 2007). However, the nature, timing, and geographical spread of such a back-migration is still a matter of considerable debate (Pennarun et al., 2012). On the one hand, some studies propose an early dispersal of M1 and U6 lineages into North Africa at ~40-45 ka (Olivieri et al., 2006), while others suggest multiple events with a major expansion of the U6 lineages in the Maghreb ~22 ka (Maca-Meyer et al., 2003; Periera et al., 2010). Bound up with these models is the proposal that the geographical patterns of the haplogroups can be shown to coincide with major technological shifts in the archaeological record. One of these relates to sub-haplogroup U6a1 and its posterior clade U6a1a, with coalescence ages of ~22 ka, which may be associated with the appearance of a culture known as the Iberomaurusian (Maca-Meyer et al., 2003). This microlithic bladelet industry is significant because it represents potentially the earliest Later Stone Age technology in the Maghreb (Morocco, Algeria, Tunisia). The genetic studies therefore also highlight the issue of whether the Iberomaurusian was a truly indigenous development to the Maghreb or whether it reflects a general spread of people and traditions from Cyrenaica with older roots in Southwest Asia.

While the published genetics research provides useful models for understanding the early peopling of North Africa by modern humans, considerable caution must be exercised in interpreting these data. One issue concerns underlying assumptions regarding the timing of dispersal events that are heavily dependent on the methodology used to estimate molecular divergence values and DNA mutation rates (Endicott et al., 2009; Scally & Durbin., 2012). Indeed there is still a huge disparity between the age of U6 and some of its individual clades, such that the age of U6a7 is consistently estimated as being older than that of U6 overall (Olivieri et al., 2006; Pereira et al., 2010). A further challenge is to assess whether any of the proposed demographic models can be demonstrated by testing them against empirical evidence in the archaeological and palaeontological records. For example, did the arrival of modern humans in the Maghreb result in abrupt changes in the archaeological record (replacement model) or were changes brought about independently and within the context of long-term population continuity (Debenath et al., 1986; Linstädter et al., 2012)? Until now, it has been difficult to assess such claims, because of the absence of high precision dating records for key regions such as the Maghreb and the scarcity of well-stratified archaeological sequences with associated human fossil remains. A site of major significance that can help remedy this situation is that of Grotte des Pigeons at Tatoralt. The cave is located in the Beni-Snassen Mountains, in northeastern Morocco (Fig. 1), and has been the subject of recent excavations that provide a long and largely unbroken sequence of archaeological deposits from ~12-110 ka years ago (Bouzouggar et al., 2007; Clark-Balzan et al., 2012), covering the

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period of the proposed arrival in the region of modern humans. The sediments include both extensive Aterian and Iberomaurusian occupation, with cemetery evidence (Bouzougar et al., 2006, 2007, 2008; Barton et al., 2007; Taylor et al., 2011; Humphrey et al., 2012). In this paper we report on the upper part of the sequence comprising the terminal Middle (MSA) and Later Stone (LSA) Age deposits of the cave. The 54 AMS (accelerator mass spectrometry) radiocarbon dates provide the first well constrained record for the appearance of the Iberomaurusian in Northwest Africa. They also provide a basis for comparing the genetics-derived chronology and enable an independent test of the timing of the transition from the MSA in this region.

Among the most intriguing elements in this research are those that concern the nature and origins of the Iberomaurusian. The techno-complex is found very widely distributed across North Africa and is associated with cemeteries containing skeletal remains of robust modern humans attributed to Mechta-Afalou types (Camps, 1974; Irish, 2000; Lahr, 1996; Humphrey and Bocaage, 2008). The Iberomaurusian is particularly well documented in cave, rock-shelter, and open-air sites in the Mediterranean coastal zone of the Maghreb with a distribution that potentially extends into Cyrenaica (McBurney, 1967; Barker et al., 2008) and Egypt (Phillips, 1972). The Iberomaurusian lithic industry is typified by microlithic backed bladelets and, apart from its geographically wide distribution, is significant because it marks a diagnostically clear change from Middle Palaeolithic/Middle Stone Age technologies in the Maghreb (Lubell, 2001; Bouzougar et al., 2008). Many specialists assign the Iberomaurusian to the Epipalaeolithic (Roche, 1963; Barton et al., 2007; Olszewski et al., 2011) but, despite the extraordinary wealth and density of findspots in the Maghreb and over a century of research, relatively little is known about how or where it originated.

Various theories have been proposed for the cultural origins of the Iberomaurusian. The term itself derives from the fusion of two words ‘Ibero’ (meaning Spanish) and ‘Maurusian’ (referring to *Mauretania tingitana*, the name first given by the Romans to northern Morocco and western Algeria). The definition was introduced by Pallary who used it to draw attention to similarities between lithic industries in Spain and Morocco that contained “*une profusion de très petites lames à dos retouché et à pointe très aiguë*” (Pallary, 1909). The implied link with southern Europe was dismissed by later archaeologists who recognised stronger African affinities and adopted alternative names reflecting regional sources such as ‘Oranian’ (Gobert and Vaufray, 1932) and ‘Mouillian’ (Goetz, 1941) from type locations in Algeria. However, the term Iberomaurusian has always persisted in the literature and, for reasons of taxonomic priority, we shall continue to use it here. Divergent with these views was an idea put forward by McBurney (1967), that the Oranian/Iberomaurusian had arisen out of an ‘Upper Palaeolithic’ industry known as the Dabban represented at the Cyrenaican site of Haua Fteah and which may be of Near Eastern origin. But a major anomaly in this scheme was that the Iberomaurusian appeared to be earlier in the Maghreb than for the rest of North Africa (McBurney, 1977; Close, 1986). More recently, it has been suggested that the development of the Iberomaurusian was part of a much wider, pan-regional phenomenon resulting in the appearance of backed bladelet technologies across much of North Africa and the Near East around 20–23 ka BP (Close and Wendorf, 1990; Vermeersch, 1992; Goring-Morris & Belfer-Cohen, 2003; Godfrey-Smith et al., 2003). However, this theory neither adequately addressed the possibility of an early Iberomaurusian in the Maghreb nor inherent differences in the tool typologies at Lower Nile sites such as Wadi Halfa, Gebel Silsila and Deir el Fakhouri which would make such comparisons less likely (Vermeersch, 1992). A more radical proposal visualised links between the Epigravettian industries of the Italian peninsula and the Iberomaurusian (Camps, 1974; Ferembach, 1985; Debénath, 2003). Although some similarities exist in the typology of the industries, there are many other lines of evidence (palaeontological, genetic, dating) that disfavour an origin of the Iberomaurusian in the Epigravettian of Italy or Sicily (Mannino et al., 2011; 2012).

1 Part of the problem in assessing the Iberomaurusian have been continuing doubts and  
2 ambiguities over the correct dating of samples and the integrity of their cultural associations.  
3 According to published studies, the earliest conventional radiocarbon ages for the  
4 Iberomaurusian come from Grotte des Pigeons (Taforalt), Morocco and Tamar Hat in  
5 Algeria. At Taforalt, Roche (1976) recorded two very early ages from ‘*terre charbonneuse*’  
6 (charcoal-rich sediments) of 21,900±400 BP (Gif-2587) and 21,100±400 BP (Gif-2586). But,  
7 for reasons that will be discussed below, both of these are now regarded as highly doubtful.  
8 Elsewhere in the Maghreb, the oldest radiocarbon date recorded for the Iberomaurusian is  
9 (MC-822) 20,600 ± 500 BP from Layer 84/5 at Tamar Hat (Saxon et al., 1974). However,  
10 despite the fact that this was one of seven dates ranging from 20,600±500 to 16,100±360 BP,  
11 five of which came from stratified contexts of the 1973 excavations, scepticism remains over  
12 the use of bulked materials which may be susceptible to cross-contamination. This is a  
13 common problem with other dated sites in the Maghreb whose ages are based on bulked  
14 samples and thus subject to mixing of carbonised material of potentially different ages.  
15 Outside the Maghreb, the best dating for the oldest Iberomaurusian still comes from the Haua  
16 Fteah in Cyrenaica, where layers excavated by McBurney can be shown to be no older than  
17 two radiocarbon dates of 16,070±100 BP (GrN-2586) and 18,620±150 bp (GrN-2585)(Close,  
18 1986). Nonetheless the dating was again based on bulked charcoal samples and therefore  
19 susceptible to similar doubts over reliability.  
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21 Allied to the uncertainties with chronology have been questions concerning the stratigraphic  
22 relationship between the Iberomaurusian and older industries. In caves in the Maghreb with  
23 well-preserved sedimentary sequences, the Iberomaurusian can often be shown to overlies  
24 Aterian deposits. However, the nature of continuity or discontinuity between these two  
25 techno-complexes has been a matter of longstanding debate. Early archaeologists such as  
26 Antoine (1937) saw no appreciable gap between the Aterian and Iberomaurusian but this was  
27 not widely accepted and was gradually replaced by a consensus in favour of a hiatus  
28 separating the Aterian from the Iberomaurusian of between five to ten thousand years  
29 (Debénath et al., 1986, 236; Close, 1980; 1988). Even so, such interpretations relied on  
30 questionable or *minimum* radiocarbon estimates that seemed to show the Aterian occupying a  
31 relatively short chronology from 40-20 ka BP (Bordes, 1976-1977; Debénath et al., 1986;  
32 Texier et al., 1988; Debénath, 2000). Newer studies based on luminescence, uranium series  
33 and AMS dating have now led to a drastic revision of this timescale with much earlier ages  
34 for both the oldest and latest Aterian occurrences (Bouzouggar et al., 2007; Roset and Harbi-  
35 Riahi, 2007; Richter et al., 2010; Jacobs et al., 2012; Clark-Balzan et al., 2012). For areas  
36 outside the Maghreb a slightly different picture has emerged. In Cyrenaica, the  
37 Iberomaurusian can be demonstrated to lie directly above the Dabban ‘Upper Palaeolithic’  
38 industry (McBurney, 1967; Barker et al., 2008), while a similar industry is also documented  
39 in Northwestern Libya (Garcea, 2004). Thus, two potentially contrasting cultural-historical  
40 models have been proposed for geographically adjacent areas: one for the Maghreb  
41 exemplified by an Aterian-Iberomaurusian succession, and one outside this region to the east  
42 with an ‘Upper Palaeolithic’ industry as a cultural forerunner of the Iberomaurusian. In this  
43 paper we re-examine the evidence for the dating of the sequence in the Maghreb and consider  
44 some of its wider implications.  
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51 The aims of this paper, therefore, are four-fold:

- 52 • To provide a first high precision Accelerator Mass Spectrometry (AMS) radiocarbon  
53 dating record for Taforalt in the Maghreb, spanning the Iberomaurusian (LSA) and  
54 the most recent pre-bladelet technology (MSA).
- 55 • To identify (dis)continuities in the stratified occupation sequence, using a  
56 combination of sedimentological data and depth-age modelling based on Bayesian  
57 analyses and a Poisson process deposition model.  
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- To assess relationships of any gaps in settlement and cultural shifts at Taforalt with environmental fluctuations by comparing their timing with existing archaeological and palaeoclimatic records in North Africa and globally.
- To use these data to examine more widely the implications for theories of modern human dispersal in North Africa proposed in the genetic evidence.

