Quaternary Science Reviews 270 (2021) 107098

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Invited review

The late persistence of the Middle Palaeolithic and Neandertals in Iberia: A review of the evidence for and against the “Ebro Frontier” model

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ARTICLE INFO

Article history:
Received 9 May 2021
Received in revised form
11 July 2021
Accepted 14 July 2021

Handling Editor: Donatella Magri

Keywords:
Pleistocene
Palaeogeography
Western Europe
Optical methods
Radiogenic isotopes
Neandertals
Mousterian
Upper Palaeolithic
Châtelperronian
Aurignacian

ABSTRACT

In the Franco-Cantabrian region and Catalonia, the Upper Palaeolithic begins with three assemblage-types found in stratigraphic order through the interval between 45,000 and 37,000 years ago: the Châtelperronian, the Protoaurignacian, and the Early Aurignacian. A stone tool, the Châtelperron point, and a bone tool, the split-based point, are index fossils of the first and the last, respectively, but neither was ever found elsewhere in Iberia. This observation triggered the proposition that, in regions situated to the south of the River Ebro drainage, the Middle Palaeolithic persisted until the time when the Early Aurignacian gave way to the Evolved Aurignacian, which is documented across all of Iberia by assemblages containing its index fossil, the Roc-de-Combe bladelet. Put forth thirty years ago, this Ebro Frontier model found support in the little radiometric evidence then available. Since, it has been shown that most apparently late occurrences of the Middle Palaeolithic were an artefact of dating error, caused by incomplete decontamination of radiocarbon dating samples, while claims have surfaced for the Early Aurignacian to be more widespread than hitherto thought. While the validity of Ebro Frontier's premises has thereby been called into question, continued support for the model is provided by the excavation of new sites, the re-excavation of old ones, the application of luminescence techniques, and the radiocarbon dating of robustly pre-treated samples. Moreover, and highlighting the key role that site formation process and taphonomy continue to play in ongoing controversies, issues of association between the samples and what they are supposed to date cast doubt on the two key claims for the presence of the Early Aurignacian in Andalusia and Portugal. Along with the Iberian System range, the Cantabro-Pyrenean cordillera represents a formidable physical obstacle to travel and communication, potentially enhanced during Last Glacial times because of rapid and major fluctuations in aridity, glacier extent, and plant cover. This barrier effect underpins the divergent culture-historical trajectories that we see unfolding at various times during the Upper Pleistocene. Beyond the Middle-to-Upper Palaeolithic transition, a well-known case in point is the interval between 20,000 and 22,000 years ago, during which the Badegoulian and the Initial Magdalenian of France and northern Spain developed in parallel with facies of the Upper Solutrean and the Solutreo-gravettian then persisting across all Iberian regions situated between Valencia and Portugal. Given known associations between technocomplexes and human types, these regions' Late Mousterian can be taken as a proxy for the persistence of Neandertal populations, and therefore constitutes a case study of choice for analyses of the variation in the intensity and frequency of biological and cultural interactions among low-density, small-scale populations of Palaeolithic hunter-gatherers. Such analyses have implications for models of the spread of genes, populations, and ideas in the course of Human Evolution, which would greatly benefit from due consideration of the issues of historical contingency that the Iberian evidence sheds much light on.

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https://doi.org/10.1016/j.quascirev.2021.107098
0277-3791/

1. Introduction

1.1. Paradigmatic framework

The Middle-to-Upper Palaeolithic transition in Europe (henceforth, the Transition) remains a matter of intense debate. Principally, this is because of the implications of the process for our understanding of Neandertals and the eventual disappearance of their phenotype.

