**1El Castillo (Cantabria, Northern Iberia) and the Transitional Aurignacian:
2using radiocarbon dating to assess site taphonomy**

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21

22Abstract

23The majority of archaeological remains found at El Castillo in northern Iberia
24were excavated between 1910 and 1914 by Hugo Obermaier. Since the
251980s 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.

46

47Keywords

48Radiocarbon; Pretreatment; Split base point; Transitional Aurignacian; Upper
49Palaeolithic; Middle Palaeolithic

50

511. Introduction

52

531.1 *The Middle to Upper Palaeolithic transition*

54

55The interpretation of archaeological sites excavated in the early twentieth
56century is plagued by stratigraphic uncertainties resulting from poor
57excavation methods and the potential mixture of excavated objects during
58decades of study and curation. However, detailed study of the original
59excavation notes, cleaning of standing sections and excavations at the site
60perimeter can recover substantial amounts of information. In addition, the
61dating of bones or charcoal from a sedimentary unit can shed light on the
62chronological homogeneity of a lithic assemblage. Here we discuss how new
63radiocarbon dates help to resolve some of the lengthy debates surrounding
64the Middle to Upper Palaeolithic transition at the site of El Castillo near Puente
65Viesgo in Cantabria, northern Iberia (Figure 1) (Bernaldo de Quirós and
66Maíllo-Fernández, 2009; Bernaldo de Quirós et al., 2008; Cabrera Valdés
67and Bernaldo de Quirós, 1996; Cabrera Valdés et al., 2006; Cabrera Valdés
68et al., 2005; Cabrera Valdés et al., 2002; Cabrera Valdés and Bischoff, 1989;
69Cabrera Valdés et al., 1993; Cabrera Valdés et al., 1997; Cabrera Valdés et
70al., 2000; Cabrera Valdés et al., 2001; Cabrera Valdés et al., 1996; d'Errico
71et al., 1998; Pastoors and Tafelmaier, 2013; Zilhão, 2006; Zilhão and
72d'Errico, 1999; Zilhão and d'Errico, 2003).

73

74The Middle Palaeolithic Mousterian, produced by Neanderthals, disappeared
75from western Europe by 41,030–39,260 cal BP (at 95.4 % probability, Higham

76et al. (2014)), if debates surrounding late Neanderthals in southern Iberia are
77excluded due to problematic dates (Wood et al., 2013). Spatially, this
78disappearance appears to have been patchy with, for example, variability in
79the age of the final Mousterian in different parts of Europe and the
80Châtelperronian in southern France and the Basque country dating between
81c.45 - 41 cal kBP (Higham, et al., 2014).

82

83The majority of Palaeolithic scholars suggest that the Upper Palaeolithic
84Aurignacian (*sensu lato*) appeared in western Europe around 42 - 41 cal kBP
85(Douka et al., 2012; Higham et al., 2012; Jacobs et al., 2015; Szmids et al.,
862010; Wood et al., 2014), probably being carried from somewhere in the east
87(Kozłowski, 2006; Mellars, 2006). The earliest Aurignacian assemblage in the
88Cantabrian region (the region including the Basque Country, Cantabria and
89Asturias) is found in level VII at Labeko Koba and is dated to 41960 – 40710
90cal kBP (Wood, et al. (2014), remodeled against IntCal13 (Reimer et al.,
912013)).

92

93Although they cannot be easily dated directly, analysis of human teeth from
94layers containing the Proto-Aurignacian at Fumane and Riparo Bombrini
95strongly suggests that anatomically modern humans (AMHs) produced the
96earliest phase of the Aurignacian (Benazzi et al., 2015), supporting the
97prevailing view (Higham et al., 2011; Kozłowski and Otte, 2000; Trinkaus,
982005). However, skeletal evidence is exceptionally scarce, especially for the
99earliest phases of the Aurignacian, and Neanderthal or hybrid authorship
100remains a possibility (Trinkaus and Zilhão, 2013; Zilhão, 2006). This is

101 particularly pertinent given aDNA from Peștera cu Oase 1, dated at 41690 –
102 37490 cal BP (OxA-11711 and GrA-22810 34950 +990, -890 BP, (Trinkaus,
103 2013)), which suggests the individual had a Neanderthal ancestor within just
104 4–6 generations (Fu et al., 2015).

105

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

118

119 1.2 Site description

120

121 The first major excavations at El Castillo were undertaken by Hugo Obermaier
122 between 1910 – 1913 (Figure 2). It was immediately recognized as one of the
123 most important Palaeolithic sites in Europe (see discussion in White (2006)),
124 containing 26 sedimentological units with archaeological assemblages ranging
125 from the early Middle Palaeolithic to the Azilian (Cabrera Valdés, 1984;

126Cabrera Valdés, et al., 2006), often separated by archaeologically sterile units.
127In addition, an extensive collection of rock art has been found within the
128karstic system behind the excavated rock-shelter (García-Diez et al., 2015;
129Leroi-Gourhan, 1965; Pike et al., 2012; Valladas et al., 1992). Most of the
130archaeological materials from this earlier excavation were sent to the Institute
131de Paléontologie Humaine (IPH) in Paris, and later repatriated to Spain and
132/or separated for further study (Cabrera Valdés, 1984). The turbulent events of
133the early 20th century and the death of Obermaier in 1946 meant that the
134intended series of monographs on the site were never written. It was not until
135the early 1980s that detailed descriptions of the original excavation notes,
136standing section, and lithic and faunal assemblages were published by
137Cabrera Valdés (1984).