### Site setting, stratigraphy and archaeological context

Grotte des Pigeons at Taforalt (34°48' 38" N, 2°24' 30" W), is located at 720 m above mean sea level overlooking the Zegzel valley in the Beni Snassen mountain range (Fig. 2). The bedrock in this area comprises steeply folded Permo-Triassic dolomitic limestones, with the cave itself having formed by rekarstification in a zone of earlier travertines and fluvial conglomerates, constituting a more ancient deep karstic fill. The currently accessible cave, with a large entrance opening to the northeast, has a floor area within the drip line of ~400 m<sup>2</sup>. Today the site lies ~40 km from the Mediterranean coast, currently within the 'thermo-Mediterranean' biozone (Blondel and Aronson, 1999).

Major excavations were undertaken at Taforalt Cave in 1944-1947, 1950-1955, and 1969-1977 (Roche, 1953, 1963, 1967, 1969, 1976), with further investigations taking place during the 1980s (Raynal, 1980; Courty et al., 1989) and a new phase of excavations that was begun in 2003 (Bouzouggar et al., 2006, 2007, 2008; Barton et al., 2007; Taylor et al., 2011). The new phase of work involved excavating from standing profiles left by Roche and other previous excavators. The aim was to collect fresh dating samples and to investigate the archaeological deposits that spanned a combined depth of over 10 m, and which contained rich Aterian hearth layers overlain by a 4-metre thick sequence of Iberomaurusian deposits. The latter included midden layers and an assemblage of partial skeletons recovered from two burial areas investigated between 1952 and 1955 by Roche (Ferembach et al., 1962; Roche, 1963).

Part of the new work involved the investigation of an area contiguous with long sections dug by Roche on the south side of the cave, which we refer to as Sector 8 (Fig. 2). Other new trenches were located on the north side of the cave (Sector 9) and in the cemetery area (Sector 10). The sedimentary sequence for Sector 8 is shown in Figure 3 and summarised schematically in Figure 4. In the main part of the cave, Roche (1963; 1976) identified at least 17 sedimentary units (layers I-XVII) containing archaeological finds which he subdivided into *endreuses* (ashy) and *argillo-sableuses* (clayey sands), with a distinct separation between the upper grey ashy series (levels I-VIII) and a lower series of reddish brown to yellow clayey sands (IX-XVII).

Like Roche, we recognise the same major stratigraphic division between the Grey Series (ashy deposits) and the underlying Yellow Series (clayey sands) but we differ in the finer descriptive detail of the sedimentary succession. The Grey Series comprises an approximately 4 m thickness of dominantly anthropogenic 'midden' deposits (ash, charcoal, bone and snail shell debris, burnt limestone, etc). Locally within Sector 8, it is possible to maintain precise and detailed lithostratigraphic control, despite the dominantly lenticular sedimentation mode resulting from constantly shifting human activity in occupation areas across the site. The results of new excavation and sampling are reported in two separate but broadly equivalent sequences, some 3 m laterally apart, and excavated in 2003-5 (units G88-100) and 2009-10 (layers 1-29), the latter located slightly deeper into the cave (Fig. 4).

In contrast to the Grey Series, the Yellow Series is finely laminated throughout, indicating emplacement by wash processes, with greater lateral continuity in stratigraphic units. These sediments are always dominated by fine to medium sands, with varying amounts of dolomitic limestone debris and minor peaks of quartzitic 'grit'. Whilst there is an archaeological presence at most levels, only rarely does the anthropogenic input reach concentrations high

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enough to be reflected in the actual lithostratigraphy (e.g. the persistent traces of burning in the distinctive horizons of Units Y3 and Y5). Three of the many points of interest in this approximately 2 m thickness of Yellow Series deposits are singled out for comment here. First, there is an increasingly strong quartzitic coarse silt component upwards in Unit Y2, with plastic deformation phenomena present below the sharp upper boundary. Second, the middle portion of Unit Y4 has a more massive structure (lacking clear boundaries and significant erosion planes), with few stones and, again, a peak in quartzitic coarse silt. Third, from the top boundary of Y5 downwards (Y13 being the lowest unit reported here), it can be observed that erosion planes (often irregular) between units and the lamination within units are more strongly characterised than in overlying deposits. The possible implications of these features of the Yellow Series will be discussed below.

In his monograph of the site, Roche (1963) described the archaeological sequence for the equivalent of Sector 8. The Iberomaurusian finds were analysed by layer but little attempt was made to explain variability across the sequence that was only alluded to briefly (Roche, 1963, 48-150). In a subsequent publication Roche subdivided the Iberomaurusian into two main phases: a *phase ancienne* and a *phase classique* (Roche, 1976, 157). This followed the tripartite model developed for the Iberomaurusian by Camps (1974), though the latest *phase évoluée* of the Iberomaurusian was missing at Taforalt. Roche's subdivisions of *ancienne* and *classique* were based on variation in the gross categories of tools (i.e. relative proportions of end-scrapers, burins, notches, backed bladelets, etc.)(Roche, 1963, 48-150), with little, if any, attention given to variability within the artefact classes themselves. His scheme was also difficult to replicate because his classification did not take account of the more widely accepted typology devised by Tixier for the Epipalaeolithic of the Maghreb (1963). In all, Roche described Iberomaurusian artefacts from eight of the grey ashy layers (*couches cendreuses*) and from nine of the underlying clayey sand layers (*couches argilo-sableuses*) (Roche, 1976). The ages on charcoals obtained from these stratigraphic units ranged from 10,800±400 BP to 16,420±190 BP, and included one from the cemetery in the grey ashy layers which yielded an age of 11,920±240 bp. None of these dates overlapped with the two appreciably older ages on burnt sediments from lower down in the clayey sands - also attributed by him to the Iberomaurusian - with ages of 21,100±400 BP and 21,900±400 BP respectively. Unfortunately there is no record of the artefacts so the association remains a matter of conjecture. Equally, our own studies of the same sequence excavated and drawn by Roche (actually surviving in our Area 3, see Fig.2) have failed to verify any of his suggested 'cultural' boundaries. In addition, neither of the two radiocarbon dates were on charcoals and it is questionable whether determinations obtained on burnt earth would be sufficiently free of extraneous sources of carbon to have provided a reliable age for the deposit. Elsewhere in the same paper Roche (1976, 157) briefly refers to the direct superposition of the Iberomaurusian over the Aterian and a suggestion that the contact between these two cultural horizons could be dated by a radiocarbon date on *Helix* snail shells of (Gif-2276) 32,370 ±1890/-2470. Again, it is impossible to verify the stratigraphic position of any of these samples as no field notes survive.

According to the analysis of lithics from the new excavations in our Area 8, we would now subdivide the Iberomaurusian into three distinctive phases. In contrast to the earlier work, this has been done on strictly defined typological and technological criteria and the phases can be correlated with specific chronostratigraphic units. The bladelet assemblages that make up the Iberomaurusian are markedly different from the flake assemblages that underlie them. These bear no obvious resemblance either in raw material or technology to the Iberomaurusian. A full study of the lithic assemblages will be published elsewhere (Hogue in prep) but the preliminary findings are summarised below.

### ***Grey Series IB3 Iberomaurusian lithic assemblages*** (Layers 2-29)

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Only a small degree of variation is present in the lithic assemblages recovered from the sedimentary layers of the Grey Series ashy deposits. Unretouched flakes and bladelets made with a soft hammer, and struck from single platform and opposed platform bladelet cores, are recorded. However, they occur in lower quantities than in the underlying deposits. There is a high frequency of burning within the assemblage. The raw materials consist of small fine-grained siliceous river cobbles known to derive from locations no further than about 25 km from the site. Sources closer to the site may have been exploited but these do not seem to include the streambed immediately below and in front of the cave. The retouched tools (Fig. 5) are dominated by backed bladelet types to the exclusion of almost all other tool classes. These pieces fall most commonly in the categories of curve-backed bladelets (Tixier types 56 through 59) and longer and more elongated pointed straight-backed bladelets (types 45-51). End-scrapers, notched and denticulated pieces, and simple retouched flakes and blades are observed in small numbers, whilst burins and most other tool forms are absent from the assemblage.

#### ***Upper Yellow Series IB2 Iberomaurusian lithic assemblages (Unit Y1).***

In contrast to the younger phase, bladelet and flake debitage is more common from this unit, which also includes greater numbers of cores. Similar small river cobbles were brought to the cave for knapping. The preferred method was to split the cobbles longitudinally before preparing a unidirectional crest down one edge of the split piece. Removal of blanks proceeded from one end of the core, with knapping sometimes switched to the other end, rather than regularly alternating between the two platforms. Bladelets show low levels of platform abrasion or other forms of preparation. The most noticeable difference from the assemblages from phase 3 is extensive use of the microburin technique. Microburins are very common in these levels (Fig. 5); some of them are quite large, and comprise predominantly distal types with the notch formed on the left lateral margin. Evidence for the use of the microburin technique is also observed in the high proportions of La Mouillah points, a backed bladelet form that retains the microburin facet either distally or proximally. Previous debates have focused on whether this type represents a formal tool in itself or is an intermediate stage in the manufacture of backed bladelets (Neeley and Barton, 1994; Olszewski et al., 2011). With the exception of the La Mouillah points, the range of retouched pieces within the Upper Yellow Series is similar to that found in the overlying Grey Series and there is clear technological continuity across the Grey-Yellow Series transition.

#### ***Lower Yellow Series IB1 Iberomaurusian lithic assemblages (Units Y2-Upper Y4)***

The assemblages from these layers are also characterised by blades and bladelets in a range of fine-grained siliceous raw materials knapped from river cobbles. There is a high degree of similarity with phase 2 in the core-reduction procedures and in the use of soft hammer percussion but a strong divergence can be seen in the method of retouching bladelet tools from those in the phases above. There is no evidence of the microburin technique in the Lower Yellow Series. The distal ends of retouched bladelets are also rarely modified. Instead the most common tool forms are blades and bladelets displaying distinctive marginal (Ouchtata) retouch, usually removing only a millimetre or two of the edge, and that frequently restricted to the proximal portion of the right lateral margin. These pieces equate largely with Tixier's type 70 the 'Ouchtata bladelet'. There are only a few steeply backed pieces present (Fig. 5).

#### ***Lower Yellow Series N-LF Non-Levallois flake assemblages (Units Lower Y4-Y11)***

There is a change in the nature of the lithic assemblage(s) from Lower Y4 which becomes much clearer from below this in Y6. The raw materials in these layers are represented by mainly coarser-grained metamorphic rocks. There are no blades or bladelets and backed tools are all but absent except in Y4. The debitage consists of flakes detached non-Levallois cores and the method of percussion is dominated by non-organic hammer techniques (hard

and soft stone). Amongst the few tools are side scrapers and thinning flakes that would appear to derive from large bifacial tools (Fig. 6).