The consensus framework defined a quarter of a century ago was "Acculturation" (Hublin et al., 1996; Hublin, 1990; Stringer and Gamble, 1993). Empirically, the model stemmed from the apparent long-term contemporaneity between two archaeological cultures: the Châtelperronian of south-western Europe, made by Neandertal people; and the pan-European Aurignacian, assumed to be a proxy for Moderns, i.e., people of ultimate African ancestry anatomically closer to present-day humans. Theoretically, the model relied on the assumption that the Neandertals were fundamentally separate, i.e., different at the biological species level and cognitively handicapped by comparison. Therefore, once Moderns started to spread into Europe, the interaction would have followed the rules of competitive exclusion; under these rules, the Neandertals' inferior intelligence would explain why they were doomed to lose out and become extinct via "replacement with no admixture" (Klein, 2003).

In this scenario, envisaging the symbolic thinking-related material culture novelties found in the late Neandertal archaeological record as a product of independent development was a logical impossibility. Acculturation therefore postulated that immigrating Moderns must have been the true creators of the symbolic artefacts found in Neandertal-associated archaeological contexts; scavenging of discarded items, exchange with Modern neighbours, or "imitation without understanding" sufficed to explain how and why such artefacts ended-up where found. Based on the very same premises, other models went as far as suggesting that the association of Neandertals and symbolic artefacts in the Châtelperronian was in fact spurious — i.e., reflected excavation error or post-depositional disturbance, if not that Moderns had made the Châtelperronian too (e.g., Bar-Yosef and Bordes, 2010; Higham et al., 2010; Mellars, 2005).

Two decades into the twenty-first century, Archaeology, Human Palaeontology, and Palaeogenetics have falsified the foundations of the Acculturation framework (Caron et al., 2011; d'Errico, 2003; d'Errico et al., 1998; Fu et al., 2016; Green et al., 2010; Hajdinjak et al., 2021; Hershkovitz et al., 2021; Hoffmann et al., 2018a, 2018b; Posth et al., 2017; Slon et al., 2018; Trinkaus, 2007; Welker et al., 2016; Zilhão, 2006c, 2007; 2011, 2013; Zilhão et al., 2015; Zilhão and d'Errico, 1999, 2003; Zilhão et al., 2006):

- Across the Balkans, Italy, and central and western Europe, it is now clear that the Aurignacian post-dates both the Châtelperronian and the coeval, so-called transitional technocomplexes, e.g., the Uluzzian and the Szeletian, thereby contradicting Acculturation's foundational premise of long-term contemporaneity between the Aurignacian and the Châtelperronian.
- The genuine nature of the Neandertals' association with the Châtelperronian at the key site of Grotte du Renne, in France, is now demonstrated by direct dating of paleoproteomics-identified Neandertal bone remains.
- Through the late Middle and the early Upper Pleistocene, intercontinental gene flow and interbreeding at the time of contact between Neandertals, Denisovans and Moderns are now known to have been routine and extensive, rather than exceptional or anecdotical, fundamentally challenging the "species" approach to past human diversity.
- The hallmarks of "symbolic thinking" and "behavioural modernity" seen among Moderns of the African Middle Stone Age have now also been found among coeval Neandertal populations of Eurasia.

In fact, with current data, symbolic material culture would appear to emerge in Europe considerably earlier than in Africa: >115,000 years ago at Cueva de los Aviones, in Spain (Hoffmann et al., 2018a; Zilhão and d'Errico, 2003), and at Krapina, in Croatia (Frayer et al., 2020), with regards to personal ornaments; >65,000 years ago at the Spanish cave sites of La Pasiega, Maltravieso, and Ardales (Hoffmann et al., 2018b), in the case of rock art (for a comprehensive review of the debate generated by this cave art dating work, see Zilhão, 2020, and references therein). This evidence renders void recent attempts at breathing new life into Acculturation based on the mtDNA identification of the makers of the Bachokirian culture of Bulgaria as Modern, and their dating to broadly the same timespan as the Châtelperronian (Hublin et al., 2020): one should not need to point out that whatever happened 40,000 to 45,000 years ago cannot explain the presence of jewellery and cave art in the archaeological record created by European Neandertals more than twenty millennia before.

