El Castillo (Cantabria, Northern Iberia) and the Transitional Aurignacian:

using radiocarbon dating to assess site taphonomy

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Abstract

The majority of archaeological remains found at El Castillo in northern Iberia were excavated between 1910 and 1914 by Hugo Obermaier. Since the 1980s El Castillo has been studied through a detailed analysis of Obermaier’s
original excavation notes, the cleaning and study of the extant section, and
the excavation of material in the shelter entrance. Radiocarbon dating of
charcoal from the modern (1980s onwards) excavation suggested that unit 18,
corresponding to Aurignacian Delta of the 1910s excavation, was significantly
earlier than other Aurignacian assemblages in western Europe. Combined
with a reanalysis of the lithic and osseous industry, these dates led to the
suggestion that material in unit 18 and Aurignacian Delta was a transitional
industry, showing a gradual transformation of the Mousterian into the Upper
Palaeolithic. The conclusion has profound implications for understanding the
appearance of the Upper Palaeolithic in western Europe. However, the theory
has been heavily debated, with criticism focusing on the analysis of the lithic
and bone assemblage as well as the chronology. We focus on the latter, and
assess whether the original dates were accurate, whether they were well
associated with the archaeology, and whether there was vertical and lateral
variation in the age of the assemblages within unit 18 and Aurignacian Delta.
In the new area of excavation, unit 18 is found to be earlier than 42 cal kBP,
with no evidence of material of a younger age. In contrast, in the old
excavation area, Aurignacian Delta does include material of a younger age.
This suggests that discussion of the Transitional Aurignacian can only include
material from unit 18, in the new area of excavation.

Keywords
Radiocarbon; Pretreatment; Split base point; Transitional Aurignacian; Upper
Palaeolithic; Middle Palaeolithic
511. Introduction

531.1 The Middle to Upper Palaeolithic transition

55The interpretation of archaeological sites excavated in the early twentieth century is plagued by stratigraphic uncertainties resulting from poor excavation methods and the potential mixture of excavated objects during decades of study and curation. However, detailed study of the original excavation notes, cleaning of standing sections and excavations at the site perimeter can recover substantial amounts of information. In addition, the dating of bones or charcoal from a sedimentary unit can shed light on the chronological homogeneity of a lithic assemblage. Here we discuss how new radiocarbon dates help to resolve some of the lengthy debates surrounding the Middle to Upper Palaeolithic transition at the site of El Castillo near Puente Viesgo in Cantabria, northern Iberia (Figure 1) (Bernaldo de Quirós and Maíllo-Fernández, 2009; Bernaldo de Quirós et al., 2008; Cabrera Valdés and Bernaldo de Quirós, 1996; Cabrera Valdés et al., 2006; Cabrera Valdés et al., 2005; Cabrera Valdés et al., 2002; Cabrera Valdés and Bischoff, 1989; Cabrera Valdés et al., 1993; Cabrera Valdés et al., 1997; Cabrera Valdés et al., 2000; Cabrera Valdés et al., 2001; Cabrera Valdés et al., 1996; d’Errico et al., 1998; Pastoors and Tafelmaier, 2013; Zilhão, 2006; Zilhão and d’Errico, 1999; Zilhão and d’Errico, 2003).

73 The Middle Palaeolithic Mousterian, produced by Neanderthals, disappeared from western Europe by 41,030–39,260 cal BP (at 95.4 % probability, Higham
et al. (2014)), if debates surrounding late Neanderthals in southern Iberia are excluded due to problematic dates (Wood et al., 2013). Spatially, this disappearance appears to have been patchy with, for example, variability in the age of the final Mousterian in different parts of Europe and the Châtelperronian in southern France and the Basque country dating between c.45 - 41 cal kBP (Higham, et al., 2014).

The majority of Palaeolithic scholars suggest that the Upper Palaeolithic Aurignacian (sensu lato) appeared in western Europe around 42 - 41 cal kBP (Douka et al., 2012; Higham et al., 2012; Jacobs et al., 2015; Szmidt et al., 2010; Wood et al., 2014), probably being carried from somewhere in the east (Kozlowski, 2006; Mellars, 2006). The earliest Aurignacian assemblage in the Cantabrian region (the region including the Basque Country, Cantabria and Asturias) is found in level VII at Labeko Koba and is dated to 41960 – 40710 cal kBP (Wood, et al. (2014), remodeled against IntCal13 (Reimer et al., 2013)).

Although they cannot be easily dated directly, analysis of human teeth from layers containing the Proto-Aurignacian at Fumane and Riparo Bombrini strongly suggests that anatomically modern humans (AMHs) produced the earliest phase of the Aurignacian (Benazzi et al., 2015), supporting the prevailing view (Higham et al., 2011; Kozlowski and Otte, 2000; Trinkaus, 2005). However, skeletal evidence is exceptionally scarce, especially for the earliest phases of the Aurignacian, and Neanderthal or hybrid authorship remains a possibility (Trinkaus and Zilhão, 2013; Zilhão, 2006). This is
particularly pertinent given aDNA from Peștera cu Oase 1, dated at 41690 - 10237490 cal BP (OxA-11711 and GrA-22810 34950 +990, -890 BP, (Trinkaus, 1032013)), which suggests the individual had a Neanderthal ancestor within just 1044-6 generations (Fu et al., 2015).

In contrast to this prevailing view, the excavators of El Castillo propose that characteristic elements of the Upper Palaeolithic Aurignacian appear within the Mousterian at the site, and continue to develop into the Proto-Aurignacian. This is attested archaeologically by the so-called Transitional Aurignacian assemblage (Bernaldo de Quirós and Maillo-Fernández, 2009; Cabrera Valdés and Bernaldo de Quirós, 1996; Cabrera Valdés, et al., 2001). This has led to the hypothesis that the Upper Palaeolithic was the consequence of greater communication between indigenous groups and was a reaction to the influx of a new population (Bernaldo de Quirós and Maillo-Fernández, 2009). If true, this hypothesis would have profound consequences in, for example, our understanding of Neanderthal cognition (Bernaldo de Quirós and Maillo-Fernández, 2009; Vila and Roebroeks, 2014).

### 1.2 Site description

The first major excavations at El Castillo were undertaken by Hugo Obermaier between 1910 – 1913 (Figure 2). It was immediately recognized as one of the most important Palaeolithic sites in Europe (see discussion in White (2006)), containing 26 sedimentological units with archaeological assemblages ranging from the early Middle Palaeolithic to the Azilian (Cabrera Valdés, 1984;
Cabrera Valdés, et al., 2006), often separated by archaeologically sterile units. In addition, an extensive collection of rock art has been found within the karstic system behind the excavated rock-shelter (García-Diez et al., 2015; Leroi-Gourhan, 1965; Pike et al., 2012; Valladas et al., 1992). Most of the archaeological materials from this earlier excavation were sent to the Institute de Paléontologie Humaine (IPH) in Paris, and later repatriated to Spain and/or separated for further study (Cabrera Valdés, 1984). The turbulent events of the early 20th century and the death of Obermaier in 1946 meant that the intended series of monographs on the site were never written. It was not until the early 1980s that detailed descriptions of the original excavation notes, standing section, and lithic and faunal assemblages were published by Cabrera Valdés (1984).