138

139Since 1980, excavations led by V. Cabrera Valdés and F. Bernaldo de Quirós
140have been undertaken towards the cave entrance (Figure 2). As the cave roof
141collapsed during the Late Pleistocene, the area occupied by humans
142decreased in size and moved towards the rear of the cave (Cabrera Valdés, et
143al., 1993). This meant that the area of modern excavations only included the
144two earliest Upper Palaeolithic levels (units 16 and 18) and the underlying
145Mousterian units. Through the careful reconciliation of Hugo Obermaier's field
146notes, annotated section drawings and photos, and the extant section,
147Cabrera Valdés (1984) was able to link the stratigraphy of the old and new
148excavations. Unit 18 could be confidently related to Obermaier's Aurignacian
149Delta by the location of several large boulders and the presence of the two
150sterile units 17 and 19 (Cabrera Valdés and Bernaldo de Quirós, 1996).

151

152This paper will examine the chronology of unit 18, Obermaier's Aurignacian
153Delta, which contains the so-called Transitional Aurignacian (Figure 2). Unit 18
154is capped by an archaeologically sterile unit 17 and unit 16, Obermaier's
155Aurignacian Gamma, containing the Proto-Aurignacian (Maíllo-Fernández and
156Bernaldo de Quirós, 2010). Likewise, unit 18 is separated from the underlying
157unit 20, Obermaier's Mousterian Alpha, by a second sterile layer, unit 19. In
158the modern excavations, both unit 18 and unit 20 have been subdivided into
159several levels on the basis of sedimentology; unit 18 into 18a (sterile), 18b
160(originally separated into b1 and b2, but now combined) and 18c, and unit 20
161into 20a-e (Cabrera Valdés, et al., 1993). Cabrera Valdés (1984) uses the
162numerical system to describe the stratigraphy throughout the entire site.
163However, for clarity in distinguishing the 1980s and 1910s excavations, we will
164use the numerical notation to describe the assemblages recovered from the
165new excavation area, and Obermaier's terminology (e.g. Aurignacian Delta) to
166describe the assemblages and stratigraphic units from the old excavation.

167

168The typological ascription of unit 18 (levels 18b and 18c) has been the focus
169of considerable debate since Cabrera Valdés and Bernaldo de Quirós (1996)
170suggested that the industry was transitional between the Charentian
171Mousterian and Aurignacian, assigning the industry its own name, the
172Transitional Aurignacian (Cabrera Valdés, et al., 2001). They argued that this
173industry appeared to be Middle Palaeolithic with abundant substrate elements
174such as sidescrapers, but also contained indicators of the Upper Palaeolithic,
175namely a bone industry, ornaments, and Upper Palaeolithic tool types

176including a limited number of bladelets. These bladelets, they argued, were an
177indigenous development, first seen in the Mousterian of units 21 and 20.
178Therefore the industry was tentatively assigned to the Neanderthals.
179Unfortunately several fragmentary human fossils from Obermaier's
180Aurignacian Delta were lost, and only two deciduous molars were recovered
181during the new excavations (Garralda, 2006).

182

183More recently, Pastoors and Tafelmaier (2013) have published an analysis of
184the lithic reduction systems in from the Mousterian to Aurignacian Gamma
185using an assemblage from Obermaier's excavation curated in the Museo
186Arqueológico Nacional, Madrid. They see a similar pattern to previous
187publications at the site, with methods of bladelet production continuing
188throughout the sequence. However, their interpretation of this pattern is
189markedly different. They suggest that it was the shape and quality of raw
190material that led to the continued use of some reduction systems throughout
191these units. However, as highlighted by Pastoors and Tafelmaier (2013),
192Obermaier probably selected which lithics to curate, and the operational
193sequences are not limited to a specific raw material type. For example, in
194Aurignacian Gamma, both flake and bladelet production were undertaken on
195quartzite (Maíllo-Fernández and Bernaldo de Quirós, 2010).

196

197Radiocarbon dates on charcoal fragments from unit 18 recovered during the
198recent excavations (Table 1 Cabrera Valdés and Bischoff, 1989; Cabrera
199Valdés, et al., 1996; Hedges et al., 1994) were around 2000 years earlier
200than the majority of Proto-Aurignacian assemblages in the region (Fortea,

2011996; Maíllo-Fernández et al., 2001; Wood, et al., 2014), and contributed to
202the development of this idea. No material from Aurignacian Delta from the old
203excavation has been dated, although Stuart (2005) and Bernaldo de Quirós et
204al. (2006) published a suite of mostly infinite radiocarbon dates on ultrafiltered
205collagen from Mousterian Alpha. Note that although originally published as
206found in Aurignacian Delta (Stuart, 2005), and repeated in Zilhão (2006), OxA-
20710187 and OxA-10188 are on a single *Palaeoloxodon antiquus* tooth from
208Mousterian Alpha (Bernaldo de Quirós, et al., 2006).

209

210The Transitional Aurignacian was defined using the lithic assemblage from the
211new area of excavation, supported by the lithic assemblage from Obermaier's
212excavation and osseous tool assemblages from both the new and old
213excavations (Cabrera Valdés, et al., 2001). Obermaier's excavation removed
214most of the main living area, leaving only the edge of the occupation zone for
215the modern excavators. Level 18c was interpreted as a dump deposit,
216containing large dispersed lenses of charcoal with abundant lithic debitage,
217whilst level 18b is thought to be a butchery area, with numerous fragments of
218skull, jaw bones and parts of the axial skeleton together with large lightly
219worked limestone pieces and quartzite hammers (Cabrera Valdés and
220Bernaldo de Quirós, 1996).

221

222The elements most diagnostic of the Early Aurignacian were uncovered by
223Obermaier, including 10 split base points, the index fossil of the Early
224Aurignacian (Peyrony, 1933; Peyrony, 1934; Sonnevile-Bordes, 1960).
225However, both level 18 and Aurignacian Delta contain tools thought to be

226 Upper Palaeolithic, including endscrapers, burins and borers. 415 pieces from
227 unit 18 have been assigned to a typological type and a technological analysis
228 has identified a flake reduction scheme as well as a blade/ bladelet reduction
229 sequence (Cabrera Valdés, et al., 2002; Cabrera Valdés, et al., 2001).