## Methods and results of a high precision radiocarbon chronology

### *AMS Radiocarbon samples*

Samples for AMS radiocarbon dating for this study were taken from Sector 8, the southeastern section of the central part of the cave, where both Iberomaurusian and underlying layers with a non-Levallois industry were present. A total of 52 radiocarbon determinations of cut-marked bones (collagen fraction) and charcoals were therefore available from the same section (Sector 8) of the cave. The majority of samples were individual large charcoals, with recorded spot heights and all can be confidently identified to stratigraphic unit (Table 1). Four were taken from sediment blocks of 10–15 cm thickness. The entire sequence runs from 0.22 m to 5.77 m below Site Datum. Three radiocarbon determinations were duplicates, measured as quality control at ORAU (Oxford Radiocarbon Accelerator Unit). All samples were pre-treated to remove potential contaminants using standard ORAU protocols for each sample type (Brock et al 2010).

As noted above, earlier studies had arrived at the hypothesis that there was a temporal gap between the initial Iberomaurusian occurrences in the Maghreb and the last instances of preceding techno-complexes. Two additional determinations (shown in Table 2 but not in Table 1), from the separate lithostratigraphic section in Sector 9 at Taforalt, represent the earliest occurrences of the Iberomaurusian yet known from this site. These were sampled and prepared in exactly the same manner as for the other determinations. However, they are excluded from the age/depth model because they come from a separate area of the site but are mentioned here to add weight to the overall study and to render the test of the ‘gap hypothesis’ as robust as possible.

### *Bayesian analysis*

Bayesian analysis is a well-established tool for combining archaeological (*prior*) information with absolute dates (*likelihoods*) to improve the precision and accuracy of chronologies (*posterior*). OxCal v.4.1 (Bronk Ramsey, 2009a) was used for Bayesian analysis in this study. Duplicate sample measurements were combined using the function R\_Combine to produce a weighted average. A Poisson process deposition model (P\_Sequence; Bronk Ramsey, 2008) was used with *prior* information on ‘depths’ (in metres) from the Sector 8 sequence. Note that, whilst actual depth at section face is shown as the vertical dimension in Fig.4, the slightly different ‘depth’ values used in the Bayesian analysis (cf. Table 1) are the result of initial adjustment to reflect the position of samples in a vertical ‘stack’ of units, each unit represented as the typical (estimated average) value of its observed thickness range. In order to provide the most realistic depiction of sedimentation for a cave site, the complexity (reasonably assumed to be random in respect of rate variation) of the underlying sediment deposition was then modelled according to a Poisson process. Since the sequence does not provide means of estimating an appropriate value for the step-size parameter (*k*) in the P\_Sequence model, the model averaging approach (Bronk Ramsey and Lee, in prep) was used to remove subjectivity in model selection. Samples from sediment blocks without spot heights were modelled using a uniform phase model, their positions within the model were constrained by using the known height limits of the blocks. These uniform phase model parameters were cross-linked into the P\_Sequence model according to their ‘depths’.

Formal outlier analysis was also utilised to account for outliers in the radiocarbon scale and the calendar scale. The outlier models are specified to allow the possible shifts in the specified scale to be drawn from a long tail Student *t* distribution. The outliers can be in the scale of anywhere between  $10^0$  and  $10^4$  years. These are the models recommended by Bronk Ramsey (2009b) for general purposes when the scale of the possible offsets is unknown.

When employed the overall model is not affected by the odd extreme outlier. Each measurement is assigned a prior probability of 5% of being an outlier.

### **Posterior chronology**

The posterior chronology for the Iberomaurusian sequence in Sector 8 is shown in Fig. 7 and Table 2. The chronology was modelled using multiple P\_Sequence functions due to the presence of different types of sediments and hiatuses in the sequence (Fig. 8). In terms of the outlier analyses applied, no outliers were found in the radiocarbon scale; and only one (OxA-23411) was found to yield  $\geq 95\%$  probability of being an outlier in the calendar scale. Such findings support the validity of the individual radiocarbon determinations themselves (Staff et al., 2011).

The model suggests that the boundary between the Yellow and Grey Series occurred in the range of 15,190-14,830 Cal BP (95.4% probability)(Table 2). In the Yellow Series, the difference in age between samples OxA-22788 (Unit Y1) and OxA-16267 (Unit Y2) was calculated to be between 1245 and 2102 years; and 2677 and 3830.5 years between samples OxA-16273 (upper Unit Y4) and OxA-16271 (lower Unit Y4) (95.4% probability; Figs. 9 and 10).

### **Discussion**

The AMS record of 54 dates for Taforalt provides the largest coherent set of radiocarbon determinations yet available for this period in the Maghreb and is an important baseline for understanding the development of this LSA technology and its relationship with stratigraphically older industries here and across North Africa. The unmodelled ages indicate a timespan of at least 9000 calendar years for Iberomaurusian occupation, beginning abruptly and with no obvious antecedents at 22,093-21,420 BP (the earliest Sector 9 sample at two  $\sigma$ ) and ending in this cave (Sector 8) at 12,698-12,548 BP (at two  $\sigma$ ), though younger ages at other sites indicate a prolonged existence in the region (Bouzouggar et al., 2008; Linstädter et al., 2012).

One of the significant implications of the new results is the fresh light they cast on the chronological relationship between the Iberomaurusian and an earlier technology characterised by flakes made using a non-Levallois technique. In the past, the assumption had been that pre-Iberomaurusian industries in this region shared a uniquely Aterian affinity. This idea was directly endorsed by Roche who believed that there was a “*superposition directe entre l’Aterian final ...et l’Epipaléolithique très ancien..*” at Taforalt (1976, 157-8), with a break possibly of relatively short duration in between. The observation was repeated by Debénath et al. (1986) who recognised the same succession in the Témara caves in western Morocco but with a potentially longer hiatus of up to 5,000 years. In our excavations at Taforalt, we could find no evidence of such a superimposition and we now suspect that, even if Roche’s observations were consistent, he failed to recognise both the vertical and lateral complexity of the sedimentary sequences. We would suggest that such an interpretation is also no longer tenable for sites in the Témara area (Contrebandiers, El Mnasra, Dar es-Soltane) where re-dating would imply a much wider gap between the Aterian and the Iberomaurusian (Schwenninger et al., 2010; Jacobs et al., 2012). At many of these and other sites the Iberomaurusian is separated from earlier (‘Middle Palaeolithic’/MSA) occupation by archaeologically sterile layers (Linstädter et al., 2012).

The nature of the first ‘radiocarbon hiatus’ in the cultural sequence at Taforalt is of particular interest because of the implications for the presence/absence of human populations in Northwest Africa at that particular time. According to the modelled Sector 8 radiocarbon ages, the gap in occupation between the Iberomaurusian (IB1) and underlying non-Levallois flake (N-LF) industry seems to have been around 3,800 years at two  $\sigma$  confidence interval. However, this separation may have been of shorter duration because of two slightly older

ages for the Iberomaurusian in Sector 9 of Taforalt. These age estimates cannot be incorporated directly into the same age-depth model for the deposits of Sector 8 (although they can be linked stratigraphically within the Yellow Series). Taking the calibrated ages for the oldest Iberomaurusian of 22,093-21,420 cal BP ( $2\sigma$ ) and the uppermost levels of the non-Levallois flake industry of 24,769-23,940 cal BP ( $2\sigma$ ) considerably reduces the break to potentially no more than 1,900 years. These observations on the hiatus are also underpinned by sedimentological data. As referred to above, from lower Y4 downwards, the units that contain the non-Levallois flake industry are characterised by strong bedding features, both in unit boundaries and internal lamination. The immediately overlying layers display no major disconformities and (even though there are small-scale signs of bioturbation) the sediments are more massive in structure and lack distinct boundaries. This part of the sequence covers a thickness range of 10-40 cm and is largely devoid of lithic artefacts. More concentrated signs of occupation with identifiable Iberomaurusian lithics occur above this in upper Y4 that feature fine sands, slightly gritty in places, with smaller stones present in bands. These observations do not suggest major gaps in the depositional sequence, certainly not one corresponding with the 'radiocarbon hiatus'.

Another critical issue in evaluating the archaeological evidence concerns the attribution of the non-Levallois industry and whether it differs significantly from the Aterian, found in deeper layers of the site. In reality, the differences are reasonably clear-cut and are helped by consistencies in the Aterian typology and technology in various sites throughout the Maghreb. For example, a particular feature of the Aterian is the use of the Levallois technique and associated tools usually include a range of scrapers, pedunculate points and bifacial foliates made on diagnostically Levallois products including blades (Bouzouggar and Barton, 2012). In contrast, such items are notably absent in the industry in the lower sequence in Sector 8, which includes occasional flake tools, but none of them are made on obvious Levallois blanks. Unfortunately, as there are no layers with Aterian artefacts in Sector 8, a direct stratigraphic relationship with the non-Levallois industry cannot be demonstrated for this part of the site. However, in Sector 9, accessible sections have revealed a thick sequence of sediments that includes Iberomaurusian layers near the top (with the reported AMS dates). The layers immediately beneath this are not archaeologically rich but include undiagnostic flakes in raw materials similar to those in the non-Levallois industry of Sector 8. At the base of the Sector 9 excavation trench and separated from the lowest Iberomaurusian by at least 130 cm are a series of charcoal-rich laminated hearth deposits. These contain clear examples of Aterian retouched tools (including a bifacial foliate) and Levallois debitage. An OSL date of  $37.57 \pm 3.42$  BP (Clark-Balzan pers comm) has been obtained from the deposits and represents the youngest age so far recorded for the Aterian at this site. No radiocarbon dating has yet been undertaken on the charcoals but if the age estimate is correct it may give greater credence to an OSL date of  $30.9 \pm 2.5$  ka years for the Aterian at Wadi Noun in Southern Morocco (Wengler, 2010, 77; Weisrock et al., 2006, 49), and to ESR dating of around  $39 \pm 4$  ka years on the later Aterian at Mugharet el 'Aliya in northern Morocco (Wrinn and Rink, 2003), where new radiocarbon dates are also anticipated (Tuross pers comm.). For the moment, Taforalt provides the only securely dated sequence for a clear cultural succession preceding the Iberomaurusian and showing that an Aterian Levallois-dominated technology was replaced by one of non-Levallois type. We believe this model can be tested more widely and has major ramifications for interpreting other lithic artefact sequences in the Maghreb.