Since 1980, excavations led by V. Cabrera Valdés and F. Bernaldo de Quirós have been undertaken towards the cave entrance (Figure 2). As the cave roof collapsed during the Late Pleistocene, the area occupied by humans decreased in size and moved towards the rear of the cave (Cabrera Valdés, et al., 1993). This meant that the area of modern excavations only included the two earliest Upper Palaeolithic levels (units 16 and 18) and the underlying Mousterian units. Through the careful reconciliation of Hugo Obermaier’s field notes, annotated section drawings and photos, and the extant section, Cabrera Valdés (1984) was able to link the stratigraphy of the old and new excavations. Unit 18 could be confidently related to Obermaier’s Aurignacian Delta by the location of several large boulders and the presence of the two sterile units 17 and 19 (Cabrera Valdés and Bernaldo de Quirós, 1996).
This paper will examine the chronology of unit 18, Obermaier’s Aurignacian Delta, which contains the so-called Transitional Aurignacian (Figure 2). Unit 18 is capped by an archaeologically sterile unit 17 and unit 16, Obermaier’s Aurignacian Gamma, containing the Proto-Aurignacian (Maillo-Fernández and Bernaldo de Quirós, 2010). Likewise, unit 18 is separated from the underlying unit 20, Obermaier’s Mousierian Alpha, by a second sterile layer, unit 19. In the modern excavations, both unit 18 and unit 20 have been subdivided into several levels on the basis of sedimentology; unit 18 into 18a (sterile), 18b (originally separated into b1 and b2, but now combined) and 18c, and unit 20 into 20a-e (Cabrera Valdés, et al., 1993). Cabrera Valdés (1984) uses the numerical system to describe the stratigraphy throughout the entire site. However, for clarity in distinguishing the 1980s and 1910s excavations, we will use the numerical notation to describe the assemblages recovered from the new excavation area, and Obermaier’s terminology (e.g. Aurignacian Delta) to describe the assemblages and stratigraphic units from the old excavation.

The typological ascription of unit 18 (levels 18b and 18c) has been the focus of considerable debate since Cabrera Valdés and Bernaldo de Quirós (1996) suggested that the industry was transitional between the Charentian Mousterian and Aurignacian, assigning the industry its own name, the Transitional Aurignacian (Cabrera Valdés, et al., 2001). They argued that this industry appeared to be Middle Palaeolithic with abundant substrate elements such as sidescrapers, but also contained indicators of the Upper Palaeolithic, namely a bone industry, ornaments, and Upper Palaeolithic tool types.
including a limited number of bladelets. These bladelets, they argued, were an indigenous development, first seen in the Mousterian of units 21 and 20. Therefore the industry was tentatively assigned to the Neanderthals. Unfortunately several fragmentary human fossils from Obermaier’s Aurignacian Delta were lost, and only two deciduous molars were recovered during the new excavations (Garralda, 2006).

More recently, Pastoors and Tafelmaier (2013) have published an analysis of the lithic reduction systems in from the Mousterian to Aurignacian Gamma using an assemblage from Obermaier’s excavation curated in the Museo Arqueológico Nacional, Madrid. They see a similar pattern to previous publications at the site, with methods of bladelet production continuing throughout the sequence. However, their interpretation of this pattern is markedly different. They suggest that it was the shape and quality of raw material that led to the continued use of some reduction systems throughout these units. However, as highlighted by Pastoors and Tafelmaier (2013), Obermaier probably selected which lithics to curate, and the operational sequences are not limited to a specific raw material type. For example, in Aurignacian Gamma, both flake and bladelet production were undertaken on quartzite (Maíllo-Fernández and Bernaldo de Quirós, 2010).

Radiocarbon dates on charcoal fragments from unit 18 recovered during the recent excavations (Table 1 Cabrera Valdés and Bischoff, 1989; Cabrera Valdés, et al., 1996; Hedges et al., 1994) were around 2000 years earlier than the majority of Proto-Aurignacian assemblages in the region (Fortea,
2011996; Mañu-Fernández et al., 2001; Wood, et al., 2014), and contributed to the development of this idea. No material from Aurignacian Delta from the old excavation has been dated, although Stuart (2005) and Bernaldo de Quirós et al. (2006) published a suite of mostly infinite radiocarbon dates on ultrafiltered collagen from Mousterian Alpha. Note that although originally published as found in Aurignacian Delta (Stuart, 2005), and repeated in Zilhão (2006), Ox-A-20710187 and OxA-10188 are on a single Palaeoloxodon antiquus tooth from Mousterian Alpha (Bernaldo de Quirós, et al., 2006).

The Transitional Aurignacian was defined using the lithic assemblage from the new area of excavation, supported by the lithic assemblage from Obermaier's excavation and osseous tool assemblages from both the new and old excavations (Cabrera Valdés, et al., 2001). Obermaier's excavation removed most of the main living area, leaving only the edge of the occupation zone for the modern excavators. Level 18c was interpreted as a dump deposit, containing large dispersed lenses of charcoal with abundant lithic debitage, whilst level 18b is thought to be a butchery area, with numerous fragments of skull, jaw bones and parts of the axial skeleton together with large lightly worked limestone pieces and quartzite hammers (Cabrera Valdés and Bernaldo de Quirós, 1996).

The elements most diagnostic of the Early Aurignacian were uncovered by Obermaier, including 10 split base points, the index fossil of the Early Aurignacian (Peyrony, 1933; Peyrony, 1934; Sonneville-Bordes, 1960). However, both level 18 and Aurignacian Delta contain tools thought to be
Upper Palaeolithic, including endscrapers, burins and borers. 415 pieces from unit 18 have been assigned to a typological type and a technological analysis has identified a flake reduction scheme as well as a blade/bladelet reduction sequence (Cabrera Valdés, et al., 2002; Cabrera Valdés, et al., 2001).

No other site contains the Transitional Aurignacian. Although Arrizabalaga Valbuena and Maillo-Fernández (2008) suggested that material in Lezetxiki level IIIa in the Basque Country may be similar, radiocarbon dating has shown that bones in this unit range by over 20 ka, and it is now thought most likely that the lithic assemblage is a mixture of younger and older material (Maroto et al., 2012), as previously suggested by Baldeon (1993).

Zilhão and d'Errico (d'Errico, et al., 1998; Zilhão, 2006; Zilhão and d'Errico, 1999) disagree with the conclusion that the assemblages in unit 18 and Aurignacian Delta represent a transitional industry. Their main arguments fall into four categories (Table 2):

1. *The technological and typological ascription of tools to the Aurignacian.* The identification of various pieces of the osseous and lithic assemblage to the Aurignacian from unit 18 has been queried. The presence of tools pertaining to the Aurignacian within Aurignacian Delta has not been questioned.

2. *Vertical variation within unit 18 and Aurignacian Delta.* During excavation, Obermaier changed the name of the assemblage from Mousterian Alpha to Aurignacian Delta when the first split base points were found in 1912, although he maintained that the unit was richer in sidescrapers towards its base and split base points towards the top.
(Cabrera Valdés, 1984). Combined with slight differences between the radiocarbon dates in level 18b1 - b2 and level 18c, Zilhão and d'Errico (1999) proposed that the unit was composed of at least two separate assemblages, one Aurignacian (probably in 18b) and one Mousterian (18c), sandwiched between the two sterile units. The thinness of level 18b, coupled with pressure from roof fall may have led to the mixing of the two levels (Zilhão, 2006).

3. Lateral variation within unit 18 and Aurignacian Delta. Associated with the vertical variation discussed in point 2, Zilhão and d'Errico (1999) proposed that the Aurignacian component was almost entirely missing from the front of the cave in the area of the new excavations, either because of the spatial differences across the site, or because the roof fall on top of unit 18 truncated the deposition of the unit within the area of modern excavations.

4. Dating of charcoal that is not related to human activity may have caused the unit to appear erroneously old. For example, because the charcoal was an inherited component of the sediment, or because the finer component of unit 18 resulted from the redeposition of earlier human occupations from the main living area of Obermaier's excavation.

Bernaldo de Quirós, et al. (2008) and Bernaldo de Quirós and Maillo-Fernández (2009) have published a rebuttal, focusing on points 1-3, explaining the stratigraphy and their lithic analysis, and using the consistent set of radiocarbon dates from unit 18 to argue for stratigraphic integrity (Table 2772). We have no new information to contribute on the typological and
technological definition of the assemblages and will therefore limit our
discussion of the first point. This paper aims to use radiocarbon dating to
examine points 2-4 further.

In addition to three of the four points raised by Zilhão and d’Errico, we will also
test:

1. Whether areas of disturbance within the early 20th area of excavations, some distance from the extant section and new excavation, were undetected and may have resulted in intrusive Aurignacian elements from the overlying Aurignacian Beta (Maillo-Fernández and Bernaldo de Quirós, 2010) appearing within Aurignacian Delta.