230

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

237

238 Zilhão and d'Errico (d'Errico, et al., 1998; Zilhão, 2006; Zilhão and d'Errico,
239 1999) disagree with the conclusion that the assemblages in unit 18 and
240 Aurignacian Delta represent a transitional industry. Their main arguments fall
241 into four categories (Table 2):

242 1. *The technological and typological ascription of tools to the Aurignacian.*

243 The identification of various pieces of the osseous and lithic
244 assemblage to the Aurignacian from unit 18 has been queried. The
245 presence of tools pertaining to the Aurignacian within Aurignacian Delta
246 has not been questioned.

247 2. *Vertical variation within unit 18 and Aurignacian Delta.* During

248 excavation, Obermaier changed the name of the assemblage from
249 Mousterian Alpha to Aurignacian Delta when the first split base points
250 were found in 1912, although he maintained that the unit was richer in
251 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.

272

Bernaldo de Quirós, et al. (2008) and Bernaldo de Quirós and Maíllo-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

278 technological definition of the assemblages and will therefore limit our
279 discussion of the first point. This paper aims to use radiocarbon dating to
280 examine points 2-4 further.

281

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

- 284 1. Whether areas of disturbance within the early 20th area of excavations,
285 some distance from the extant section and new excavation, were
286 undetected and may have resulted in intrusive Aurignacian elements
287 from the overlying Aurignacian Beta (Maíllo-Fernández and Bernaldo
288 de Quirós, 2010) appearing within Aurignacian Delta.
- 289 2. The accuracy of dates on charcoal produced before the development of
290 ABOx-SC (Bird et al., 1999). Radiocarbon dates on Pleistocene-aged
291 materials are extremely sensitive to young contaminants. Just 1 %
292 modern contamination in a sample of 50 ka BP will cause a measured
293 age of 37 ka BP. Until around 2000 few chemical cleaning or 'pre-
294 treatment' techniques were able to always effectively remove such
295 contamination, leading to the underestimation of many dates (Higham,
296 2011). Although these charcoal samples were not identified to species
297 any inbuilt age is likely to be a few hundred years, which is insignificant
298 in comparison to the large error range.

299

300 2. Materials and methods

301

302 2.1 Sample selection

303

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).

313

The sampled materials fall into three groups:

315

2.1.1 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 Arqueología de Cantabria.

327

2.1.2 Group 2: Cut-marked fauna from the Obermaier excavation During the 100 years since excavation, much of the faunal assemblage from El Castillo has been subject to repeated study and frequent relocation before deposition within several institutions (Cabrera Valdés, 1984). A small collection of bone, sediment and lithics from the 1913 excavation was sent to the American Museum of Natural History (AMNH) by Hugo Obermaier in collaboration with Nels Nelson in response to a request for reference material for construction of a copy of the cave section (White, 2006). This section was never built and the collection appears to have remained unstudied until 2007-8 (Tejero et al., 2010). Although repackaged, the labels written by Nelson are found within the boxes containing the archaeological materials. As the least studied faunal collection from El Castillo, this collection was considered the most suitable for assessing the integrity of the original assemblage, as it was less likely to be affected by minor post-excavation mixing and conservation treatment which may result from study, relocation and curation over the course of 100 years. As with all of the material recovered by Obermaier there are no detailed indications of the location of the assemblage in plan, but the area excavated in 1913 is shown in figure 2c. Cut-marked bone was selected (Table 3).

346

2.1.3 Group 3: Split base point blank Unfortunately the collection of split base points from El Castillo, the largest in Iberia (Cabrera Valdés, 1984; Liolios, 2006; Tejero, 2010; Tejero, 2013), was not suitable for dating. The points have been separated from the faunal bone since excavation and are heavily conserved (Cabrera Valdés, 1984). However, a piece of antler, thought to be a blank for a split base point was discovered by Tejero et al. (2012) (Figure 3d)

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

359

360 2.2 Radiocarbon dating

361

362 Radiocarbon dating was undertaken using the methods described in Brock, et
363 al. (2010) at the Oxford Radiocarbon Accelerator Unit (ORAU). Given the poor
364 preservation of bone collagen at some sites in the Cantabrian region (Wood,
365 et al., 2014; Wood et al., 2013), a large number of bones were screened to
366 assess collagen preservation using %N (Brock et al., 2010; Brock et al.,
367 2012). Subsequently, 300 - 1000 mg material was taken for dating from a
368 subsample of bones the screening test identified as most likely to contain
369 collagen. Samples were taken with a tungsten carbide drill away from any
370 visible glue or conservation treatment. However, as a precaution, if glue was
371 visible or suspected anywhere on the bone, the drilled powder was washed in
372 a series of solvents prior to demineralisation in 0.5 M HCl overnight. The
373 insoluble crude collagen was washed in 0.1 M NaOH (room temperature, 30
374 minutes) to remove alkali soluble humic acids, and 0.5 M HCl (room
375 temperature, 1 hour), before gelatinization in 0.001 M HCl (70 °C, 20 hours)
376 and filtration to remove large insoluble particulates (Ezee™ filter, 45 – 90 µm).
377 Gelatin was then ultrafiltered using a precleaned 30 kDa MWCO Vivaspın™ 15

378ultrafilter, and freeze-dried. The product was combusted in an elemental
379analyser (ANCA-GSL), connected to an isotope-ratio mass spectrometer
380(Sercon 20-20) operating in continuous mode, allowing measurement of
381carbon and nitrogen stable isotope and elemental information. Excess carbon
382dioxide was cryogenically collected and converted to graphite over an iron
383catalyst, and dated in an Accelerator Mass Spectrometer (Ramsey et al.,
3842004). All dates are corrected for a sample size specific background (Wood et
385al., 2010).