Turning to the Iberomaurusian, although the deposits at Taforalt represent a thick and fairly continuous record of human occupation, there are in fact subtle variations in the cultural sequence. The clearest example is the switch from IB1 with marginally backed ('Ouchtata') blades and bladelets to IB2 dominated by microlithic backed bladelets. The actual transition between the two phases is marked by a sharp sedimentary contact between Units Y2/Y1. This is clearly an erosive boundary so it is impossible to know whether the time gap of 857 years (between 15,686-15,010 BP and 17,204-16,898 BP at  $2\sigma$ ) in the radiocarbon model is more

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apparent than real. Yet, observations of the sediments towards the top of Unit Y2 reveal some unusual geological phenomena, which may provide clues about the environmental conditions during the later formation of this unit. A raised silt content would suggest that wash input was capturing aeolian dust from the exterior surroundings. It appears too that the signal of regional aridity implied by these processes evidently came to a brusque end with a phase of instability indicated by plastic deformation (wetness and possibly even transient ground freezing), in the uppermost part of this unit. The wider consequences of these observations will be explored further below. Also of relevance is the temporal relationship between the IB2 and IB3 assemblages. Here the techno-typological changes are relatively minor and relate mostly to the highly varied appearance of the microlithic bladelet forms in IB3. These introductions seem to have been made during an uninterrupted period of cave use, and we would therefore hypothesise that such differences in typology may represent a drift in the intensity and nature of activities across the site.

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One of the key aims of this paper has been to assess whether gaps in settlement and shifts in lithic cultural phases can be correlated with phases of rapid climatic change. Palaeoclimatic records available from Atlantic and the Alboran Sea marine cores (Combourieu Nebout et al. 2002; Sánchez-Goñi et al., 2002; Fletcher and Sánchez-Goñi, 2008) confirm that major climatic shifts occurred in the western Mediterranean during the Late Pleistocene, and these could have had a significant impact on human populations. Of particular interest are so-called Heinrich Events marked by the incursion of cold polar surface waters into the Mediterranean (Moreno et al., 2005). These appear to have been associated with phases of greater aridity in Iberia and Northwest Africa as documented in pollen sequences from the Alboran Sea cores (Combourieu Nebout et al., 2002; Jiménez-Espejo et al., 2007; Sánchez-Goñi, 2006; Fletcher and Sánchez-Goñi, 2008) and increased input of windborne dust from the Sahara (Moreno et al., 2002; Moreno, 2012). In contrast, the periods following Heinrich episodes appear to have been relatively warm and humid, as for example the ‘Last Glacial Maximum’ phase after HE2 (Penaud et al., 2010) and the phase of major warming at the beginning of Greenland Interstadial 1e, the latter marked by a rise in Sea Surface Temperatures and the diversion westward of moisture bearing winds bringing higher precipitation to the Maghreb (Moreno et al. 2005; Rodrigo-Gámiz et al. 2011). Climate modelling also suggests that annual rainfall may have fallen below 100 mm per year during certain Heinrich Events (Sepulchre et al., 2007). A further source of information comes from the direct comparison between the radiocarbon dated sequence at Taforalt with the NGRIP ice-core timescale (Fig.7), which allows broad correlation with D-O (Dansgaard-Oeschger) stadial-interstadials of the Greenland record (Bond et al., 1993; Dansgaard et al., 1993; Rodrigo-Gámiz et al. 2011).

Beginning with the Grey Series, the radiocarbon model confirms that this unit began accumulating close to the start of Greenland Interstadial 1e and continued throughout most of GI1, a phase of relatively humid conditions. However, it is also clear that the Grey ash deposit is heavily anthropogenic (midden) and that the accumulation rate was extremely rapid (at c.1.7 m/kyr) so that any obvious palaeoenvironmental signal may have been effectively swamped. Only the presence of cedar (*Cedrus* sp.) charcoals upwards from Unit G89 (Ward, 2007) would imply more ‘montane’ (cooling) conditions, and this could indicate the onset of Younger Dryas or Greenland Stadial 1 at the very top of this sequence (Fig. 7). One other potential sign of variation occurs near the base of the Grey Series where the remains of Barbary ground squirrel (*Atlantoxerus getulus*) suggest cooler, drier conditions (Bouzouggar et al., 2008). Moving downward (backwards in time) into the Yellow Series, clearer evidence of climatic variation (instability) occurs in the sediments of upper Y2 and here it is interesting to note that the dating model places this period of deposition within the same time span as Heinrich Event 1 (HE1). It also marks the point at which IB1 assemblages are replaced by those of IB2, and may be evidence that the dislocation in the cultural signature was influenced by climatic change. However, it is difficult to ascertain the length of break between the two Iberomaurusian phases because of the erosive unconformity. A more marked

1 example of climate-cultural change occurs earlier in Yellow Series sequence. Here there is a  
2 clear time lag between the earliest Iberomaurusian and the N-LF industry. The stratigraphic  
3 expression of this 'gap' is not, as in the younger example, an erosion plane. Rather, there is a  
4 body of sediment that is generally finer than the norm and which contains significant silt  
5 (dust). It would therefore appear that the sedimentation rate dropped drastically (to less than  
6 0.05 m/kyr), probably in a significantly arid and cool period. It is perhaps relevant that the  
7 'gap' calculated here includes the time span of HE2, marking the onset of Greenland Stadial  
8 2 (GS2) and following the more variable and probably often more moist environmental  
9 conditions normally reconstructed for the preceding GS3. The latter may be reflected in the  
10 strong bedding structure present in the underlying Sector 8 Units Y13-Y5 at Taforalt. Some  
11 indication of cooler climatic conditions is also implied by a rise in cedar (*Cedrus* sp.)  
12 charcoals in Y6-5 which disappears by the middle of Y4 (Ward pers comm.).

13 Lastly, what are the implications for the genetic theories of modern human dispersal in North  
14 Africa? Two of the most recent scenarios put forward in those studies have suggested that  
15 the Iberomaurusian either, 1) originated in populations that gradually spread westward from  
16 Cyrenaica, or, 2) developed independently somewhere in the Maghreb and was subsequently  
17 transmitted eastwards (and possibly west) via an expansion of haplogroups U6a1 and U6a1a  
18 lineages. Archaeologically, in order to satisfy the conditions of the first hypothesis, one  
19 would expect logically that the oldest expression of this 'culture' should occur in the east.  
20 Despite new claims for an earliest age at Haua Fteah of ~19 ka (Barker et al., 2010) we would  
21 suggest caution in the interpretation as this is so far based on dates on two shells from so-  
22 called transitional Layers XIV-XV of the old excavation. Equally, suggestion of early dating  
23 of sites in Upper Egypt (Close, 2002) are based on old charcoal dates from open sites, whilst  
24 the oldest age estimate from western Libya at Ain Shakshuk of  $16,750 \pm 60$  BP (Barich and  
25 Garcea, 2008) is still substantially younger than the oldest Iberomaurusian recorded in the  
26 Maghreb. Secondly, if the progenitor of the Iberomaurusian was an industry with retouched  
27 blades and chamfered pieces like the Dabban then it follows that, given the earlier presence  
28 of Iberomaurusian in the Maghreb, there should also be signs of the Dabban or similar blade  
29 industry in this region. Here again, the criteria are not clearly met as there are no immediately  
30 pre-Iberomaurusian blade industries yet known in the Maghreb; so far the most westerly  
31 findspot of a blade industry that might fit this description is in the Jebel Gharbi of  
32 Northwestern Libya, with estimated ages of ~30 ka BP (Garcea, 2004). At the Haua Fteah,  
33 the earliest Dabban can now be firmly anchored by tephro-chronology to just before ~40 ka  
34 BP (Lowe et al., 2012). The dating is significant because it brings the Dabban more closely  
35 into line with other early blade technologies such as the Ahmarian of the Near East (Belfer-  
36 Cohen, Goring-Morris, 2003; Marks, 2003) and at Nazlet Khater in Egypt (Vermeersch,  
37 2010), which are of broadly similar age. However it is unlikely on technological grounds that  
38 there was any demographic connection between these regions (Marks 1975; Iovita, 2009). It  
39 also follows that any interactions between early Upper Palaeolithic blade technologies did not  
40 extend very far if at all into the Maghreb.

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48 The second scenario, which envisages the earliest occurrence of the Iberomaurusian in the  
49 Maghreb, offers a better fit with the archaeological data but raises other important issues. One  
50 of these concerns the relationship of the Iberomaurusian with older technologies in this  
51 region. As has been shown above, there are no obvious antecedents for the blade and bladelet  
52 industries in the Maghreb and it is generally agreed that sterile layers separate the  
53 Iberomaurusian from anything earlier, with no suggestion of cultural continuity (Bouzougar  
54 et al., 2008; Linstädter et al., 2012; Nespoulet et al., In press). A question therefore arises  
55 whether the replacement of non-Levallois flake assemblages by the Iberomaurusian is  
56 equivalent to the Middle Stone Age (MSA) to Late Stone Age (LSA) transition seen in other  
57 parts of Africa (Clark, 1959; McBrearty and Brooks, 2000; Mitchell and Barham, 2008)?  
58 Unfortunately, the only useful comparisons that can be made are with the earliest bladelet  
59 technologies in regions that are geographically distant from the Maghreb. For example, in  
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1 Northeast Africa and the Nile Valley, bladelet industries become prevalent after ~25 ka ago  
2 (Schild and Wendorf, 2010). But in these regions the situation is made more complex because  
3 the Middle Palaeolithic/MSA includes both Levallois flake assemblages (Nazlet Safaha 2)  
4 and blade technologies (Taramsa Hill, Nazlet Khater) which were present from as early as  
5 MIS 3 (Van Peer, 2004; Vermeersch, 2010). Nonetheless, it is significant that there are no  
6 reported cases of either backed bladelets or ‘ouchtata’ forms in the MSA blade assemblages  
7 (Vermeersch 2010, 86). Further afield the systematic manufacture of bladelets seems to have  
8 begun somewhat earlier. For instance, in East Africa, assemblages with a major bladelet  
9 component can be dated to 45 ka BP at Mochena Borago rockshelter (Southwest Ethiopian  
10 Highlands) (Brand et al., 2012) and to 46 ka BP at Enkapune ya Muto (Kenya) (Ambrose,  
11 1998). In other areas of sub-Saharan Africa at Mumba rockshelter, northern Tanzania, newly  
12 reported OSL ages suggest that production of bladelets became abundant around  $49.1 \pm 4.3$   
13 ka BP (Gliganic et al., 2012), while at Border Cave microliths made on opposed platform  
14 cores are common from 44–42 ka cal BP (Villa et al., 2012). At each of these sites there are  
15 signs of continuous sedimentation and occupation with underlying layers, which seem to  
16 imply gradual cultural transitions. The only area which might offer some parallels with the  
17 Maghreb is in the southern margins of Southern Africa where from the end of Marine Isotope  
18 Stage 3 (~25 ka ago) microlithic assemblages made on quartzites become manifest and are  
19 succeeded by systematic bladelet production in Robberg-type assemblages from around ~19  
20 ka ago (Klein, 1974; Wadley, 1997; Mitchell, 2002). Thus over much of Africa standardised  
21 microlithic bladelet production (LSA) can generally be seen to supercede technologies  
22 characterised by more variable flake and blade manufacture (MSA) although the adoption of  
23 changes was by no means synchronous across the whole continent (Mitchell, 2008). On the  
24 basis of these considerations, we would suggest that the MSA-LSA template can also be  
25 applied to North Africa but that the introduction of bladelet technologies was considerably  
26 delayed in the Maghreb and their appearance after ~21 ka BP and subsequent spread may  
27 partly be explained by the demographic expansion of sub-clades of U6. However, it does  
28 leave several questions unanswered: why did these innovations emerge when they did in the  
29 Maghreb: did they arise in response to palaeoclimatic shifts (e.g. Greenland Stadial 2), or  
30 were these innovations linked to subsequent demographic rise or the result of the influx of  
31 new peoples into this region following the disappearance of the MSA? These and other  
32 questions can ultimately only be answered by focusing research on other sites in the Maghreb  
33 similar to Taforalt, which have long sequences that cover a comparable time span.  
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## 38 **Conclusions**