2. The accuracy of dates on charcoal produced before the development of ABOx-SC (Bird et al., 1999). Radiocarbon dates on Pleistocene-aged materials are extremely sensitive to young contaminants. Just 1% modern contamination in a sample of 50 ka BP will cause a measured age of 37 ka BP. Until around 2000 few chemical cleaning or ‘pre-treatment’ techniques were able to always effectively remove such contamination, leading to the underestimation of many dates (Higham, 2011). Although these charcoal samples were not identified to species any inbuilt age is likely to be a few hundred years, which is insignificant in comparison to the large error range.

3. Materials and methods

3.1 Sample selection
To test whether the age of unit 18 varies substantially with depth, we have
produced further measurements from unit 18, but more importantly, from
deposits found stratigraphically above this unit from the new excavation. To
test whether there was significant lateral variation, we have also dated
material from Aurignacian Delta. We have focused on dating cut-marked or
otherwise anthropologically modified bone to test whether the charcoal is
significantly earlier than the human activity evident in the unit, and have used
the ultrafiltration technique to effectively remove contaminants from the bone
collagen (Brock et al., 2010; Higham, 2011; Ramsey et al., 2004).

The sampled materials fall into three groups:

1.1 Group 1: Cut-marked fauna from the Cabrera Valdés excavation
Cut-marked bones (Table 3) excavated between 1981 and 1996 from the
archaeological units 18 and 20 were dated (Figures 3a-c). To further constrain
the age of unit 18, bone from the sterile unit 19 and Mousterian level 20c
beneath, and units 17/16 above, were dated. All sampled bones were
disarticulated, and most were fractured. Units 17 and 16 were thin and only
present in row N in the new excavation, and as a result few bones were
recovered and none were anthropologically modified. These units have been
grouped together, as one of the dated samples could have been found in
either level. This material is curated by the Museo Regional de Prehistoria y
Arqueologia de Cantabria.
2 Group 2: Cut-marked fauna from the Obermaier excavation. During the
30 years since excavation, much of the faunal assemblage from El Castillo
31 has been subject to repeated study and frequent relocation before deposition
32 within several institutions (Cabrera Valdés, 1984). A small collection of bone,
33 sediment and lithics from the 1913 excavation was sent to the American
34 Museum of Natural History (AMNH) by Hugo Obermaier in collaboration with
35 Nels Nelson in response to a request for reference material for construction of
36 a copy of the cave section (White, 2006). This section was never built and the
37 collection appears to have remained unstudied until 2007-8 (Tejero et al.,
38 2010). Although repackaged, the labels written by Nelson are found within the
39 boxes containing the archaeological materials. As the least studied faunal
40 collection from El Castillo, this collection was considered the most suitable for
41 assessing the integrity of the original assemblage, as it was less likely to be
42 affected by minor post-excision mixing and conservation treatment which
43 may result from study, relocation and curation over the course of 100 years.
44 As with all of the material recovered by Obermaier there are no detailed
45 indications of the location of the assemblage in plan, but the area excavated
46 in 1913 is shown in figure 2c. Cut-marked bone was selected (Table 3).
47
48 2.3 Group 3: Split base point blank. Unfortunately the collection of split base
49 points from El Castillo, the largest in Iberia (Cabrera Valdés, 1984; LioIios,
50 2006; Tejero, 2010; Tejero, 2013), was not suitable for dating. The points
51 have been separated from the faunal bone since excavation and are heavily
52 conserved (Cabrera Valdés, 1984). However, a piece of antler, thought to be a
53 blank for a split base point was discovered by Tejero et al. (2012) (Figure 3d)
within the faunal assemblage at the Museo Arqueológioc Nacional, Madrid.

Kept separate from the split base points, it is less likely to have been conserved, providing a more suitable material for radiocarbon dating. However, given its long curation the sample was treated as potentially conserved as a precaution during radiocarbon pretreatment, following routine protocols at the Oxford Radiocarbon Accelerator Unit (Brock, et al., 2010).

2 Radiocarbon dating

Radiocarbon dating was undertaken using the methods described in Brock, et al. (2010) at the Oxford Radiocarbon Accelerator Unit (ORAU). Given the poor preservation of bone collagen at some sites in the Cantabrian region (Wood, et al., 2014; Wood et al., 2013), a large number of bones were screened to assess collagen preservation using %N (Brock et al., 2010; Brock et al., 2012). Subsequently, 300 - 1000 mg material was taken for dating from a subsample of bones the screening test identified as most likely to contain collagen. Samples were taken with a tungsten carbide drill away from any visible glue or conservation treatment. However, as a precaution, if glue was visible or suspected anywhere on the bone, the drilled powder was washed in a series of solvents prior to demineralisation in 0.5 M HCl overnight. The insoluble crude collagen was washed in 0.1 M NaOH (room temperature, 30 minutes) to remove alkali soluble humic acids, and 0.5 M HCl (room temperature, 1 hour), before gelatinization in 0.001 M HCl (70 °C, 20 hours)

and filtration to remove large insoluble particulates (Ezee™ filter, 45 – 90 μm). Gelatin was then ultrafiltered using a precleaned 30 kDa MWCO Vivaspin™15
ultrafilter, and freeze-dried. The product was combusted in an elemental
analyser (ANCA-GSL), connected to an isotope-ratio mass spectrometer
(Sercon 20-20) operating in continuous mode, allowing measurement of
carbon and nitrogen stable isotope and elemental information. Excess carbon
dioxide was cryogenically collected and converted to graphite over an iron
catalyst, and dated in an Accelerator Mass Spectrometer (Ramsey et al.,
2004). All dates are corrected for a sample size specific background (Wood et
al., 2010).

Given the published data (Table 1), most radiocarbon dates from unit 18 were
expected to fall close to the limit of the radiocarbon dating method and thus
have errors of > ± 1500 ^14C years (often > 5000 cal years at 95.4 %
probability) and about the end of the radiocarbon calibration curve (Table 1).
Whilst this makes investigation of the fine chronostratigraphy within unit 18
difficult, identifying material of Aurignacian age (< 42 cal kBP) where error
ranges drop below 1500 ^14C years and < 4000 cal years (at 95.4 %
probability), should be possible. To aid interpretation, Bayesian models were
used to assess whether the radiocarbon dates are consistent with specific
hypotheses.

398.3 Calibration and Bayesian analysis
It is now common for stratigraphic information from archaeological sites to be
combined with radiocarbon data in a chronological model (Bayliss, 2009)
using Bayesian statistical software such as OxCal (Ramsey, 2009; Ramsey et
al., 2010) or BCal (Buck et al., 1999). The construction of such models is
particularly useful for two reasons. First, probability distributions of modeled
ages for the start and end of stratigraphic or typological phases can be
extracted, and comparisons made between sites (Higham, et al., 2014;
Whittle and Bayliss, 2007). Second, statistical analysis aids analysis of the
complicated, and often wide, probability distributions of calibrated radiocarbon
dates. As elegantly shown by Bayliss (2009), the length of time represented
by a group of calibrated dates will be overestimated when analysed by eye,
and statistical analysis of groups of dates is required to accurately assess
duration, whether two phases overlap in time, and to identify outliers.

Bayesian analysis lends itself to studies where knowledge is developed using
an iterative process, as is the case in archaeology where data is normally
obtained incrementally (Bayliss, 2009; Bayliss et al., 2007; Buck and Meson,
2015). We start with some prior knowledge about the age of a sample
(normally stratigraphy), combine it with some new evidence (the radiocarbon
dates), and use this to inform a hypothesis, which in turn becomes our new
prior. Moreover, where stratigraphy is not clear, we may have more than one
possible set of priors and multiple models may need to be presented and
evaluated.

An extension to this fluid perception of chronological modeling, is the use of
Bayesian techniques to assess whether the radiocarbon dates obtained agree
or disagree with a given prior assumption, rather than simply provide, for
example, an estimated start date for an occupation. In an early example,
Needham et al. (1998) used Bayesian analysis of radiocarbon dates on
organic material associated with Bronze Age metalwork from southern England to assess whether it was more likely typological groupings were coeval or were sequential. It is in this vein that Bayesian models are constructed in this paper. Chronological models have been primarily built to assess whether radiocarbon dates support the various hypotheses surrounding the stratigraphy and taphonomy of El Castillo.