386

387Given the published data (Table 1), most radiocarbon dates from unit 18 were
388expected to fall close to the limit of the radiocarbon dating method and thus
389have errors of $> \pm 1500$ ^{14}C years (often > 5000 cal years at 95.4 %
390probability) and abut the end of the radiocarbon calibration curve (Table 1).
391Whilst this makes investigation of the fine chronostratigraphy within unit 18
392difficult, identifying material of Aurignacian age (< 42 cal kBP) where error
393ranges drop below 1500 ^{14}C years and < 4000 cal years (at 95.4 %
394probability), should be possible. To aid interpretation, Bayesian models were
395used to assess whether the radiocarbon dates are consistent with specific
396hypotheses.

397

3982.3 Calibration and Bayesian analysis

399It is now common for stratigraphic information from archaeological sites to be
400combined with radiocarbon data in a chronological model (Bayliss, 2009)
401using Bayesian statistical software such as OxCal (Ramsey, 2009; Ramsey et
402al., 2010) or BCal (Buck et al., 1999). The construction of such models is

403 particularly useful for two reasons. First, probability distributions of modeled
404 ages for the start and end of stratigraphic or typological phases can be
405 extracted, and comparisons made between sites (Higham, et al., 2014;
406 Whittle and Bayliss, 2007). Second, statistical analysis aids analysis of the
407 complicated, and often wide, probability distributions of calibrated radiocarbon
408 dates. As elegantly shown by Bayliss (2009), the length of time represented
409 by a group of calibrated dates will be overestimated when analysed by eye,
410 and statistical analysis of groups of dates is required to accurately assess
411 duration, whether two phases overlap in time, and to identify outliers.

412

413 Bayesian analysis lends itself to studies where knowledge is developed using
414 an iterative process, as is the case in archaeology where data is normally
415 obtained incrementally (Bayliss, 2009; Bayliss et al., 2007; Buck and Meson,
416 2015). We start with some prior knowledge about the age of a sample
417 (normally stratigraphy), combine it with some new evidence (the radiocarbon
418 dates), and use this to inform a hypothesis, which in turn becomes our new
419 prior. Moreover, where stratigraphy is not clear, we may have more than one
420 possible set of priors and multiple models may need to be presented and
421 evaluated.

422

423 An extension to this fluid perception of chronological modeling, is the use of
424 Bayesian techniques to assess whether the radiocarbon dates obtained agree
425 or disagree with a given prior assumption, rather than simply provide, for
426 example, an estimated start date for an occupation. In an early example,
427 Needham et al. (1998) used Bayesian analysis of radiocarbon dates on

428organic material associated with Bronze Age metalwork from southern
429England to assess whether it was more likely typological groupings were
430coeval or were sequential. It is in this vein that Bayesian models are
431constructed in this paper. Chronological models have been primarily built to
432assess whether radiocarbon dates support the various hypotheses
433surrounding the stratigraphy and taphonomy of El Castillo.

434

435All radiocarbon dates presented in the paper have been calibrated in OxCal
436v.4.2 (Ramsey, 2009) against IntCal13 (Reimer, et al., 2013). Any models
437referred to in this paper published before 2013 have been rerun against this
438calibration curve. Age models have been constructed in OxCal v.4.2 (Ramsey,
4392009), assuming all dates have a 5 % prior probability of being an outlier
440within the *General t-type Outlier Model* (Ramsey, 2009).

441

442Archaeological units are considered *Phases* and are arranged in stratigraphic
443order within a *Sequence*, assuming those lower in the stratigraphy are older
444than those above. A *Boundary* is placed above and below each *Phase*. The
445posterior probability distribution functions (PDFs) of these *Boundaries* provide
446an estimate for the transition date between units. It is possible to establish
447whether two *Boundary* PDFs are different by subtracting one from the other
448using the *Difference* function in OxCal. If the resulting PDF does not include
449zero at 95.4 % probability, the two *Boundaries* are considered different
450(Supplementary information 1). Convergence, or the degree to which a
451representative solution has been generated, should typically be above 95 %
452(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

477GifA-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.

512

3.3 Group 3: Split base point blank

514

The antler blank from Obermaier's excavation of Aurignacian Delta (OxA-21713) 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).

520

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 El

526Castillo (Trou de la Mère Clochette, NE France (Szmidi et al., 2010) and
527Peskő, 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 (Arrizabalaga 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 redeposited 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.

557

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.

566

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

576 Aurignacian Delta are probably of an age typical of the Early Aurignacian.

577 Presumably lithics of this age also exist in the assemblage from the old

578 excavation.

579

580 Given the mixture of pre- and post-42 cal kBP material within Aurignacian

581 Delta, material from the early 20th century excavations cannot be used to

582 support the identification of the Transitional Aurignacian. Neither can this

583 assemblage be used to assess the integrity of the assemblage in unit 18 of

584 the new excavations (Zilhão and d'Errico, 1999). New analyses of material

585 from Obermaier's excavation, such as that completed by Pastoors and

586 Tafelmaier (2013) need take into consideration the possibility that material

587 from Aurignacian Delta is not temporally homogenous. The proportion of

588 younger material cannot be assessed from the limited dating work undertaken

589 here. In contrast, the radiocarbon data supports the interpretation that unit 18

590 only contains material that is earlier than 42 cal kBP.

591

592 4.2 Chronological relationship of unit 18 with sites across western Europe

593

594 Several sites containing Mousterian assemblages from the Cantabrian region

595 have been dated after samples were rigorously cleaned with, for example

596 ABOx-SC, ultrafiltration and ninhydrin (de Torres et al., 2010; Maroto, et al.,

597 2012; Wood, et al., 2013). With the exception of the anonymously late Middle

598 Palaeolithic assemblage within Esquilleu unit III (Maroto, et al., 2012), dates

599 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.