39 In this paper we have presented the first high precision record of AMS dates for the Late  
40 Pleistocene Maghreb, providing a framework for understanding the development of the  
41 Iberomaurusian, the oldest backed bladelet LSA technology in Northwest Africa. In  
42 examining the dating evidence at Taforalt, several gaps in the sequence were noted, including  
43 one of possibly as little as 1,900 calendar years separating the first appearance of the  
44 Iberomaurusian at 22-21.4 ka Cal BP from the underlying non-Levallois flake technology,  
45 tentatively attributed to the MSA. A further gap in dating (but this time also coinciding with  
46 an erosive unconformity) can be seen between the earliest Iberomaurusian industry with  
47 ‘Ouchtata’ retouched blades (IB1) and one above containing microlithic backed bladelets  
48 (IB2). The duration of this gap may have been of the order of one to two thousand years and  
49 confirms that fully developed microlithic components had emerged in the Iberomaurusian by  
50 15.5-15 ka cal BP. A major accumulation of ashy midden deposits can be identified at  
51 Taforalt at 15.2-14.2 ka cal BP and use of the cave in the Iberomaurusian was shown to have  
52 continued until about 12.6 ka cal BP (Tables 1 and 2).  
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57 Assessing the relationship of these gaps to potential environmental shifts has been possible  
58 with reference both to cave sedimentological data and palaeoclimatic records for the western  
59 Mediterranean. Using broad comparisons with available oceanic and atmospheric records, it  
60 has been observed that the disappearance of the latest MSA at around 24 ka cal BP may have  
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been coincident with pronounced cooling of Atlantic and western Mediterranean waters in Heinrich Event 2 (Penaud et al., 2010), which would have produced a marked increase in continental aridity (Moreno et al., 2005). In contrast, the emergence of the Iberomaurusian seems to have taken place against the relatively warm and moist conditions indicated for the LGM at these latitudes (Penaud et al., 2010). At Taforalt, finer silts were observed in the intervening archaeologically sterile sediments between the proposed MSA and LSA levels that have been interpreted as a signal of increased regional aridity. Higher in the sequence, the erosive hiatus separating the Iberomaurusian phases IB1 and IB2 can be shown to coincide with Heinrich Event 1, although oceanic studies have suggested this was not necessarily as severely arid as the earlier Heinrich episode (Penaud et al., 2010) and might be correlated with increased marine palaeoproductivity (Rodríguez-Gámiz et al., 2011). The latter could have had major beneficial consequences for populations living on and near the coast. Finally, we do not believe it purely fortuitous that the timing of midden accumulation at Taforalt (Grey Series) occurred so close to the beginning of Greenland Interstadial 1e. During this period the projected northwards migration of the Inter-Tropical Convergence Zone and increased Monsoon activity would have brought much wetter conditions to this area (Rodríguez-Gámiz et al., 2011). Such circumstances might explain or have given rise to some behavioural changes that occurred in the Iberomaurusian in this period (e.g. evidence of increased dietary breadth, greater sedentism, use of the deeper part of the cave site as a cemetery).

In conclusion, while present genetic models for the dispersal of humans in North Africa are largely inconclusive, we would suggest that the new dating evidence supports an independent origin of the Iberomaurusian in the Maghreb (~22 ka cal BP). The latter implies innovation and transmission of new ideas that may have arisen in the Maghreb at a time of environmental instability or that were transmitted via rapid population movements from an area fringing the Maghreb. However it does not seem likely that the impetus for change came from areas in the south on the Atlantic margin where only younger phases of the Iberomaurusian are so far known (e.g. the Agadir region, Bouzouggar pers obs.). Parallel developments may have led to the appearance of backed bladelet technologies in Libya and Cyrenaica, but here these seem to have been more deeply rooted in the Dabban. Clearly this picture may change in the light of fresh evidence but our proposal for the MSA-LSA transition in the Maghreb provides a robust model that is capable of extensive testing.

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18

### 19 Figure Captions 20

21 Fig. 1. Distribution of Iberomaurusian sites. 1. Cap Rhir, 2. El Khenzira, 3. Contrebandiers, 4.  
22 El Harhoura II, 5. Dar es-Soltan I, 6. Ghar Cahal, 7. Kehf El Hammar, 8. Hattab II, 9. Ifri El  
23 Baroud, 10. Ifri n' Ammar, 11. Kifan Bel Ghomari, 12. Taforalt, 13. La Mouillah, 14.  
24 Rachgoun, 15. Columnata, 16. Cap Ténès, 17. Rolland, 18. Rassel, 19. Oued Kerma, 20. El  
25 Hamel, 21. El-Onçor, 22. Afalou Bou Rhummel, 23. Tamar Hat, 24. Taza, 25. Ouchtata  
26 localities, 26. Horizon Collignon.  
27  
28

29 Fig. 2. Plan of Taforalt showing earlier Roche excavations and main sectors of the recent  
30 field campaigns.  
31  
32

33 Fig. 3. Main section on the south side of the cave (Sector 8) showing the Grey Series  
34 overlying the Yellow Series. Scale is 2 metres long. (photo: Ian Cartwright; copyright:  
35 Institute of Archaeology).  
36  
37

38 Fig. 4. Schematic section through the Grey and Yellow Series deposits in Sector 8,  
39 illustrating different excavation columns and AMS radiocarbon dates (see Tables 1 and 2).  
40  
41

42 Fig. 5. Three phases of the Iberomaurusian. Top row: IB3 curve-backed microlithic points;  
43 Middle: IB2 curve-backed microlithic points including 'La Mouillah points' (right); Bottom:  
44 IB1 Straight backed blades and bladelets, with Ouchtata retouch (second and third from right  
45 and extreme right). Scale in cm. (Drawings by Josh Hogue).  
46  
47

48 Fig. 6. Flake debitage from the non-Levallois industry. Scale in cm. (photo: Nick Barton).  
49

50 Fig. 7. Age-depth model for Taforalt cultural sequence. Posterior AMS chronology is  
51 modelled with one P Sequence function for samples with spot heights.  
52  
53

54 Fig. 8. Apparent Sedimentation Rates, Yellow Series in Sector 8. The modelled C14 date  
55 ranges (95.4%) are plotted by the two lines against depth in the sequence, so that  
56 sedimentation rate approximates to the slope of the lines. Human input tends to increase the  
57 slope (sedimentation rate), particularly at the strongly anthropogenic Units Y3, Y5 and Y7.  
58 Most instances of apparent low slope are likely to be 'jumps' (as indicated in the diagram)  
59 caused by demonstrable erosion events; in this respect, the Y8-11 sequence could be shown  
60  
61  
62  
63  
64  
65

as a series of small steps. Only the markedly decreased slope within Unit Y4 appears to represent a truly significant slowing of sedimentation (see main text for discussion).

Fig. 9. Modelled chronological break between MSA non-Levallois flake technology and the oldest Iberomaurusian.

Fig. 10. Modelled chronological break between Iberomaurusian IB1 and IB2 industries in Y2 and Y1 respectively.

#### Table Captions

Table 1. Un-calibrated Radiocarbon determinations from Grotte des Pigeons (Sector 8) at Taforalt, Morocco. The dating samples are presented by averaged depths from the surface; where ranges shown, this indicates that the samples came from sediment blocks of known thickness.

Table 2. Radiocarbon determinations, their un-modelled calibrated ages, (IntCal09) and the modelled posterior age highest probability density (HPD) ranges at 68.2% and 94.5%. Samples marked with an asterisk (\*) are duplicates and two asterisks (\*\*) are their combined ages. The sample named “YG” indicates the modelled age for the Yellow / Grey series transition at 4m.