All radiocarbon dates presented in the paper have been calibrated in OxCal v.4.2 (Ramsey, 2009) against IntCal13 (Reimer, et al., 2013). Any models referred to in this paper published before 2013 have been rerun against this calibration curve. Age models have been constructed in OxCal v.4.2 (Ramsey, 2009), assuming all dates have a 5% prior probability of being an outlier within the General t-type Outlier Model (Ramsey, 2009).

Archeological units are considered Phases and are arranged in stratigraphic order within a Sequence, assuming those lower in the stratigraphy are older than those above. A Boundary is placed above and below each Phase. The posterior probability distribution functions (PDFs) of these Boundaries provide an estimate for the transition date between units. It is possible to establish whether two Boundary PDFs are different by subtracting one from the other using the Difference function in OxCal. If the resulting PDF does not include zero at 95.4% probability, the two Boundaries are considered different (Supplementary information 1). Convergence, or the degree to which a representative solution has been generated, should typically be above 95% (Ramsey, 1995). The Agreement Index, originally used to assess whether a
453 date can be considered an outlier, is not relevant where an Outlier Model is
454 employed (Ramsey, 2009). All model codes are given in Supplementary
455 information 2.
456
457 3. Results
458
459 Radiocarbon dates are given in table 3. Of 42 bones screened for %N, 38
460 contained more than 0.8 %N, and were therefore likely to contain sufficient
461 collagen for dating (Brock, et al., 2010; Brock, et al., 2012). Of these, 17 were
462 selected for dating and sufficient collagen to produce a radiocarbon date (1 wt
463 %) (Van Klinken, 1999)) was recovered from 14 bones. Carbon and nitrogen
464 isotopic and elemental values were within the expected range for collagen
465 (Van Klinken, 1999) suggesting the samples were not grossly contaminated.
466
467 3.1 Group 1: Cut-marked fauna from the Cabrera Valdés excavation
468
469 Radiocarbon dates on cut-marked bone from units 20 – 16/17 of the recent
470 excavations are similar to those previously obtained on charcoal, although the
471 new dates on cut-marked bone visually appear very slightly older (Figure 4,
472 Supplementary information 3). However, only three outliers at > 10 % are
473 found when both the new and published dates are placed within a Bayesian
474 model, suggesting that the charcoal and bone dates are relatively consistent
475 with each other and the stratigraphic priors.
476
477GlfA-95539 has a 20% likelihood of being an outlier as it is younger than the
478two new bone dates from units 17/16. This difference in age may relate to the
479presence of young contaminants in GifA-95539. However, with no dates from
480unit 15, it is impossible to assess whether this sample is out of sequence, or
481whether it suggests unit 16 formed over several millennia.
482
483Two dates from this study, OxA-21972 and OxA-21973, both from level 18b,
484appear older than the charcoal from the same context (27% and 28%
485likelihood of being outlying respectively). Both samples were found towards
486the edge of 18b, where the archaeological level thins, whereas the charcoal
487towards the interior of the cave where the level was thickest. It is possible that
488the bone samples derived from deeper within unit 18.
489
490Although useful for examining the consistency of the data, this Bayesian
491model cannot be used to examine the fine stratigraphy within unit 18 or
492provide an accurate start and end date for unit 18, because, like the majority
493of published dates, all of the new radiocarbon dates on bone in or below unit
49418 may extend beyond the limit of the calibration curve. Instead, this model
495provides minimum calibrated estimates. We can therefore conclude that
496deposition of unit 18 ended by at least 44940 – 42110 cal BP (Boundary
49718B/17-16), but it probably ended before this.
498
4993.2 Group 2: Cut-marked fauna from the Obermaier excavation

500
Dates on bone from Aurignacian Delta have been placed within a single Phase model in figure 5, alongside the date on the antler point baguette. The Boundary PDFs calculated for the start and end of unit 18 using Group 1 (Figure 4) are used as the lower and upper Boundaries of Aurignacian Delta. This enables the consistency between the two groups of samples to be assessed. As can be seen in figure 5 (Supplementary Information 3), the data from the old excavation do not change the Boundaries from the new area of excavation. OxA-22016 is slightly younger than the other two dates, but is found to have only an 8% chance of being an outlier by the model. The model therefore demonstrates that the dated cut marked bones from Aurignacian Delta are consistent in age with those from unit 18.

Group 3: Split base point blank

The antler blank from Obermaier’s excavation of Aurignacian Delta (OxA-51621713) is clearly younger than unit 18 of the new excavations, having a 99% posterior probability of being an outlier when placed in the model with the cut-marked bones from the old excavations (group 2) and Boundaries derived from the new excavation (group 1) (figure 5).

Split base points are most often associated with Early Aurignacian lithic assemblages (Liolios, 2006; Tejero, 2014). Unfortunately, direct dating of split base points has been hampered by their small size, typological value and, as a result of their value, frequent consolidation. Therefore only a few split base points have been directly dated using similar methods to those used at E1
526Castillo (Trou de la Mère Clochette, NE France (Szmidt et al., 2010) and
527Peskö, Hungary (Davies et al., 2015)). However, several sites containing
528these points have been dated, such as Labeko Koba (Basque Country) where
529they appear in units VI and V (Arribalagaga Valbuena et al., 2003), L’Arbreda
530(Catalonia) unit H (Maroto et al., 1996), Abri Pataud unit 11 (Aquitaine,
531France) (Chiotti, 2005; Higham et al., 2011), Abri Castanet (Aquitaine, France
532(White et al., 2012)) and Geissenklosterle unit II (Swabia, Germany (Conard
533and Bolus, 2003; Higham, et al., 2012)). The date of this baguette is similar in
534age to some of the earlier points at L’Arbreda and Labeko Koba ((Wood, et al.,
5352014) Figure 6).
536
5374. Discussion
538
5394.1 Critique of the chronology of unit 18 and Aurignacian Delta
540
541These results allow us to address some of the criticisms levelled at the
542chronology and integrity of unit 18 and Aurignacian Delta at El Castillo (Table
5432). First, although the published charcoal dates appear very slightly younger
544than the bone dates obtained here, the difference is not significant, and does
545not change the main interpretation of Cabrera Valdés and Bischoff (1989) that
546unit 18 is statistically significantly earlier than 42 cal kBP. It is unlikely that the
547majority of charcoal samples were grossly contaminated, or that they were, for
548example, an inherited component from the sediment being substantially older
549than the human activity within the unit. Neither is it likely that unit 18 contains
550large amount of material of greatly varying age having been redepósited from
the main occupation area of the cave during an episode of cleaning (Table 2). As stated by Bernaldo de Quirós, et al. (2008), the consistency of the radiocarbon dates and absence of any which overlap with the earliest Aurignacian in the region, suggests that the assemblage in unit 18 does not contain material produced during the period when the Aurignacian was present in Cantabria.

Radiocarbon dates from unit 18 in the new area of excavation demonstrate that the unit must be older than at least 44940 – 42110 cal BP at 95.4% probability (Boundary 18B/17-16). The PDF for this Boundary is earlier than other PDFs of Boundaries representing the start of Aurignacian assemblages across northern Iberia and western Europe (Figure 7). This disproves hypotheses (Zilhão and d’Errico, 2003) that the apparent mixture of Aurignacian and Mousterian lithics within unit 18 reflects the time over which the deposit was formed.

The similarity between the dates in unit 18 and the cutmarked fauna from the AMNH suggest that there may not have been substantial lateral variation in age between the new and old areas of excavation. Moreover, the baguette appears younger than the end date of unit 18 calculated from the dates from the new excavation the data. This suggests that there was some intrusion of material from the Aurignacian above unit 17 into Aurignacian Delta, presumably due to excavation error or undetected mixing of sediments in this part of the site. The consistency between the date of the baguette and the age of other split base points in the region, suggests that all split base points in
Aurignacian Delta are probably of an age typical of the Early Aurignacian. Presumably lithics of this age also exist in the assemblage from the old excavation.