628

6295. Conclusion

630

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.

638

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.

647

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

651Zilhão (2006) proposes, amongst other things, that various tools have been
652misidentified. Chronologically the position of unit 18 is clear, at the end, and
653possibly the very end, of the Middle Palaeolithic Mousterian in the Cantabrian
654region and before the start of the Upper Palaeolithic Aurignacian. We hope
655that this will allow a more secure comparison of unit 18 to assemblages of a
656similar age in the future.

657

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659

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678

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- 1026
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1028 Figure Headings

1029 Figure 1: Location of El Castillo and other sites mentioned in the text. 1. La
 1030 Güelga, 2. Esquilleu, 3. El Castillo, 4. Cueva Morín, 5. Arrillor, 6. Labeko
 1031 Koba, 7. Lezetxiki, 8. L'Arbreda, 9. Abri Romaní, 10. Abri Castenet, 11. Abri
 1032 Pataud, 12. Trou de la Mère Clochette 13. Geissenklosterle, 14. Peskö.

1033

1034 Figure 2: El Castillo a) photograph and b) drawing of the extant standing
 1035 section of the 1914 excavation. c) detailed image of units 17-21. Image shows
 1036 a 1m wide section. d) plan of the excavation with excavation areas marked
 1037 (red, 1912; blue 1913; green 1914; black 1980) as well as the extent of levels
 1038 18b (grey) and 18c (striped). For colour, please see web version.

1039

1040 Figure 3: Examples of a-c) examples of dated cut-marked and
 1041 anthropogenically modified bone and d) the antler blank baguette type from
 1042 Aurignacian Delta. For colour, please see web version.

1043

1044Figure 4: Bayesian model of dates from the modern excavation of El Castillo
1045unit 21 – 16/17. Radiocarbon dates are calibrated in IntCal13 (Reimer, et al.,
10462013) and calibration and modeling has been undertaken in OxCal v.4.2
1047(Ramsey, 2009) assuming all samples have a 5 % prior likelihood of being a
1048outlier within the *General t-type Outlier Model* (Ramsey, 2009). Grey
1049probability distributions represent dates obtained in this study, red distributions
1050radiocarbon dates obtained in previous studies (see Table 1 for references)
1051whilst the teal distribution represents the average of 7 ESR dates on teeth
1052(Rink et al., 1996). Pale distributions depict the calibrated PDF and dark
1053distributions the modeled PDF. The 68.2 % and 95.4 % modeled probability
1054ranges are indicated by horizontal bars beneath the PDFs. For colour, please
1055see web version.

1056

1057Figure 5: Bayesian model of dates from the 1910-1913 excavation of El
1058Castillo unit Aurignacian Delta. Radiocarbon dates are calibrated in IntCal13
1059(Reimer, et al., 2013) and calibration and modeling has been undertaken in
1060OxCal v.4.2 (Ramsey, 2009) assuming all samples have a 5 % prior likelihood
1061of being a outlier within the *General t-type Outlier Model* (Ramsey, 2009). The
1062probability distribution functions for the start and end of unit 18 are taken from
1063the chronological model derived for the modern excavation (Figure 4) to
1064assess whether the samples from Aurignacian Delta are of a consistent age
1065with the area of modern excavation.

1066

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.

1074

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.

1084

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 (Ramsey, 2009) 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

1091are not all on anthropogenically modified bone. References are given in table
10924.

1093

1094**Table headings**

1095Table 1; Published radiocarbon dates from El Castillo. Dates are calibrated
1096against IntCal13 (Reimer, et al., 2013) in OxCal v.4.2 (Ramsey, 2009). ZR
1097refers to an acid-base-acid protocol, AF an ultrafiltration protocol and an
1098asterisk a treatment with solvent washing prior to the main pretreatment
1099(Brock, et al., 2010).

1100

1101Table 2; A summary of the debate surrounding the Transitional Aurignacian at
1102El Castillo compared to the results of this study.

1103

1104Table 3; Samples selected for radiocarbon dating from El Castillo.

1105

1106Table 4; Radiocarbon dates from El Castillo produced in this study. Dates are
1107calibrated against IntCal13 (Reimer, et al., 2013) in OxCal v.4.2 (Ramsey,
11082009). AF refers to an ultrafiltration protocol and an asterisk a treatment with
1109solvents prior to the main pretreatment (Brock, et al., 2010). C:N ratio of
1110collagen should be 2.9-3.4, %C should be >30 % and isotopic ratios should lie
1111within the approximate range of each species (Van Klinken, 1999). ¹ denotes
1112a calibrated date which may extend beyond the limit of the calibration curve.

1113

1114Table 5; Radiocarbon dates from the uppermost dated contexts containing
1115dated Middle Palaeolithic assemblages in the Cantabrian region (Asturias,

1116 Cantabria, Basque Country). Dates are calibrated against IntCal13 (Reimer, et
1117 al., 2013) in OxCal v.4.2 (Ramsey, 2009). AF refers to an ultrafiltration protocol
1118 and XR to ABOx-SC (Brock, et al., 2010).