This new setting implies a profound change to our understanding of the Transition because putative species-specific, genetic-based cognitive capabilities must now be removed from the range of potential explanations for the observed outcomes. Therefore, of the models that, through the late twentieth century, purported to explain Neandertals and their fate, only "Assimilation" (Smith et al., 2005; Trinkaus, 2007) remains consistent with the emerging empirical evidence, as geneticists are now beginning to acknowledge explicitly (Lalueza-Fox, 2021). Even though the issue continues to be debated, the implication of this new consensus is that the Transition ought to be seen as a question of History to be explained in terms of demography, social interactions, and population dynamics rather than the battlefield that it has been for the better part of the last quarter of a century — one in which the Neandertals' species-ness and intelligence were to be endlessly fought. This is the more so because of the Transition's relative proximity in time and, hence, the availability of dating methods that are appropriate for the study of processes unfolding at the scale of centuries rather than tens of millennia.

Despite this potential, looking at the Transition as an object of historical enquiry has been crippled by logical issues (e.g., concluding the premise) and the limitations of the empirical record (e.g., poor dating, uneven distribution of finds in time and space, uncertainty of association between material culture and human types). A paradigmatic example of the interpretative complications that stem from these issues is provided by ongoing debates concerning the "Ebro Frontier" model of the Transition in Iberia.

1.2. The Ebro frontier model

Building on ideas first put forward by Vega (1990) and Villaverde and Fumanal (1990), Ebro Frontier posited that the Mousterian, a technocomplex of the Middle Palaeolithic, persisted in parts of the peninsula long after the Upper Palaeolithic had already begun elsewhere in Europe (Zilhão, 1993b, 2000, 2006b, 2009). The argument was that only such a persistence could explain why the Protoaurignacian, and the Early Aurignacian remained unknown in Portugal as much as in eastern, central, and southern Spain, and this even if simply in the form of isolated finds of the corresponding index fossils. Given that Iberia is a core area of Europe's Palaeolithic settlement, it could hardly be the case that humans had deserted it at the end of the Middle Palaeolithic (as some have posited; e.g., Galván et al., 2014). Rather, if, despite 150 years of research, the Protoaurignacian and the Early Aurignacian fail to materialise over such a vast expanse of Iberia's geography it must be, so the model argued, because the corresponding chronostratigraphic time slot was occupied by a Late Mousterian.

At the time of initial formulation, there was nothing to suspect that the late persistence pattern could result from biases in research or preservation, and available chronometric results indicated that the time lag involved could be as much as ten millennia (Zilhão, 1993a). As the dating record improved, however, it became clear that we were looking at a much shorter interval, in the range of four millennia only: having begun sometime during the 42nd millennium, the pattern would have come to an end sometime during the interval between 37.0 and 37.4 ka (thousands of calendar years) ago (using the IntCal20 curve; 36.5–37.0 ka ago, using the IntCal13 curve) (Reimer et al., 2020; Zilhão et al., 2017). Regardless of its exact duration, the key palaeoanthropological corollary of Ebro Frontier was that, owing to the well-established association between technocomplexes and human types that characterises the Upper Pleistocene prehistory of western Europe, the bearers of such a Late Mousterian must have been Neandertal people.

Despite its consistency with the environmental, demographic, and archaeological information available at the time of formulation, Ebro Frontier has always remained open to challenge over two crucial points. The first is that, with regards to the initial stages of the Upper Palaeolithic, the model resorts to an "absence" argument, thereby inviting objection via the motto that "absence of evidence is not evidence of absence." The second concerns the "presence" side of things: the reality of beyond-the-Ebro Neandertals persisting for significantly longer than elsewhere in Europe requires Middle Palaeolithic sites dated to the 37–42 ka interval to be there indeed, which impinges on the reliability of the chronometric results supporting the model. Consequently, debates have tended to revolve around the empirical rather than the logical side of the problem: Can the dating evidence underpinning Ebro Frontier be trusted indeed (Wood et al., 2013)?