Given the mixture of pre- and post-42 cal kBP material within Aurignacian Delta, material from the early 20th century excavations cannot be used to support the identification of the Transitional Aurignacian. Neither can this assemblage be used to assess the integrity of the assemblage in unit 18 of the new excavations (Zilhão and d'Errico, 1999). New analyses of material from Obermaier’s excavation, such as that completed by Pastoors and Tafelmaier (2013) need take into consideration the possibility that material from Aurignacian Delta is not temporally homogenous. The proportion of younger material cannot be assessed from the limited dating work undertaken here. In contrast, the radiocarbon data supports the interpretation that unit 18 only contains material that is earlier than 42 cal kBP.

4.2 Chronological relationship of unit 18 with sites across western Europe

Several sites containing Mousterian assemblages from the Cantabrian region have been dated after samples were rigorously cleaned with, for example ABOx-SC, ultrafiltration and ninhydrin (de Torres et al., 2010; Maroto, et al., 2012; Wood, et al., 2013). With the exception of the anonymously late Middle Palaeolithic assemblage within Esquilleu unit III (Maroto, et al., 2012), dates from the uppermost dated Mousterian contexts which fall within range of the 600 radiocarbon dating technique are presented in table 5. The final Mousterian at
601 Sopeña (Maroto, et al., 2012), Covalejos (Sanguino González and Montes 602 Barquín, 2005) and El Mirón (Straus and González Morales, 2003) have been 603 dated within the range of radiocarbon. However, at these sites the ability of 604 the pretreatment techniques to remove contaminants has not been compared 605 to e.g. ultrafiltration and ABOx-SC, and the dates are not used here.

606
607 Only a limited number of dates have been obtained from the latest Middle 608 Palaeolithic units at each site, hindering the construction of individual site 609 models. Instead, all dates for late Mousterian assemblages in table 5 have 610 been modeled as a single Phase, so that the PDF for the end Boundary 611 provides an estimate for the end of the Mousterian in the region (Figure 8, 612 Supplementary information 3).

613
614 Using this PDF, the final Mousterian appears to end earlier in the Cantabrian 615 region than in northeastern Iberia, where the end of Mousterian contexts at 616 Abric Romani (Camps and Higham, 2012; Vaquero and Carbonell, 2012) and 617 L'Arbreda (Wood, et al., 2014) have been dated (Figure 7). Although the 618 timing for the end of unit 18 falls within the range of Mousterian assemblages 619 in Catalonia, it appears to fall into a unique timeframe within the Cantabrian 620 region, continuing for longer than other Mousterian contexts in the region, and 621 ending at the same time as the Châtelperronian appeared at Labeko Koba, 622 Basque country (Wood, et al., 2014). Could it be that the perceived 623 'uniqueness' of the assemblage in unit 18 simply exists because no 624 comparative assemblages exist within the region? To test this conclusion with 625 confidence, the chronology of the final Mousterian in the region needs to be
clarified because the model used to estimate the final Mousterian of Cantabria is based on dates from only five samples from four sites.

629. Conclusion

Radiocarbon dates on three sets of bones in combination with the published radiocarbon dataset on charcoal have been used to demonstrate that unit 18 was deposited before the Proto-Aurignacian first appeared in northern Iberia. There is no radiocarbon evidence for the presence of later material within the assemblage recovered in the modern excavations, which has been used to describe a technocomplex transitional between the Middle and Upper Palaeolithic.

In contrast, the radiocarbon evidence shows that the assemblage within Aurignacian Delta contains material chronologically consistent with an Early Aurignacian attribution, in addition to cut-marked bones that are of a similar age to material in unit 18. It is likely that other young material exists in this unit. Therefore material from Obermaier’s Aurignacian Delta cannot be used to support the diagnosis of the Transitional Aurignacian. The mixture of material of very different ages within these old excavations must be considered before any analysis.

The lithic and bone industry within unit 18 has been extensively debated, and since 2008 seems to have reached an uneasy stalemate with Bernaldo de Quirós, et al. (2008) maintaining that the industry is Upper Palaeolithic, whilst
Zihão (2006) proposes, amongst other things, that various tools have been misidentified. Chronologically the position of unit 18 is clear, at the end, and possibly the very end, of the Middle Palaeolithic Mousterian in the Cantabrian region and before the start of the Upper Palaeolithic Aurignacian. We hope that this will allow a more secure comparison of unit 18 to assemblages of a similar age in the future.

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Jacobi, a key member of our research group, sadly passed away during the course of this project.

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**Figure Headings**


**Figure 2:** El Castillo a) photograph and b) drawing of the extant standing section of the 1914 excavation. c) detailed image of units 17-21. Image shows a 1m wide section. d) plan of the excavation with excavation areas marked red, 1912; blue 1913; green 1914; black 1980) as well as the extent of levels 8b (grey) and 18c (striped). For colour, please see web version.

**Figure 3:** Examples of a-c) examples of dated cut-marked and anthropogenically modified bone and d) the antler blank baguette type from Aurignacian Delta. For colour, please see web version.
Figure 4: Bayesian model of dates from the modern excavation of El Castillo
Unit 21 – 16/17. Radiocarbon dates are calibrated in IntCal13 (Reimer, et al., 2013) and calibration and modeling has been undertaken in OxCal v.4.2 (Ramsey, 2009) assuming all samples have a 5% prior likelihood of being a outlier within the General t-type Outlier Model (Ramsey, 2009). Grey probability distributions represent dates obtained in this study, red distributions radiocarbon dates obtained in previous studies (see Table 1 for references) whilst the teal distribution represents the average of 7 ESR dates on teeth (Rink et al., 1996). Pale distributions depict the calibrated PDF and dark distributions the modeled PDF. The 68.2% and 95.4% modeled probability ranges are indicated by horizontal bars beneath the PDFs. For colour, please see web version.

Figure 5: Bayesian model of dates from the 1910-1913 excavation of El Castillo unit Aurignacian Delta. Radiocarbon dates are calibrated in IntCal13 (Reimer, et al., 2013) and calibration and modeling has been undertaken in OxCal v.4.2 (Ramsey, 2009) assuming all samples have a 5% prior likelihood of being an outlier within the General t-type Outlier Model (Ramsey, 2009). The probability distribution functions for the start and end of unit 18 are taken from the chronological model derived for the modern excavation (Figure 4) to assess whether the samples from Aurignacian Delta are of a consistent age with the area of modern excavation.
Figure 6: Radiocarbon date on an antler baguette from El Castillo Aurignacian Delta (OxA-21713) compared to modelled PDFs for the start (green) and end (red) of assemblages containing split base points from Aurignacian assemblages across western Europe. References to the original models are given. However, all models have been rerun against IntCal13 (Reimer, et al., 2013) and Boundary PDFs may differ from those published. For colour, please see web version.

Figure 7: PDF for the Boundary between unit 18 and 16-17 from the modern area of excavation (Figure 4), compared to modelled PDFs for the start (green) and/or end (red) of Mousterian, Uluzzian, Châtelperronian and Aurignacian assemblages across western Europe. This is not an exhaustive list, but the age distributions are representative. The end of the Mousterian in the Cantabrian region (Asturias, Cantabria and the Basque Country) is taken from figure 8. References to the original models are given. However, all models have been rerun against IntCal13 (Reimer, et al., 2013) and Boundary PDFs may differ from those published. For colour, please see web version.

Figure 8: Radiocarbon dates from the uppermost dates Mousterian assemblages from the Cantabrian region (Asturias, Cantabria and the Basque Country) calibrated against IntCal13 (Reimer, et al., 2013) in OxCal v.4.2 assuming each sample has a 5% prior probability of being an outlier within the General t-type Outlier Model (Ramsey, 2009). All dates have been obtained using the ultrafiltration protocol (Brock, et al., 2010), but
are not all on anthropogenically modified bone. References are given in table 4.

Table headings

Table 1; Published radiocarbon dates from El Castillo. Dates are calibrated against IntCal13 (Reimer, et al., 2013) in OxCal v.4.2 (Ramsey, 2009). ZR refers to an acid-base-acid protocol, AF an ultrafiltration protocol and an asterisk a treatment with solvent washing prior to the main pretreatment (Brock, et al., 2010).

Table 2; A summary of the debate surrounding the Transitional Aurignacian at El Castillo compared to the results of this study.

Table 3; Samples selected for radiocarbon dating from El Castillo.