B)

D)

CS5

1 cm

CS6

1 cm

CS27

1 cm

CS1

1 cm

Modelled date (cal BP)

Context	Industry	Chronology										
		Sample type	Lab No.	Date (BP or years $\pm 1\sigma$)	Calibrated date (cal BP, 95.4% probability range)	Method	Pre-treat	Yield (mg)	Yield (%)	%C	$\delta^{13}\text{C}$ (‰ VPDB)	C:N
16	Aurignacian	Charcoal	GifA-95539 ¹	34300 $\pm$ 1000	41140 - 36440	AMS						
18B1	Transitional Aurignacian	Charcoal	AA-2406 ²	38500 $\pm$ 1800	47210 - 39810 ⁸	AMS						
18B2	Transitional Aurignacian	Charcoal	OxA-2473 ¹	37100 $\pm$ 2200	47680 - 37700 ⁸	AMS	ZR	25	60.4	63.3	-26.4	N/A
18B2	Transitional Aurignacian	Charcoal	AA-2407 ²	37700 $\pm$ 1800	46320 - 38880 ⁸	AMS						
18B2	Transitional Aurignacian	Charcoal	OxA-2474 ¹	38500 $\pm$ 1300	45350 - 40710	AMS	ZR	29.2	60.2	63.3	-26.5	N/A
18B2	Transitional Aurignacian	Charcoal	OxA-2475 ¹	40700 $\pm$ 1600	48290 - 42180 ⁸	AMS	ZR	93	48.9	23.1 ⁵	-25.1	N/A
18C	Transitional Aurignacian	Charcoal	GifA-89147 ¹	39500 $\pm$ 2000	48690 - 40840 ⁸	AMS						
18C	Transitional Aurignacian	Charcoal	OxA-2478 ¹	39800 $\pm$ 1400	46760 - 41720	AMS	ZR	58.3	56.1	60.0	-26.6	N/A
18C	Transitional Aurignacian	Charcoal	AA-2405 ²	40000 $\pm$ 2100	49120 - 41370 ⁸	AMS						
18C	Transitional Aurignacian	Charcoal	OxA-2476 ¹	40700 $\pm$ 1500	47980 - 42250 ⁸	AMS	ZR	131	60.6	56.7	-26.4	N/A
18C	Transitional Aurignacian	Charcoal	OxA-2477 ¹	41100 $\pm$ 1700	48830 - 42420 ⁸	AMS	ZR	93.4	61	50.0	-25.6	N/A
18C	Transitional Aurignacian	Tooth		39900 $\pm$ 4600 ^{3, 9}		ESR						
20B2	Mousterian	Charcoal	GifA-89144 ¹	39300 $\pm$ 1900	48270 - 40660 ⁸	AMS						
20B2	Mousterian	Charcoal	GifA-92506 ¹	43300 $\pm$ 2900	... - 43560 ⁸	AMS						
Mousterian alpha	Mousterian	Palaeo-oxodon antiquus	OxA-10187 ⁴	42900 $\pm$ 1400	49570 - 44250 ⁸	AMS	AF* ⁶	12	3.3	42.6	-19.7	3.4
			OxA-10188 ⁴	>47300		AMS	AF* ⁶	8.2	1	44.4	-20.4	3.4
Mousterian alpha	Mousterian	Stephanorhinus	OxA-10327 ⁴	>45700		AMS	AF* ⁶	5	0.7	39.9	-20.7	3.7 ⁷

Mousterian alpha	Mousterian	Tooth	OxA-10233 ⁴	42100 ± 1500	49130 - 43260 ⁸	AMS	AF ^{*6}	14.8	2.2	42.6	-19.6	3.3
		Stephan- orhinus Tooth	OxA-10328 ⁴	45700 ± 1700	... - 46410 ⁸	AMS	AF ^{*6}	14.8	2.2	43.2	-19.9	3.4
Mousterian alpha	Mousterian	Megalo- ceros giganteus Bone	OxA-10329 ⁴	>43800		AMS	AF ^{*6}	3.9	0.7	45.5	-20.6	3.5 ⁷

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 %C
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.

Area of debate	d'Errico et al. 1998, Zilhão and d'Errico 1999, 2003, Zilhão 2006a	Bernaldo de Quirós et al. 2008	This study
<p><i>Technological and typological ascription of tools to the Aurignacian.</i></p>	<ul style="list-style-type: none"> • 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. 	<ul style="list-style-type: none"> • 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. 	<ul style="list-style-type: none"> • Not studied.
<p><i>Vertical variation within unit 18 and Aurignacian delta.</i></p>	<ul style="list-style-type: none"> • 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. 	<ul style="list-style-type: none"> • 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. 	<ul style="list-style-type: none"> • 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.

<i>Lateral variation within unit 18 and Aurignacian delta.</i>	<ul style="list-style-type: none"> Aurignacian component was almost entirely missing from the front of the cave, but was present at the rear. 	<ul style="list-style-type: none"> See comments about typology above. 	<ul style="list-style-type: none"> 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.
<i>Dating of charcoal that is not related to human activity may have caused the unit to appear erroneously old.</i>	<ul style="list-style-type: none"> Charcoal may have been an inherited component of the sediment. Charcoal may have been redeposited from the main area of excavation into unit c. 	<ul style="list-style-type: none"> Large number of radiocarbon dates consistent with ESR dates on teeth. 	<ul style="list-style-type: none"> Dates on bone from above unit 18 place unit 18 beyond the earliest Aurignacian in northern Spain.