1.3. The stratigraphy-has-precedence principle

When radiocarbon is applicable, as is usually the case in cave and rock-shelter settings, where bone and charcoal tend to preserve well, dating ought to be straightforward. The progress made over the last twenty years in the precision of mass spectrometry measurements and the calibration of the radiocarbon timescale makes it possible to routinely date samples in the 30–45 ka ago range. Moreover, this can now be done with the precision required — 95.4 % probability intervals that are less-than-a-millennium wide — to resolve events of interest to the assessment of processes or phenomena of Ebro Frontier's posited duration. Progress in pre-treatment and processing techniques — ABOx-SC (Acid-Base-Oxidation-Stepped Combustion) and AOx-SC (where the alkaline step is skipped), for charcoal, and ultrafiltration, for bone — has also significantly ameliorated sample decontamination protocols and brought increased reliance on the accuracy of the results, i.e., on the ages reported by dating labs being, within uncertainty, the samples' true ages. However, problems remain.

Recent applications of CSRD (Compound Specific Radiocarbon Dating) have shown that ultrafiltration may be insufficient to completely remove contaminants, e.g., ones introduced when preparing the specimens (Marom et al., 2012). In the case of the Spy Neandertals, it is noteworthy that the results obtained for the bones rediscovered among the fauna, which had remained free of consolidants, nonetheless yielded ultrafiltrated bulk collagen ages that are a few millennia younger than those obtained using CSRD (Devièse et al., 2021). This and other experiments (e.g., the redating of the Western Crimean Mousterian to >50 ka instead of 35–40 ka; Spindler et al., 2021) invite caution in the assessment of radiocarbon ages close to the method's limit of applicability, even in the case of preservative-free bone samples yielding good quality, ultrafiltrated collagen; full confidence is only possible if different techniques, namely OSL (Optically Stimulated Luminescence) dating of the deposit itself, or U-series dating of stratigraphically constraining flowstone samples, provide independent corroboration.

Even when nothing is wrong with the pre-treatment and measurement of a sample, or the calibration curve used, and experimental replication supports the accuracy of a given age, it is not uncommon that results deviate from expectations. In such cases, one must ponder the possibility that the fault lies in our assessment of the sample as significant for the understanding of the event or process of interest, as the founding fathers of radiocarbon dating duly warned (Waterbolk, 1971, 1983). This is the more so in cave and rock-shelter sites because of the element of doubt introduced by post-depositional disturbance, which varies in degree but is ubiquitous. In such kinds of sites, the ideal sample will be one of self-sufficient relevance. For instance, the direct dating of a split-based bone or antler point from a given site provides space/time data on the chronology and geographic distribution of the Early Aurignacian even if the object lacks adequate contextual information; and it is the same with the direct dating of diagnostic Neandertal and Modern osteological remains to assess the tempo and mode of Assimilation in Europe.

Most of the time, however, applications of radiocarbon in Palaeolithic archaeology use a dating-by-association rationale: in a nutshell, the remains of human activity found within a certain stratigraphic envelope are assumed to belong in a "closed find" context whose datable organic components are suitable for the assessment of that activity's age. In practice, this assumption cannot be taken for granted, and this for a number of reasons, the most common being: (a) the potential presence of items that are inherited (e.g., charcoal from remobilised soil sediment, or charcoal and faunal remains biogenically or geogenically reworked from previous occupations of the place), or intrusive (e.g., charcoal and bone introduced subsurface as a result of the activity of roots, animal burrowing, or carnivore denning); (b) the dated deposit being of a multicomponent nature (e.g., when sedimentation hiatuses or deflationary processes originate palimpsests that conflate human activity remains from disparate periods); (c) the sample's age being different from the time of the human activity targeted by the dating (e.g., when fossil or subfossil ivory or shell are used as raw-material for the manufacture of points or objects of personal ornamentation). First and foremost, dating-by-association therefore requires that the selection of samples be informed by a good understanding of stratigraphy and site formation processes, and also by a solid assessment of the degree of homogeneity and stratigraphic integrity of the context the sample is intended to date (as investigated, for instance, via stone tool refitting). Such an understanding is also required to meaningfully assess the results for consistency, whether internal or external, i.e., agreement between age and stratigraphic depth, or between a result or sequence of results and well-established culture-stratigraphic frameworks.