Figure 1

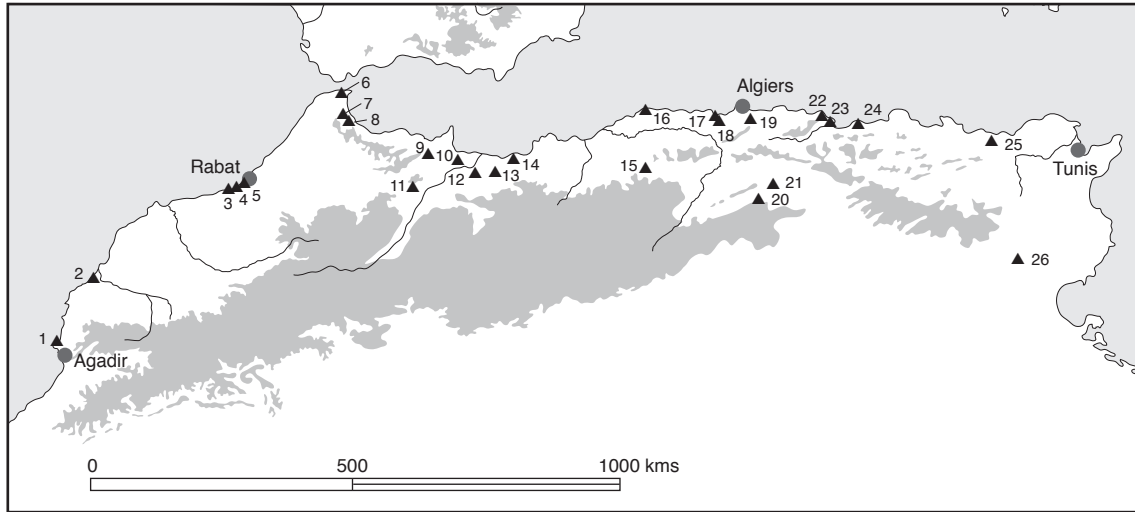
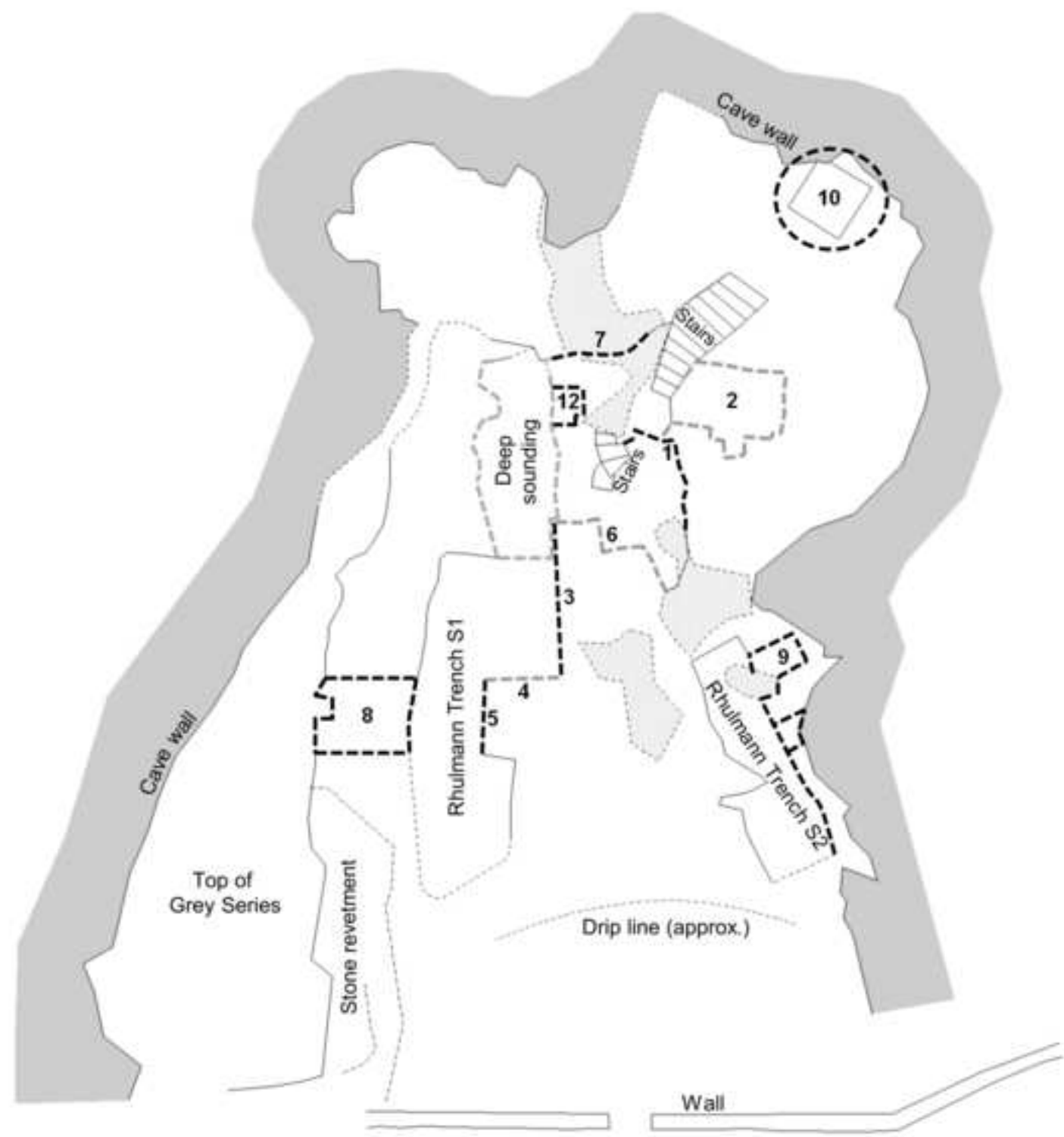
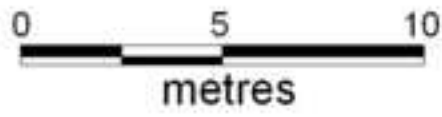



Figure 2

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### Grotte des Pigeons Site Plan



 Significant ancient calcite masses (effectively part of the bedrock)

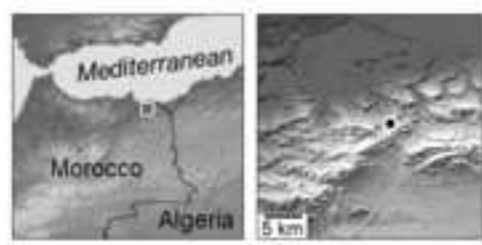


Figure 3  
[Click here to download high resolution image](#)



Figure 4

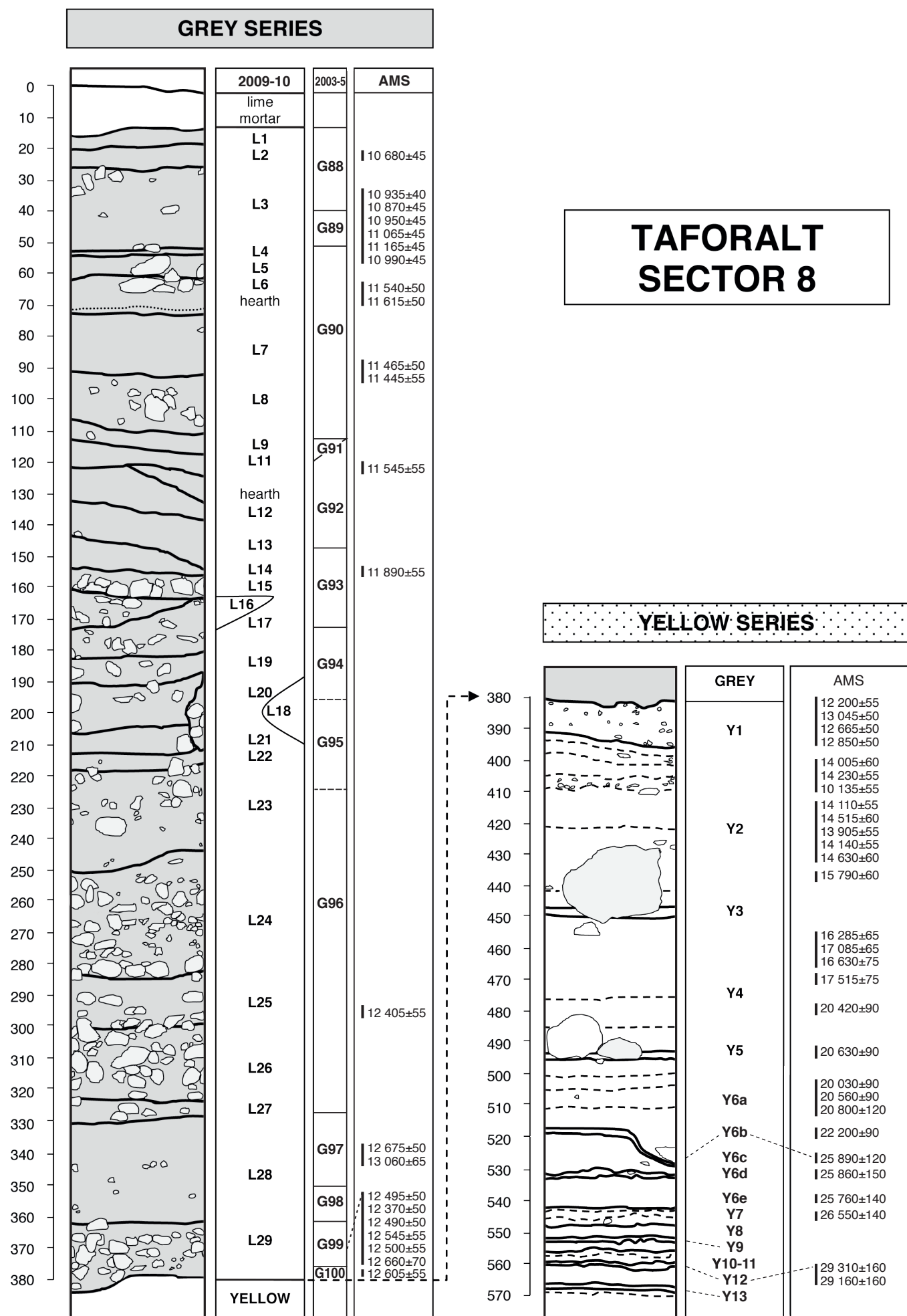
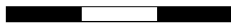


Figure 5



cm

Figure 6  
[Click here to download high resolution image](#)



Figure 7

Phase

NGRIP\_180

Depth (m)