Sample	Context	Industry	Excavation year, square, spit or find number	Sample type	Modification
Group 1: Cut-marked fauna from the Cabrera Valdés excavation					
CS2	Level 16	Sterile	1981, N15, spit 3	cf. Bos/ Bison, tibia	Unmodified
CS3	Level 16/17	Sterile	1981, N15, spit 3	Cervus elaphus, tibia	Unmodified
CS5	Level 18B	Transitional Aurignacian	1981, L-11, find 79	cf. Bos/ bison, femur/ tibia	Cutmarked
CS6	Level 18B	Transitional Aurignacian	1981, G13, find 51	Indeterminate, diaphysis fragment	Cutmarked
CS7	Level 18B	Transitional Aurignacian	1981, J-11, find 42	Indeterminate, diaphysis fragment	Cutmarked
CS15	Level 18C	Transitional Aurignacian	1987, N-16-2, find 1616	Cervus elaphus, tibia	Cutmarked
CS17	Level 18C	Transitional Aurignacian	1987, N-16-5, find 945	Cervus elaphus, humerus/ femur	Cutmarked
CS19	Level 18C	Transitional Aurignacian	1985, N-17-5, find 436	Cervus elaphus, tibia	Cutmarked
CS24	Level 19	Sterile	1993, N16-9, find 11	Ursus spelaeus, canine	Unmodified
CS25	Level 19	Sterile	1993, N-16-7, find 22	Cervus elaphus, rib	Unmodified
CS27	Level 20C	Mousterian	1996, N16-2, find 1291	cf. Bos/ Bison, humerus	Cutmarked
CS31	Level 20C	Mousterian	1996, N16-7, find 1515	Cervus elaphus, radius	Cutmarked
Group 2: Cut-marked fauna from the Obermaier excavation					
AMNH 1	Aurignacian delta	Transitional Aurignacian		Indeterminate, diaphysis fragment	Cutmarked
AMNH 2	Aurignacian delta	Transitional Aurignacian		cf. Cervus, diaphysis fragment	Cutmarked
AMNH 4	Aurignacian delta	Transitional Aurignacian		cf. Cervus, cf. femur	Cutmarked
AMNH 8	Aurignacian delta	Transitional Aurignacian		Indeterminate, pelvis	Cutmarked
Group 3: Split base points					
CS1	Aurignacian Delta	Aurignacian	Collection number 51/33/102/2/3	Cervus elaphus, antler	Split base point baguette (Tejero, 2012)

Context	Sample type	Pre-Treat	Lab Code	Date (BP)	Calibrated date (cal BP, 95.4 % probability range)	Yield (mg)	Yield (%)	%C	$\delta^{13}\text{C}$ (‰VPDB)	C:N
<i>Cueva Morin</i> . When the same charcoal fragment was cleaned with ABA it produced a younger date (OxA-19083 41800 $\pm$ 450). Therefore GifA-96264 on charcoal from level 11, not treated with ABOx-SC, is not included.										
11	Charcoal	XR	OxA-19459 ¹	43600 $\pm$ 600	48340 - 45650	N/A	N/A	84.5	-24.2	N/A
<i>Esquilieu</i> . When ABOx-SC and ABA treatments have been used to clean charcoal the dates are very different (Maroto et al. 2012). Dates on charcoal not treated with ABOx-SC have not been included.										
VI	Bone	AF	OxA-19965 ¹	43700 $\pm$ 1400	49890 - 45140 ⁴	12.1	1.3	46.2	-19.1	3.4
		AF	OxA-19966 ¹	44100 $\pm$ 1300	49950 - 45800 ⁴	13.5	1.4	44.4	-19.2	3.4
<i>Arrillor</i>										
Lmc	Bone	AF	OxA-21986 ²	44900 $\pm$ 2100	... - 45490 ⁴	8.4	1.5	37.4	-19.5	3.2
Lamc	Bone, cutmarked <i>Cervus elaphus</i> astragalus	AF	OxA-22654 ²	>46800	N/A	42.4	4.2	41.9	-20.7	3.2
Lamc	Bone, cutmarked cf. <i>Cervus elaphus</i> diaphysial fragment	AF	OxA-22655 ²	45600 $\pm$ 2300	... - 45780 ⁴	35.6	4	42.6	-20.9	3.3
<i>La Güelga</i> . Dates from the uppermost Middle Paleolithic within the D exterior excavation area are at or beyond the limit of radiocarbon and not included										
D interior, level 9	Bone	AF	OxA-19244 ³	43700 $\pm$ 800	48990 - 45500 ⁴	26.4	2.5	44	-19.0	3.3
		AF	OxA-19245 ³	44300 $\pm$ 1200	49950 - 45850 ⁴	15.2	1.7	45.1	-19.0	3.3

1. Maroto et al., 2012
2. Higham et al., 2014
3. Menendez et al., 2009
4. May extend beyond the calibration curve

Sample	Context	Industry	OxA	Date (BP)	Calibrated date (cal BP, 95.4% probability range)	Treatment	Yield (mg)	Yield (%)	%C	$\delta^{13}\text{C}$ (‰ VPDB)	$\delta^{15}\text{N}$ (‰ AIR)	C:N
Group 1: Cut-marked fauna from the Cabrera Valdes excavation												
CS2	Level 16	Proto-Aurignacian	22200	38600 ± 1000	44610 - 41350	AF	33.69	3.3	41.4	-22		2.9
CS3	Level 16/17	Sterile	22201	39100 ± 1000	44960 - 41750	AF	17.14	1.7	42.1	-20.1		3.0
CS5	Level 18B	Transitional Aurignacian	21972	45800 ± 2300	... - 45910 ¹	AF	12.92	2.7	44.3	-20.8	6.1	3.2
CS6	Level 18B	Transitional Aurignacian	21973	46000 ± 2400	... - 45940 ¹	AF*	11.18	2.4	43.8	-19.4	3.1	3.2
CS7	Level 18B	Transitional Aurignacian	Failed on low % yield			AF	3.43	0.8				
CS15	Level 18C	Transitional Aurignacian	22403	42700 ± 1600	49690 - 43900 ¹	AF*	21.29	2.7	43.6	-21.7	4.9	3.2
CS17	Level 18C	Transitional Aurignacian	22202	43100 ± 1700	49950 - 44360 ¹	AF*	25.59	2.5	41.8	-20.5		3.0
CS19	Level 18C	Transitional Aurignacian	22203	42000 ± 1500	49050 - 43180 ¹	AF*	14.91	1.8	41.4	-20.3		3.0
CS24	Level 19	Sterile	Failed on low % yield			AF	1.96	0.5				
CS25	Level 19	Sterile	21974	44900 ± 2100	... - 45490 ¹	AF	14.47	3.4	41.4	-20	5.1	3.2
CS27	Level 20C	Mousterian	22204	48700 ± 3400	65220 - 43660 ¹	AF*	12.74	1.3	41.9	-20.3		3.1
CS31	Level 20C	Mousterian	22205	49400 ± 3700	68300 - 44220 ¹	AF	19.47	1.9	40.3	-20.8		3.1
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	3.3
AMNH4	Aurignacian delta	Transitional Aurignacian	22018	42100 ± 1500	49120 - 43270 ¹	AF	13.13	1.3	41.9	-19.9	3.7	3.3
AMNH8	Aurignacian delta	Transitional Aurignacian	22637	39900 ± 1100	45790 - 42160	AF	71.81	7.0	45.0	-20.4	4.9	3.3
Group 3: Split base points												
CS1	Aurignacian Delta	Aurignacian	21713	35000 ± 600	40990 - 38430	AF*	13.95	4.8	47.4	-19.6	2.5	3.3