Finally, the interpretation of age measurements also depends on the broader theoretical framework under which the dating is carried out. To take one of the examples above, the significance of the accurate dating of a split-based bone point depends on (a) the dated specimen having been correctly classified, (b) the validity of "split-based bone point" as a type of bone tool, (c) the validity of that type as an "index fossil" of the Early Aurignacian, (d) the validity of "Early Aurignacian" as a subdivision of the Aurignacian, (e) the validity of "Aurignacian" as a technocomplex, and (f) the validity of the "technocomplex" concept to express, and organise, the variation observed in Palaeolithic material culture. Where the Transition is implicated, these issues are extensively discussed by Teyssandier and Zilhão (2018); for further elaboration, readers are referred to that paper. In the following, Mousterian, Châtelperronian and Aurignacian, as well as the latter's subdivisions, are used as technocomplexes in those authors' sense. More than one century of research has shown that these categories do refer to empirically recognisable, time-and-space bounded entities and, therefore, that, in western Europe, interpretations of the archaeological record have to be assessed for consistency with the following set of established facts:

- The Mousterian is a Middle Palaeolithic technocomplex characterised, among others, by the use of a particular stone tool technology, the Levallois method; in the Upper Palaeolithic, that method is no longer used.
- The only human phenotype associated with the Middle Palaeolithic is the Neandertal phenotype.
- When found in stratigraphic association with the Mousterian or the Aurignacian, the Châtelperronian always overlies the former and always underlies the latter; the only human phenotype so far found in association with the Châtelperronian is the Neandertal phenotype.
- When found in stratigraphic succession, the different technological facies of the Aurignacian always respect the ordering implied by the naming of its subdivisions (for which Bayesian modelling provides reliable chronological boundaries): Proto (*c.* 41.5–40.0 ka), Early (a.k.a., Aurignacian I; *c.* 40.0–37.5 ka), Evolved, and Late (a.k.a., Aurignacian II, and III-IV, respectively; *c.* 37.5–35.0 ka) (Banks et al., 2013a, 2013b).
- In the Early Aurignacian and thereafter, phenotypically, all human remains are Modern or of mixed-ancestry; the makers of the Protoaurignacian remain unknown.
- Through the 45–35 ka interval, a number of artefact types have "index fossil" value: Levallois cores and blanks, of the Middle Palaeolithic; Châtelperron points, of the Châtelperronian; carinated scrapers/cores, of the Aurignacian; split-based bone points, of the Early Aurignacian; nosed scrapers/cores and Dufour bladelets of the Roc-de-Combe subtype, of the Evolved Aurignacian.

These premises substantiate the stratigraphy-has-precedence principle that I have abided by when writing about the Transition in Europe (e.g., Zilhão, 2007, 2011, 2013) and informs my assessments here too. In the following, I adopt the structure used in my previous comprehensive review of the Transition in Iberia (Zilhão, 2006b). For details on the sites therein discussed and for which no new evidence of significance has emerged, readers are referred to that review. Here, I focus on the developments of relevance to assess the issues that have structured the last quarter century of debates:

- The existence (or otherwise) and age of a Châtelperronian phase at the beginning of the Upper Palaeolithic of Cantabrian Spain and Catalonia.
- The nature of the so-called "Transitional Aurignacian" of El Castillo cave.
- The age and geographic distribution of Iberia's Protoaurignacian and Early Aurignacian occurrences.
- The age and geographic distribution of the Middle Palaeolithic sites that have been dated to the same timespan as the Protoaurignacian or the Early Aurignacian.
- The age and industrial characterisation of the earliest Upper Palaeolithic assemblages from Iberian regions situated beyond the Ebro.