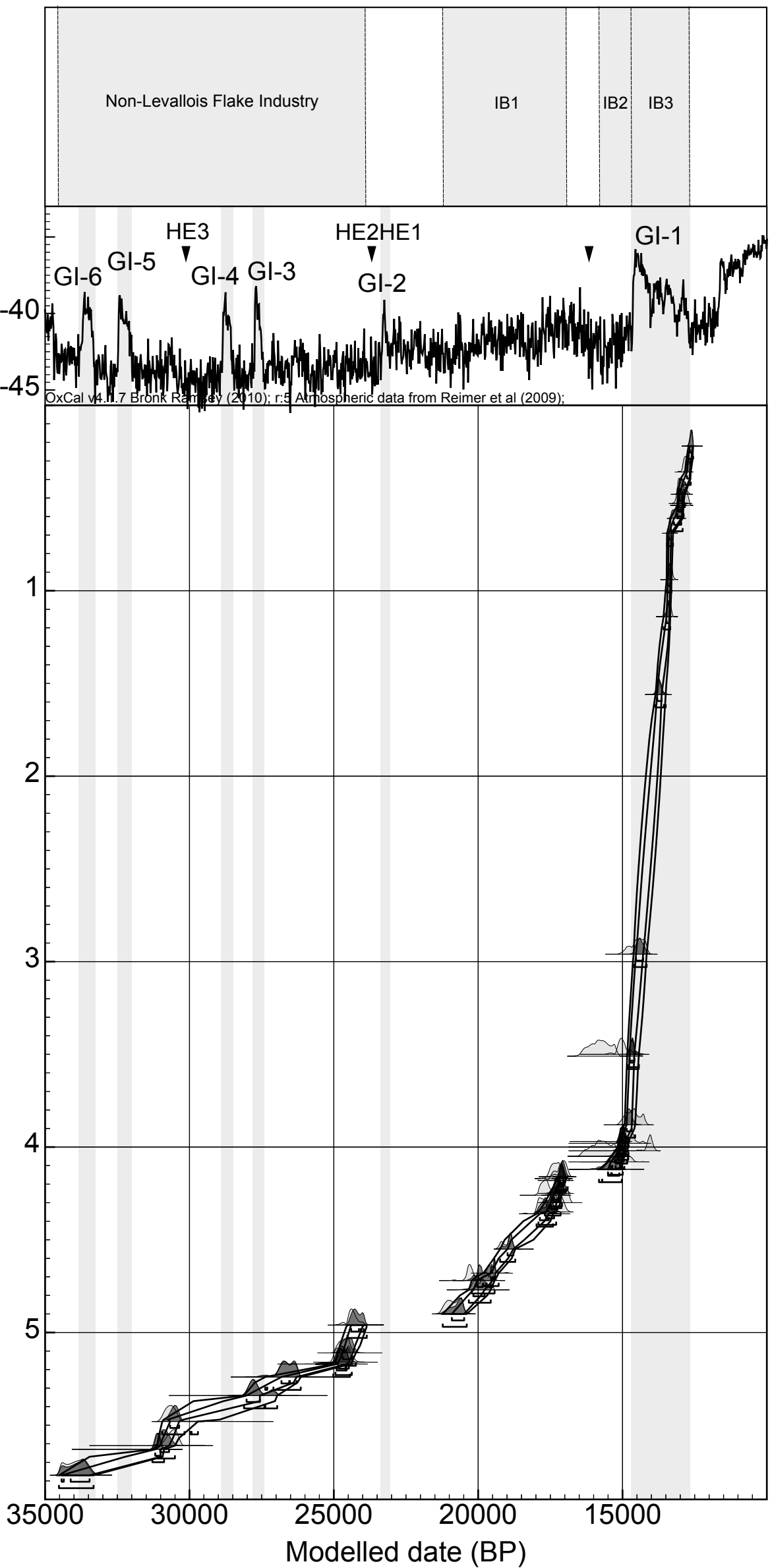


Figure 8

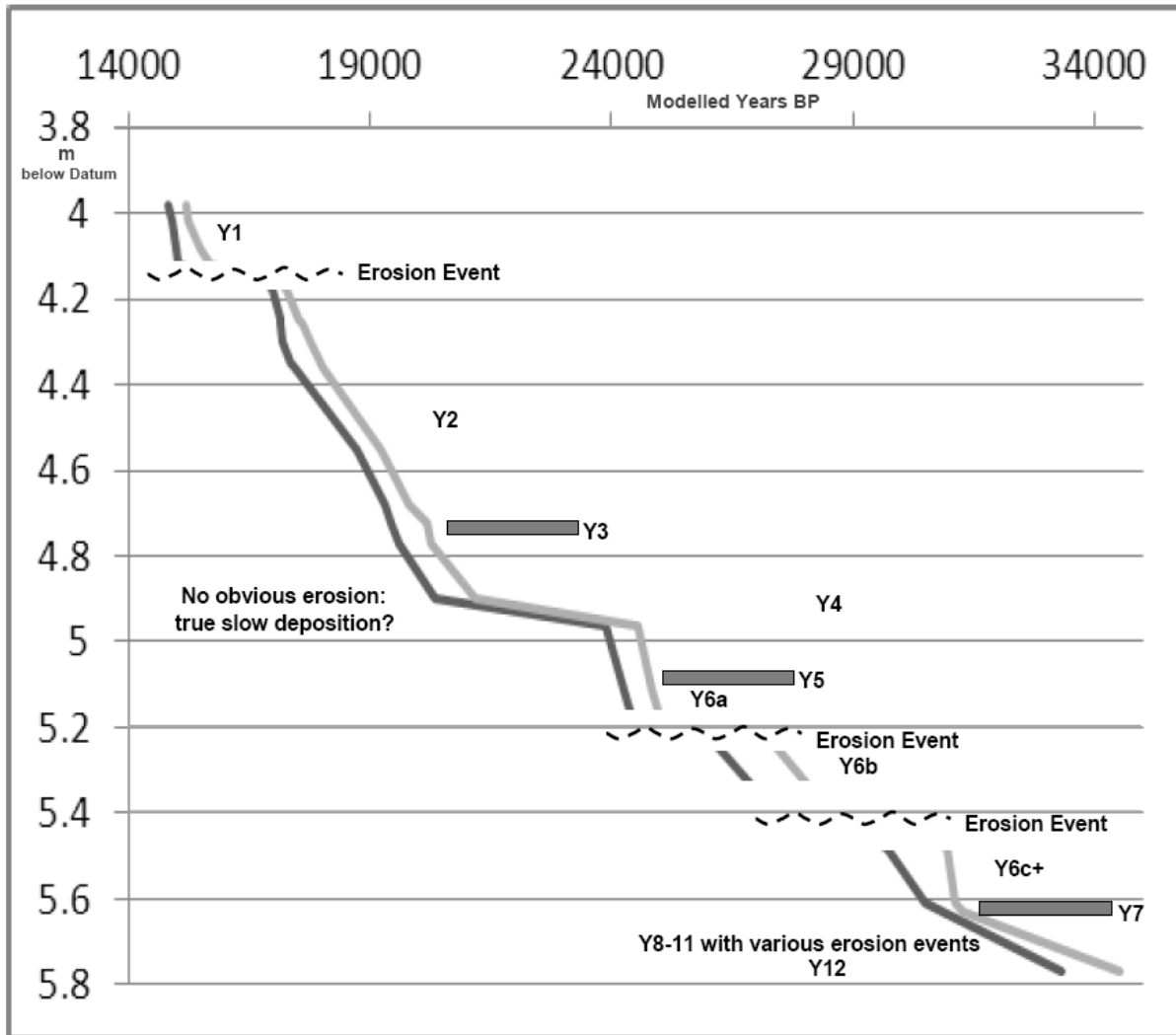
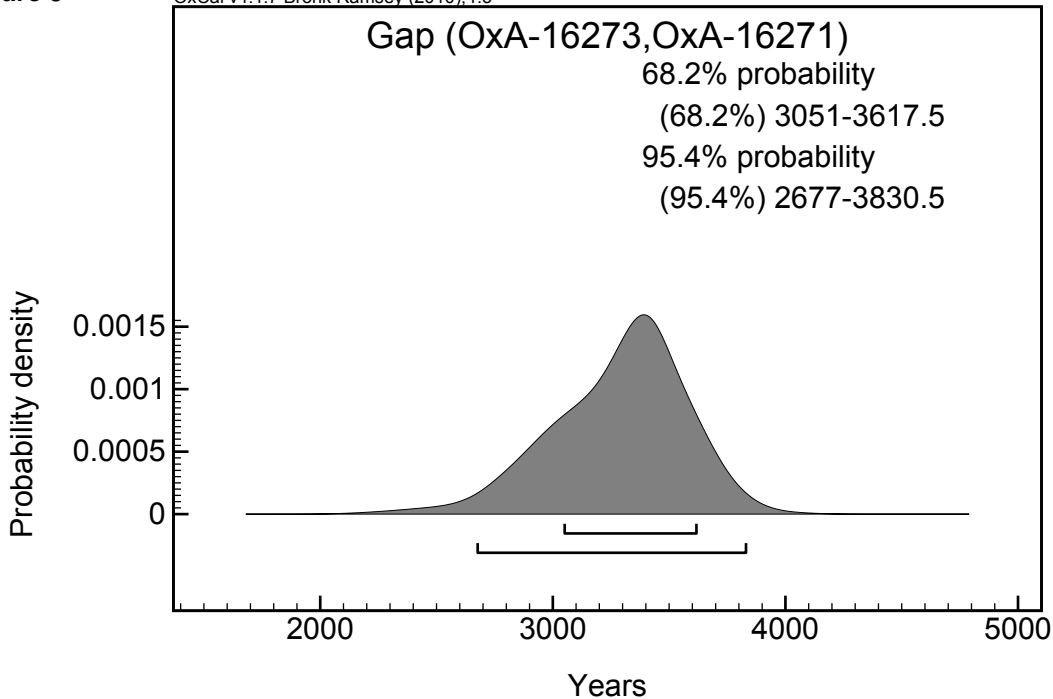


Fig. 8 Apparent Sedimentation Rates, Yellow Series in Sector 8.

The modelled  $C^{14}$  date ranges (95.4%) are plotted by the two lines against depth in the sequence, so that sedimentation rate approximates to the slope of the lines. Human input tends to increase the slope (sedimentation rate), particularly at the strongly anthropogenic Units Y3, Y5 and Y7. Most instances of apparent low slope are likely to be 'jumps' (as indicated in the diagram) caused by demonstrable erosion events; in this respect, the Y8-11 sequence could be shown as a series of small steps. Only the markedly decreased slope within Unit Y4 appears to represent a truly significant slowing of sedimentation (see main text for discussion).