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("Aurignacian 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

Bronk Ramsey, C., 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon*, 51(1), 337-360.

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

Name	Unmodelled (cal BP)				Modelled (cal BP)				Convergence
	68.2% probability range		95.4% probability range		68.2% probability range		95.4% probability range		
	from	to	from	to	from	to	from	to	
Boundary End 17-16					42720	39410	43590	36580	98
GifA95539	40080	37590	41140	36450	42860	40070	43750	38350	99.8
OxA-22201	43860	42280	44960	41750	43220	42100	44030	41630	99.9
OxA-22200	43440	41920	44610	41350	43090	41940	43910	41400	99.9
Boundary 18B/17-16					44130	42550	44940	42110	99.9
OxA-2475	45790	42950	48280	42180	44980	43580	45490	42850	100
OxA-2474	43770	41660	45350	40720	44810	43290	45330	42600	100
AA-2407	43760	40410	46310	38880	44900	43370	45420	42600	100
OxA-2473	43780	39400	47680	37700	44940	43400	45460	42610	100
AA-2406	44510	41290	47210	39820	44910	43400	45420	42640	100
OxA-21973	...	47620	...	45940	45420	44030	45890	42960	99.9
OxA-21972	...	47570	...	45910	45420	44030	45890	42970	99.9
Boundary 18C/18B					45690	44420	46240	43430	99.9
ESR2	44440	35250	49030	30670	45980	44780	46700	44040	100
OxA-2477	46270	43130	48820	42420	45960	44790	46660	44100	100
OxA-2476	45670	43020	47980	42250	45940	44770	46630	44070	100
AA-2405	45930	42200	49110	41370	45970	44770	46670	44040	100
OxA-2478	44840	42530	46750	41720	45920	44740	46600	43990	100
GifA-89147	45460	41930	48680	40850	45960	44770	46670	44020	100
OxA-22203	47040	44060	49050	43180	45970	44820	46660	44190	100
OxA-22202	48250	45050	49950	44360	46010	44870	46720	44270	100
OxA-22403	47830	44700	49690	43900	45990	44850	46700	44250	100
Boundary 19/18C					46390	45130	47280	44590	99.9
OxA-21974	49760	46920	...	45490	47510	45830	48590	45300	100
Boundary 20C/19					48560	46480	49480	45790	99.9
GifA-92506	49060	44980	...	43570	49340	47310	49950	46510	99.9
GifA-89144	45190	41860	48260	40660	49250	47190	49920	46400	99.9
OxA-22205	56510	45690	68300	44220	49540	47580	50000	46720	99.9
OxA-22204	54680	45310	65220	43660	49510	47550	50000	46710	99.9
Boundary Start 20C					50110	47980	50850	46660	97.6

SOM Table 2: Results of model presented in Figure 5

Name	Unmodelled (cal BP)				Modelled (cal BP)				Convergence
	68.2% probability range		95.4% probability range		68.2% probability range		95.4% probability range		
	from	to	from	to	from	to	from	to	
Boundary 18B/17-16					43880	42440	44700	41990	99.6
OxA-21713	40190	38870	40990	38430	45180	43380	45940	42460	99.9
OxA-22637	44570	42780	45790	42160	44900	43460	45510	42810	99.9
OxA-22018	47150	44170	49120	43270	45450	44090	46080	43320	99.9
OxA-22016	42270	38790	44670	36760	45000	43250	45690	42420	99.9
Boundary 19/18C					46090	44970	46840	44450	99.7

SOM Table 3: Results of model presented in Figure 8

Name	Unmodelled (cal BP)				Modelled (cal BP)				Convergence
	68.2% probability range		95.4% probability range		68.2% probability range		95.4% probability range		
	from	to	from	to	from	to	from	to	
Boundary End final Mousterian Cantabria					47330	45840	48060	44480	95.3
OxA-19244 and 19245	47900	46350	48860	45810	47700	46560	48380	46100	99.7
OxA-22655	...	47460	...	45780	47900	46520	49110	45950	99.6
OxA-21986	49759	46918	...	45488	47870	46500	49030	45870	99.6
OxA-19965 and 19966	48250	46170	49490	45570	47760	46520	48610	45980	99.6
OxA-19459	47470	46120	48340	45650	47580	46500	48220	46020	99.6
Boundary Start final Mousterian Cantabria					48630	46860	50420	46360	95

References

Bronk Ramsey, C. (1995). Radiocarbon calibration and analysis of stratigraphy: The OxCal program. *Radiocarbon*, 37(2), 425-430.

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Reimer, P. J., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Bronk Ramsey, C., Grootes, P. M., Guilderson, T. P., Hafliðason, H., Hajdas, I., Hatte, C., Heaton, T. J., Hoffmann, D. L., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., Manning, S. W., Niu, M., Reimer, R. W., Richards, D. A., Scott, E. M., Southon, J. R., Staff, R. A., Turney, C. S. M., van der Plicht, J. (2013). IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. *Radiocarbon*, 55(4) 1869-1887.