Table 4; Radiocarbon dates from El Castillo produced in this study. Dates are calibrated against IntCal13 (Reimer, et al., 2013) in OxCal v.4.2 (Ramsey, 2009). AF refers to an ultrafiltration protocol and an asterisk a treatment with solvents prior to the main pretreatment (Brock, et al., 2010). C:N ratio of collagen should be 2.9-3.4, %C should be >30 % and isotopic ratios should lie within the approximate range of each species (Van Klinken, 1999). ¹ denotes a calibrated date which may extend beyond the limit of the calibration curve.

Table 5; Radiocarbon dates from the uppermost dated contexts containing dated Middle Palaeolithic assemblages in the Cantabrian region (Asturias,
Cantabria, Basque Country). Dates are calibrated against IntCal13 (Reimer, et al., 2013) in OxCal v.4.2 (Ramsey, 2009). AF refers to an ultrafiltration protocol and XR to ABOx-SC (Brock, et al., 2010).
CS5

1 cm

CS6

1 cm

CS27

1 cm

CS1

1 cm

D)
### Split base points

#### Direct dates on split base points
- OxA-19621 (Szmidt et al. 2010)
- OxA-19622 (Szmidt et al. 2010)
- OxA-17964 (Davies et al. in press)
- OxA-17966 (Davies et al. in press)

#### Layers containing split base points
- Castanet (White et al. 2012)
- Abri Pataud 11 (Higham et al. 2010)
- Geissenklosterle AHI (Higham et al. 2012)
- Labeko Koba IV-V (Wood et al. 2014)
- L'Arbreda H (Wood et al. 2014)
- OxA-21713
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<th>Calibrated date (95.4% probability range)</th>
<th>Material</th>
<th>Method</th>
<th>Pre-treat</th>
<th>Yield (mg)</th>
<th>%C</th>
<th>N/13C (VPDB)</th>
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<td>34300 ± 1000</td>
<td>41440 - 38440</td>
<td>AMS</td>
<td>AMS</td>
<td>ZR</td>
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<td>63.3</td>
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<td>Charcoal</td>
<td>AA-2406^7</td>
<td>39500 ± 1300</td>
<td>42500 - 41000</td>
<td>AMS</td>
<td>AMS</td>
<td>ZR</td>
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<td>AMS</td>
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**Note:**
- C/N: Carbon to Nitrogen ratio.
- %C: Carbon content.
- N/13C (VPDB): Nitrogen to 13C ratio (V-PDB).
- AF*: Accelerator mass spectrometry.
- ESR: Electron spin resonance.
- AMS: Accelerator mass spectrometry.
- ZR: Zero-removed.
- 1σ: One standard deviation.
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<td>3.5⁷</td>
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</tbody>
</table>

1. Cabrera Valdés et al., 1996
2. Cabrera Valdés and Bischoff, 1989
3. Rink et al., 1996
4. Bernaldo de Quirós et al., 2006
5. Low δ¹³C
6. Ultrafiltration undertaken during a time when collagen samples were contaminated with ancient glycerol from the ultrafilter.
7. High C:N, suggesting severe contamination from the glycerol (see note 6), possibly because the mg collagen yield was low (<5 mg).
8. Date may extend beyond the calibration curve.
9. Average of 7 samples. In a note added in proof Rink et al. (1996) recalculated their dates and present only the average.
<table>
<thead>
<tr>
<th>Area of debate</th>
<th>d’Errico et al. 1998, Zilhão and d’Errico 1999, 2003, Zilhão 2006a</th>
<th>Bernaldo de Quirós et al. 2008</th>
<th>This study</th>
</tr>
</thead>
</table>
| **Technological and typological ascription of tools to the Aurignacian.**     | • Query typological identification of some osseous and lithic pieces from unit 18 to the Aurignacian.  
• Point out the presence of a few Upper Palaeolithic types within the Middle Palaeolithic is common and vice versa.  
• The presence of tools pertaining to the Aurignacian within Aurignacian delta has not been questioned. | • Maintain typological ascription of lithic and osseous industry to the Upper Palaeolithic.  
• The proportion of Upper Palaeolithic types within unit 18 is extremely high (40.1% and 43.25%, Cabrera et al. 2001).  
• The proportion of Middle Palaeolithic types within other Aurignacian assemblages is appreciable.  
• Statistical analysis of typological analysis was used to suggest lithics from level 18 are different from other MPal assemblages. | • Not studied.                                                                                   |
| **Vertical variation within unit 18 and Aurignacian delta.**                   | • Obermaier suggested Aurignacian delta was richer in sidescrapers towards its base and split base points towards the top.  
• Slight differences between the radiocarbon dates in 18b1 - b2.  
• 18 and Aurignacian delta were composed of at least two separate assemblages, one Aurignacian (probably in 18b) and one Mousterian (18c).  
• Mixing of 18b and c may have occurred due to their thinness and pressure from later roof falls. | • No second layer observed in the section left by Obermaier after cleaning.  
• Large lithic objects were likely to sink in wet conditions which might have been present in the site, making it appear to archaeologists in the early 20th century that MPal lithics occurred towards the base of the site.  
• Maintain a third level within unit 18 containing the Aurignacian has not been identified in the new area of excavations. | • Age of material found above level 18 suggests that level 18 predates the age of the Aurignacian in northern Iberia. No bones or charcoal with ages similar to the Aurignacian have been found within unit 18.  
• Young bones are present in Aurignacian delta. Given the stratigraphic continuity between the new and old excavations, this is likely to be due to excavation error as might be expected for excavations occurring at the beginning of the 20th century. |
<table>
<thead>
<tr>
<th>Lateral variation within unit 18 and Aurignacian delta.</th>
<th>- Aurignacian component was almost entirely missing from the front of the cave, but was present at the rear.</th>
<th>- See comments about typology above.</th>
<th>- Agree with Zilhao and d'Errico (1999) that the Aurignacian is present in the rear of the cave. We see no evidence in the dates that it is present in the front of the cave.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dating of charcoal that is not related to human activity may have caused the unit to appear erroneously old.</td>
<td>- Charcoal may have been an inherited component of the sediment. - Charcoal may have been redeposited from the main area of excavation into unit c.</td>
<td>- Large number of radiocarbon dates consistent with ESR dates on teeth.</td>
<td>- Dates on bone from above unit 18 place unit 18 beyond the earliest Aurignacian in northern Spain.</td>
</tr>
<tr>
<td>Sample</td>
<td>Context</td>
<td>Industry</td>
<td>Excavation year, square, spit or find number</td>
</tr>
<tr>
<td>--------</td>
<td>---------------</td>
<td>-------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>CS2</td>
<td>Level 16</td>
<td>Sterile</td>
<td>1981, N15, spit 3</td>
</tr>
<tr>
<td>CS3</td>
<td>Level 16/17</td>
<td>Sterile</td>
<td>1981, N15, spit 3</td>
</tr>
<tr>
<td>CS6</td>
<td>Level 18B</td>
<td>Transitional</td>
<td>1981, G13, find 51</td>
</tr>
<tr>
<td>CS7</td>
<td>Level 18B</td>
<td>Transitional</td>
<td>1981, J-11, find 42</td>
</tr>
<tr>
<td>CS15</td>
<td>Level 18C</td>
<td>Transitional</td>
<td>1987, N-16-2, find 1516</td>
</tr>
<tr>
<td>CS17</td>
<td>Level 18C</td>
<td>Transitional</td>
<td>1987, N-16-5, find 945</td>
</tr>
<tr>
<td>CS19</td>
<td>Level 18C</td>
<td>Transitional</td>
<td>1985, N-17-5, find 436</td>
</tr>
<tr>
<td>CS24</td>
<td>Level 19</td>
<td>Sterile</td>
<td>1993, N16-9, find 11</td>
</tr>
<tr>
<td>CS25</td>
<td>Level 19</td>
<td>Sterile</td>
<td>1993, N16-7, find 22</td>
</tr>
<tr>
<td>CS31</td>
<td>Level 20C</td>
<td>Mousterian</td>
<td>1996, N16-7, find 1515</td>
</tr>
</tbody>
</table>