**Figure 9**

OxCal v4.1.7 Bronk Ramsey (2010); r:5



**Figure 10**

OxCal v4.1.7 Bronk Ramsey (2010); r:5

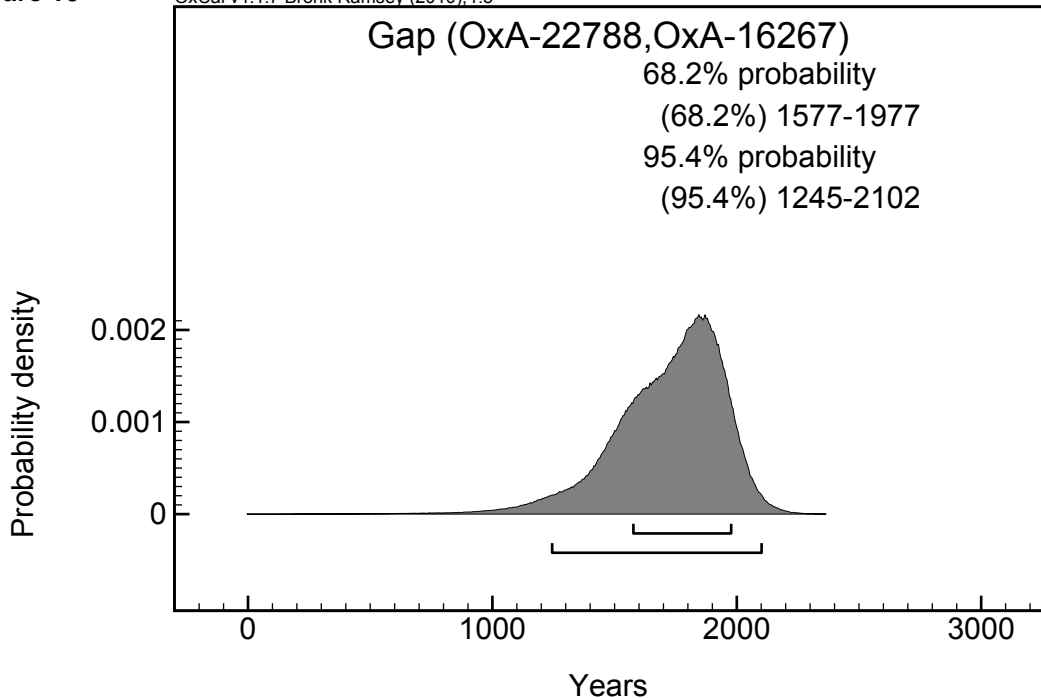


Table 1

Unit	Sample	<sup>14</sup> C determination	Uncertainty	Av Depth (m)	Layer	Species	Ref.
Grey series	OxA-24111	10680	45	0.22	L2	<i>Ammotragus</i>	1
	OxA-13479	10935	40	0.36	G88	<i>Pinus sp.</i>	2
	OxA-23404	10870	45	0.36-0.48	L3	<i>Pinus sp.</i>	3
	OxA-13480	10950	45	0.36-0.48	G89	<i>Pinus sp.</i>	4
	OxA-13516	11065	45	0.48	G89	<i>Pinus sp.</i>	5
	OxA-24112	11165	45	0.53	L4	<i>Ammotragus</i>	6
	OxA-13517	10990	45	0.54	G90	<i>Dicotyledonous</i>	7
	OxA-24113	11540	50	0.69-0.61	L6	<i>Juniperus / Tetraclinus</i>	8
	OxA-23405	11615	50	0.69-0.61	L6	<i>Gazella</i>	9
	OxA-23407	11465	50	0.94	L8	<i>Juniperus / Tetraclinus</i>	10
	OxA-23406	11445	55	0.94	L8	<i>Juniperus / Tetraclinus</i>	11
	OxA-23408	11545	55	1.14	L11	<i>Pinus sp.</i>	12
	OxA-23409	11890	55	1.56	L15	<i>Pinus sp.</i>	13
	OxA-23410	12405	55	2.96	L25	<i>Juniperus / Tetraclinus</i>	14
	OxA-13477	12675	50	3.50	G97	Conifer	15
	OxA-23411	13060	65	3.51	L28	<i>Juniperus / Tetraclinus</i>	16
	OxA-13478	12495	50	3.88	G99	<i>Juniperus / Tetraclinus</i>	17
	OxA-22902	12370	50	3.97-3.88	G99	Conifer	18
	OxA-22904	12490	50	3.97-3.88	G99	Conifer	19
	OxA-22787	12545	55	3.97-3.88	G99	Conifer	20
	OxA-22785	12500	55	3.97-3.88	G99	<i>cf Juniperus</i>	21
	OxA-22784	12660	70	3.97-3.88	G99	<i>cf Juniperus</i>	22
	OxA-24109	12605	55	3.98	G100	<i>Bos</i>	23
Yellow series	OxA-22786	12200	55	4.02	Y1	<i>cf Cedrus</i>	24
	OxA-22903	13045	50	4.05	Y1	<i>cf Juniperus</i>	25
	OxA-22905	12665	50	4.08	Y1	<i>cf Arbutus</i>	26
	OxA-22788	12850	55	4.12	Y1	Conifer	27
	OxA-16267	14005	60	4.16	Y2	<i>Tetraclinus articulata</i>	28
	OxA-22907	14230	55	4.17	Y2	<i>cf Juniperus</i>	29
	OxA-22906	14135	55	4.18	Y2	Conifer	30
	OxA-22908	14110	55	4.25	Y2	<i>cf Arbutus</i>	31
	OxA-16268	14515	60	4.26	Y2	<i>Tetraclinus articulata</i>	32
	OxA-13519	13905	55	4.30	Y2	<i>Juniperus / Tetraclinus</i>	33
	OxA-22909	14140	55	4.35	Y2	Conifer	34
	OxA-16272	14630	60	4.36	Y2	<i>Quercus sp.</i>	35
	OxA-16269	15790	60	4.55	Y2	<i>Juniperus sp.</i>	36
	OxA-16270	16285	65	4.68	Y3	<i>Pinus sp.</i>	37
	OxA-13518	17085	65	4.72	Y3	<i>Quercus sp.</i>	38
	OxA-16242	16630	75	4.77	Y4	<i>Dicot unidentified</i>	39
	OxA-16273	17515	75	4.90	Y4	<i>Pinus sp.</i>	40
	OxA-16271	20420	90	4.96	Y4	<i>Pinus sp.</i>	41

OxA-16274	20630	90	5.11	Y5	Conifer	42
OxA-22910	20030	90	5.11-5.16	Y6	<i>cf Cedrus</i>	43
OxA-16275	20560	90	5.16	Y6a	<i>Pinus sp.</i>	44
OxA-24110	20800	120	5.17	Y6	<i>Panthera</i>	45
OxA-13607	22200	90	5.24	Y6	<i>Taxus sp.</i>	46
OxA-16243	22890	120	5.34	Y6b	<i>Juniperus sp.</i>	47
OxA-16244	25860	150	5.48	Y6d	<i>Pinus sp.</i>	48
OxA-13556	25760	140	5.61	Y?	<i>Quercus sp.</i>	49
OxA-16276	26550	140	5.63	Y7	<i>Pinus sp.</i>	50
OxA-16278	29310	160	5.77	Y12	<i>Cupressus sempervirens</i>	51
OxA-16277	29160	160	5.77	Y12	<i>Cupressus sempervirens</i>	52

Table 1. Un-calibrated Radiocarbon determinations from Grotte des Pigeons (Sector 8) at Taforalt, Morocco. The dating samples are presented by averaged depths from the surface; where ranges shown, this indicates that the samples came from sediment blocks of known thickness.

Table 2

	Sample	<sup>14</sup> C date	Uncertainty	Un-modelled (Cal BP)		Modelled (Cal BP)		
				68.2%	95.4%	68.2%	95.4%	
Sector 8	OxA-24111	10680	45	12644-12568	12698-12548	12662-12581	12709-12554	1
	OxA-13479	10935	40	12879-12710	12942-12649	12765-12665	12835-12636	2
	OxA-23404	10870	45	12808-12646	12899-12615	12868-12735	12913-12684	3
	OxA-13480	10950	45	12894-12718	13051-12646	12893-12759	12944-12699	4
	OxA-13516	11065	45	13085-12890	13108-12747	13031-12897	13085-12841	5
	OxA-24112	11165	45	13135-12962	13220-12865	13065-12935	13098-12884	6
	OxA-13517	10990	45	12940-12738	13070-12684	13076-12937	13100-12886	7
	OxA-24113	11540	50	13432-13315	13527-13258	13361-13281	13423-13161	8
	OxA-23405	11615	50	13566-13362	13636-13310	13374-13286	13427-13098	9
	OxA-23407 *	11465	50	13385-13272	13445-13200			10
	OxA-23406 *	11445	55	13378-13254	13433-13173			11
	OxA-23406/07**	11456	37	13373-13271	13430-13211	13425-13349	13473-13299	10/11
	OxA-23408	11545	55	13440-13314	13562-13263	13476-13380	13579-13346	12
	OxA-23409	11890	55	13830-13673	13906-13492	13796-13646	13856-13505	13
	OxA-23410	12405	55	14631-14164	14958-14110	14540-14291	14622-14166	14
	OxA-13477	12675	50	15183-14886	15447-14606	14755-14596	14844-14444	15
	OxA-23411	13060	65	16135-15261	16406-15190	14759-14600	14849-14450	16
	OxA-13478	12495	50	14935-14255	15057-14201	14866-14691	14935-14571	17
	OxA-22902	12370	50	14560-14141	14910-14068	14951-14771	15051-14670	18
	OxA-22904	12490	50	14924-14251	15051-14196	14974-14785	15055-14664	19
	OxA-22787	12545	55	15015-14568	15125-14237	14986-14794	15063-14669	20
	OxA-22785 *	12500	55	14949-14256	15066-14201			21
	OxA-22784 *	12660	70	15175-14788	15494-14524			22
	OxA-22784/85**	12562	44	15010-14606	15160-14245	14991-14797	15065-14670	21/22
	OxA-24109	12605	55	15089-14659	15204-14261	15096-14932	15171-14831	23
	YG					15110-14940	15190-14830	
	OxA-22786	12200	55	14140-13957	14482-13827	15144-14987	15233-14888	24
	OxA-22903	13045	50	16045-15251	16372-15183	15204-15022	15342-14955	25
	OxA-22905	12665	50	15180-14870	15431-14589	15372-15050	15476-14995	26
	OxA-22788	12850	55	15505-15095	15873-14973	15515-15076	15686-15010	27
	OxA-16267	14005	60	17157-16920	17416-16819	17126-16974	17204-16898	28
	OxA-22907	14230	55	17487-17147	17615-16991	17161-17020	17237-16950	29
	OxA-22906	14135	55	17400-17009	17523-16921	17190-17055	17268-16979	30
	OxA-22908	14110	55	17381-16974	17500-16901	17479-17241	17532-17131	31
	OxA-16268	14515	60	17861-17550	17933-17256	17530-17242	17587-17158	32
OxA-13519	13905	55	17062-16863	17179-16785	17727-17311	17763-17195	33	
OxA-22909	14140	55	17402-17017	17527-16925	17962-17409	17985-17350	34	
OxA-16272	14630	60	17939-17673	18046-17492	18002-17625	18032-17459	35	

	OxA-16269	15790	60	19240-18795	19305-18740	18943-18797	19208-18721	36
	OxA-16270	16285	65	19547-19397	19807-18965	19544-19407	19801-19310	37
	OxA-13518	17085	65	20386-20182	20505-19955	19987-19542	20181-19445	38
	OxA-16242	16630	75	19888-19568	20094-19474	20076-19786	20264-19597	39
	OxA-16273	17515	75	21126-20536	21283-20465	20763-20430	21160-20360	40
	OxA-16271	20420	90	24512-24207	24769-23940	24400-23963	24529-23859	41
	OxA-16274	20630	90	24812-24459	24970-24345	24688-24345	24852-24236	42
	OxA-22910	20030	90	24150-23770	24310-23546	24764-24367	24890-24279	43
	OxA-16275	20560	90	24744-24375	24940-24252	24840-24479	24943-24378	44
	OxA-24110	20800	120	24960-24556	25121-24431	24903-24555	25020-24439	45
	OxA-13607	22200	90	26857-26311	27501-26173	26814-26292	27374-26146	46
	OxA-16243	22890	120	28017-27106	28104-26936	28023-27561	28112-26962	47
	OxA-16244	25860	150	30850-30483	30994-30342	30670-30358	30943-29707	48
	OxA-13556	25760	140	30744-30395	30926-30290	31016-30707	31120-30504	49
	OxA-16276	26550	140	31208-31032	31291-30936	31186-30996	31287-30880	50
	OxA-16278 *	29310	160	34461-33660	34567-33422			51
	OxA-16277 *	29160	160	34428-33432	34509-33297			52
	OxA-16277/78**	29236	114	34445-33560	34520-33406	34430-33461	34522-33322	51/52
Sector 9	OxA-16260	18005	75	21560-21343	21804-21194	21560-21370	21746-21242	60
	OxA-16240	18185	75	21893-21499	22093-21420	21794-21480	22040-21431	61

Table 2. Radiocarbon determinations, their un-modelled calibrated ages, (IntCal09) and the modelled posterior age highest probability density (HPD) ranges at 68.2% and 94.5%. Samples marked with an asterisk (\*) are duplicates and two asterisks (\*\*) are their combined ages. The sample named “YG” indicates the modelled age for the Yellow / Grey series transition at 4m.