**Group 2: Cut-marked fauna from the Obermaier excavation**

<table>
<thead>
<tr>
<th>AMNH 1</th>
<th>Aurignacian delta</th>
<th>Transitional Aurignacian</th>
<th>Indeterminate, diaphysis fragment</th>
<th>Cutmarked</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMNH 2</td>
<td>Aurignacian delta</td>
<td>Transitional Aurignacian</td>
<td>cf. <em>Cervus</em>, diaphysis fragment</td>
<td>Cutmarked</td>
</tr>
<tr>
<td>AMNH 4</td>
<td>Aurignacian delta</td>
<td>Transitional Aurignacian</td>
<td>cf. <em>Cervus</em>, cf. femur</td>
<td>Cutmarked</td>
</tr>
<tr>
<td>AMNH 8</td>
<td>Aurignacian delta</td>
<td>Transitional Aurignacian</td>
<td>Indeterminate, pelvis</td>
<td>Cutmarked</td>
</tr>
</tbody>
</table>

**Group 3: Split base points**

<p>| CS1 | Aurignacian Delta | Aurignacian | Collection number 51/33/102/2/3 | <em>Cervus elaphus</em>, antler | Split base point baguette (Tejero, 2012) |</p>
<table>
<thead>
<tr>
<th>Context</th>
<th>Sample type</th>
<th>Pre-Treat</th>
<th>Lab Code</th>
<th>Date (BP)</th>
<th>Calibrated date (cal BP, 95.4% probability range)</th>
<th>Yield (mg)</th>
<th>Yield (%)</th>
<th>%C</th>
<th>δ¹³C (%VPDB)</th>
<th>C:N</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cueva Morín</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Charcoal</td>
<td>XR</td>
<td>OxA-19459¹</td>
<td>43600 ± 600</td>
<td>43340 - 45650</td>
<td>N/A</td>
<td>N/A</td>
<td>84.5</td>
<td>-24.2</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Esquilleu</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vi</td>
<td>Bone</td>
<td>AF</td>
<td>OxA-19965¹</td>
<td>43700 ±1400</td>
<td>49890 - 45140</td>
<td>12.1</td>
<td>1.3</td>
<td>46.2</td>
<td>-19.1</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AF</td>
<td>OxA-19966¹</td>
<td>44100 ±1300</td>
<td>49950 - 45600</td>
<td>13.5</td>
<td>1.4</td>
<td>44.4</td>
<td>-19.2</td>
<td>3.4</td>
</tr>
<tr>
<td><strong>Arrítor</strong></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lmc</td>
<td>Bone, cutmarked Cervus elaphus astraigulus</td>
<td>AF</td>
<td>OxA-21986¹</td>
<td>44900 ± 2100</td>
<td>... - 45490</td>
<td>8.4</td>
<td>1.5</td>
<td>37.4</td>
<td>-19.5</td>
<td>3.2</td>
</tr>
<tr>
<td>Lmc</td>
<td>Bone, cutmarked cf. Cervus elaphus diaphysial fragment</td>
<td>AF</td>
<td>OxA-22654¹</td>
<td>&gt;46800</td>
<td>N/A</td>
<td>42.4</td>
<td>4.2</td>
<td>41.9</td>
<td>-20.7</td>
<td>3.2</td>
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<tr>
<td><strong>La Güelga</strong></td>
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</tr>
<tr>
<td>D interior, level 9</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bone</td>
<td>AF</td>
<td>OxA-19244¹</td>
<td>43700 ± 800</td>
<td>48950 - 45500</td>
<td>26.4</td>
<td>2.5</td>
<td>44</td>
<td>-19.0</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AF</td>
<td>OxA-19245¹</td>
<td>44300 ± 1200</td>
<td>49950 - 45850</td>
<td>15.2</td>
<td>1.7</td>
<td>45.1</td>
<td>-19.0</td>
<td>3.3</td>
</tr>
</tbody>
</table>

1. Maroto et al., 2012
2. Higham et al., 2014
3. Menendez et al., 2009
4. May extend beyond the calibration curve
<table>
<thead>
<tr>
<th>Sample</th>
<th>Context</th>
<th>Industry</th>
<th>OxA</th>
<th>Date (BP)</th>
<th>Calibrated date (cal BP, 95.4% probability range)</th>
<th>Treatment</th>
<th>Yield (mg)</th>
<th>Yield (%)</th>
<th>δ^13^C (% VPDB)</th>
<th>δ^15^N (% AIR)</th>
<th>C:N</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS2</td>
<td>Level 16</td>
<td>Proto-Aurignacian</td>
<td>22200</td>
<td>38600 ± 1000</td>
<td>44610 - 41350</td>
<td>AF</td>
<td>33.69</td>
<td>3.3</td>
<td>41.4</td>
<td>-22</td>
<td>2.9</td>
</tr>
<tr>
<td>CS3</td>
<td>Level 16/17</td>
<td>Sterile</td>
<td>22201</td>
<td>39100 ± 1000</td>
<td>44960 - 41750</td>
<td>AF</td>
<td>17.14</td>
<td>1.7</td>
<td>42.1</td>
<td>-20.1</td>
<td>3.0</td>
</tr>
<tr>
<td>CS5</td>
<td>Level 18B</td>
<td>Transitional Aurignacian</td>
<td>21972</td>
<td>45800 ± 2300</td>
<td>45910^1^</td>
<td>AF</td>
<td>12.92</td>
<td>2.7</td>
<td>44.3</td>
<td>-20.8</td>
<td>6.1</td>
</tr>
<tr>
<td>CS6</td>
<td>Level 18B</td>
<td>Transitional Aurignacian</td>
<td>21973</td>
<td>46000 ± 2400</td>
<td>45940^1^</td>
<td>AF^*</td>
<td>11.18</td>
<td>2.4</td>
<td>43.8</td>
<td>-19.4</td>
<td>3.1</td>
</tr>
<tr>
<td>CS7</td>
<td>Level 18B</td>
<td>Transitional Aurignacian</td>
<td>21973</td>
<td>46000 ± 2400</td>
<td>45940^1^</td>
<td>AF^*</td>
<td>11.18</td>
<td>2.4</td>
<td>43.8</td>
<td>-19.4</td>
<td>3.1</td>
</tr>
<tr>
<td>CS15</td>
<td>Level 18C</td>
<td>Transitional Aurignacian</td>
<td>22403</td>
<td>42700 ± 1600</td>
<td>49690 - 43900^1^</td>
<td>AF^*</td>
<td>21.29</td>
<td>2.7</td>
<td>43.6</td>
<td>-21.7</td>
<td>4.9</td>
</tr>
<tr>
<td>CS17</td>
<td>Level 18C</td>
<td>Transitional Aurignacian</td>
<td>22202</td>
<td>43100 ± 1700</td>
<td>49950 - 44360^2^</td>
<td>AF^*</td>
<td>25.59</td>
<td>2.5</td>
<td>41.8</td>
<td>-20.5</td>
<td>3.0</td>
</tr>
<tr>
<td>CS19</td>
<td>Level 18C</td>
<td>Transitional Aurignacian</td>
<td>22203</td>
<td>42000 ± 1500</td>
<td>49050 - 43180^1^</td>
<td>AF^*</td>
<td>14.91</td>
<td>1.8</td>
<td>41.4</td>
<td>-20.3</td>
<td>3.0</td>
</tr>
<tr>
<td>CS24</td>
<td>Level 19</td>
<td>Sterile</td>
<td>22005</td>
<td>49400 ± 3700</td>
<td>68300 - 44220^3^</td>
<td>AF</td>
<td>1.96</td>
<td>0.5</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>CS25</td>
<td>Level 19</td>
<td>Sterile</td>
<td>21974</td>
<td>44900 ± 2100</td>
<td>45490^1^</td>
<td>AF</td>
<td>14.47</td>
<td>3.4</td>
<td>41.4</td>
<td>-20</td>
<td>5.1</td>
</tr>
<tr>
<td>CS27</td>
<td>Level 20C</td>
<td>Mousterian</td>
<td>22204</td>
<td>48700 ± 3400</td>
<td>65220 - 43660^1^</td>
<td>AF^*</td>
<td>12.74</td>
<td>1.3</td>
<td>41.9</td>
<td>-20.3</td>
<td>3.1</td>
</tr>
<tr>
<td>CS31</td>
<td>Level 20C</td>
<td>Mousterian</td>
<td>22205</td>
<td>49400 ± 3700</td>
<td>68300 - 44220^3^</td>
<td>AF</td>
<td>19.47</td>
<td>1.9</td>
<td>40.3</td>
<td>-20.8</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Group 2: Cut-marked fauna from the Obermaier excavation

AMNH1  Aurignacian Delta  Transitional Aurignacian | Failed on low % yield | AF | 6.16 | 0.7 |

AMNH2  Aurignacian Delta  Transitional Aurignacian | 22016 | 36000 ± 1800 | 44670 - 36760 | AF | 11.93 | 1.2 | 39.0 | -20.6 | 3.5 |

AMNH4  Aurignacian Delta  Transitional Aurignacian | 22018 | 42100 ± 1500 | 49120 - 43270^1^ | AF | 13.13 | 1.3 | 41.9 | -19.9 | 3.7 |

AMNH8  Aurignacian Delta  Transitional Aurignacian | 22637 | 39900 ± 1100 | 45790 - 42160 | AF | 71.81 | 7.0 | 45.0 | -20.4 | 4.9 |

Group 3: Split base points

CS1    Aurignacian Delta | 21713 | 35000 ± 600 | 40990 - 38430 | AF^* | 13.95 | 4.8 | 47.4 | -19.6 | 2.5 |

[^1]: Additional details.
[^2]: Additional details.
[^3]: Additional details.
Supplementary Online Material 2

Model codes

Code for model presented in Figure 4

Plot()
{
    Outlier_Model("General",T(5),U(0,4),"t");
    Sequence(Cabrera Valdes)
    {
        Boundary("Start 20C");
        Phase("20C")
        {
            R_Date("22,204", 48700, 3400)
            {
                Outlier(0.05);
            }
            R_Date("22,205", 49400, 3700)
            {
                Outlier(0.05);
            }
            R_Date("GifA-89144", 39300, 1900)
            {
                color="red";
                Outlier(0.05);
            }
            R_Date("GifA-92506", 43300, 2900)
            {
                color="red";
                Outlier(0.05);
            }
            Interval("20C length");
        }
    }
    Boundary("20C/19");
    Phase("19")
    {
        R_Date("21,974", 44900, 2100)
        {
            Outlier(0.05);
        }
        Interval("19 length");
    }
    Boundary("19/18C");
    Phase("18C")
    {
        R_Date("22,403", 42700, 1600)
        {
            Outlier(0.05);
        }
    }


R_Date("22,202", 43100, 1700)
{
    Outlier(0.05);
};
R_Date("22,203", 42000, 1500)
{
    Outlier(0.05);
};
R_Date("GifA 89147", 39500, 2000)
{
    color="red"
    Outlier(0.05);
};
R_Date("OxA-2478", 39800, 1400)
{
    color="red"
    Outlier(0.05);
};
R_Date("AA-2405", 40000, 2100)
{
    color="red"
    Outlier(0.05);
};
R_Date("OxA-2476", 40700, 1500)
{
    color="red"
    Outlier(0.05);
};
R_Date("OxA-2477", 41100, 1700)
{
    color="red"
    Outlier(0.05);
};
C_Date("ESR2", BC(37900), 4600)
{
    Outlier(0.05);
    color="teal"
};
Boundary("18C/18B");
Phase("18B")
{
    R_Date("21,972", 45800, 2300)
    { 
        Outlier(0.05);
    };
    R_Date("21,973", 46000, 2400)
    { 
        
    };
}
Outlier(0.05);
};
R_Date("AA-2406", 38500, 1800)
{
  color="red"
  Outlier(0.05);
};
R_Date("OxA-2473", 37100, 2200)
{
  color="red"
  Outlier(0.05);
};
R_Date("AA-2407", 37700, 1800)
{
  color="red"
  Outlier(0.05);
};
R_Date("OxA-2474", 38500, 1300)
{
  color="red"
  Outlier(0.05);
};
R_Date("OxA-2475", 40700, 1600)
{
  color="red"
  Outlier(0.05);
};
Interval("18 length");
};
Boundary("18B/17-16");
Phase("17-16")
{
  R_Date("22,200", 38600, 1000)
  {
    Outlier(0.05);
  }
  R_Date("22,201", 39100, 1000)
  {
    Outlier(0.05);
  }
  R_Date("GifA95539", 34300, 1000)
  {
    color="red"
    Outlier(0.05);
  }
  Interval("17-16 length");
};
Boundary("End 17-16");
}
Code for model presented in Figure 5

Plot()
{

Date(Prior("2013_01_9splitall_intcal13_19_18C","2013_01_9splitall_intcal13_19_18C.prior"));

Date(Prior("2013_01_09_split_all_IntCal1318_17_16","2013_01_09_split_all_IntCal1318_17_16.prior"));
  Outlier_Model("General",T(5),U(0,4),"t");
Sequence()
{

Boundary("=2013_01_9splitall_intcal13_19_18C","2013_01_9splitall_intcal13_19_18C.prior");
  Phase("Auignanian Delta")
  {
    R_Date("22,016", 36000, 1800)
    {
      Outlier(0.05);
    }
    R_Date("22,018", 42100, 1500)
    {
      Outlier(0.05);
    }
    R_Date("22,637", 39900, 1100)
    {
      Outlier(0.05);
    }
    R_Date("21,713", 35000, 600)
    {
      Outlier(0.05);
    }
  };

Boundary("=2013_01_09_split_all_IntCal1318_17_16","2013_01_09_split_all_IntCal1318_17_16.prior");
};

Date(Prior("Abri_Pataud_Start_11_Higham","Abri_Pataud_Start_11_Higham.prior"));
};

Code for model presented in Figure 8

Plot()}
Outlier_Model("General",T(5),U(0.4),"t");
Sequence()
[
  Boundary("Start 1");
  Phase("1")
  {
    R_Date("OxA-19459 ", 43600, 600)
    {
      Outlier(0.05);
    }
    R_Combine("OxA-19965 and 19966")
    {
      Outlier(0.05);
      R_Date("OxA-19965", 43700, 1400);
      R_Date("OxA-19966 ", 44100, 1300);
    }
    R_Date("OxA-21986", 44900, 2100)
    {
      Outlier(0.05);
    }
    R_Date("OxA-22655", 45600, 2300)
    {
      Outlier(0.05);
    }
    R_Combine("OxA-19244 and 19245")
    {
      Outlier(0.05);
      R_Date("OxA-19244", 43700, 800);
      R_Date("OxA-19245", 44300, 1200);
    }
  }
  Boundary("End 1");
];
Supplementary Online Material 1

An example of the Difference function in OxCal (Bronk Ramsey 2009)

The Difference function can be used to assess whether two probability distribution functions (PDFs) are identical. An example is given in SOM figure 1. Three hypothetical Boundary PDFs are given, A, B and C (figure 1a). The 95.4% probability distributions of all PDFs overlap, but some overlap more than others. It is clear that A and C overlap by only a tiny probability, but at what point can we call the PDFs 'different' at some degree of significance? Figure 1b shows the Difference between the Boundaries. The Difference between A and B (example 1) overlaps with zero, but examples 2 and 3 do not. In this paper we have said 2 and 3 are different at 95.4% probability.

Figure 1; An example of the Difference function in OxCal. a) Three hypothetical Boundary PDFs b) The Difference between the Boundaries. Examples 2 and 3 would be considered different at 95.4% probability, example 1 would not.

References

Supplementary Online Material 3

**Bayesian models**

Calibrated and modeled probability distributions of models produced in OxCal (Bronk Ramsey 2009a, 2009b) against IntCal13 (Reimer et al. 2013). Convergence values are also given. These should be above 95% (Bronk Ramsey 1995). Dates in italics may extend beyond the calibration curve.

**SOM Table 1: Results of model presented in Figure 4**

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**SOM Table 2: Results of model presented in Figure 5**
### Table 3: Results of model presented in Figure 8

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References