The location of all the Transition sites mentioned in the text is provided in Fig. 1. Throughout, individual dating results will be quoted with their 68.3 % confidence intervals, in the format "age ± standard deviation," following the reporting conventions of radiocarbon and luminescence dating laboratories. However, the 95.4 % confidence interval of these ages is used when considering their equivalent time ranges — in the case of radiocarbon, after calibration with the IntCal20 curve or, in the case of shell samples, with the Marine20 curve (Heaton et al., 2020; Reimer et al., 2020). Note that ages are given in years BP (Before Present), i.e., counting back from 1950 CE in the case of radiocarbon, in years before the time of sample collection in the case of OSL, and in years before 2000 CE in the case of stadial and interstadial boundaries derived from the Greenland oxygen isotope record (Rasmussen et al., 2014).

2. To the north

Building on Zilhão and d'Errico (1999), my 2006 review concluded that the chronostratigraphy of the Transition in the Cantabrian strip and Catalonia was closely aligned with western Europe's: the Upper Palaeolithic began with the Châtelperronian, followed by the Protoaurignacian and then the Early Aurignacian. Using the empirical evidence acquired since, the following sections will assess whether this scenario remains unfalsified.

2.1. The Mousterian

It was once proposed that the cave site of Ermitons (Sadernes, Girona) represented persistence into the Aurignacian time range of a Middle Palaeolithic Neandertal population inhabiting the mountainous interior of the province (Maroto, 2001-2002; Ortega and Maroto, 2001). Similar claims were made for the rock-shelter of Fuentes de San Cristóbal (Veracruz, Huesca), in Aragón (Rosell and Canals, 2014; Rosell et al., 2000), and the cave site of Esquilleu (Cillórigo de Liébana), in Cantabria (Baena et al., 2012). If confirmed, these claims would imply that, in northern Iberia, the Transition had been a mosaic process featuring a long-term contemporaneity of technocomplexes and human types.

My 2006 review argued, however, that (a) level IV of Ermitons was dated by minimum ages only and in any case was a multi-component carnivore den that also yielded some Châtelperronian lithics (see below), (b) the uppermost Middle Palaeolithic of Fuentes de San Cristóbal, level P, yielded a single diagnostic (a Mousterian point), while the large standard deviation of the single charcoal date then available (36,000 ± 1900 BP; OxA-8590) precluded any certainty that the site was indeed late, and (c) the young dates for Esquilleu reflected the mixed composition of uppermost levels III-V as, in my view, they contained material that was either intrusive (e.g., a level III bone dated to the Tardiglacial) or reworked (e.g., Mousterian lithics derived from the underlying, extensively bioturbated levels VI-X).

All three sites have since been redated (Maroto et al., 2012). Level IV of Ermitons yielded an ibex tooth date of 40,580 + 550/-470 BP (GrA-33813) and a cave bear tooth date of >45,000 BP (GrA-33814). These results concur with a multi-component interpretation of the level, even though it cannot be excluded that the younger is also a minimum age only, seeing as it was obtained on non-ultrafiltrated collagen. Fuentes de San Cristóbal yielded a series of charcoal dates for the base of the sequence (levels E-G) that are not age/depth consistent. In addition, the samples were pretreated with the standard ABA (Acid-Base-Acid) protocol; these facts suggest that we are dealing with minimum ages only and that the site's Middle Palaeolithic is indeed older than indicated by the result for uppermost level P. Level III of Esquilleu yielded three ultrafiltrated collagen dates ranging between 19,300 ± 100 BP

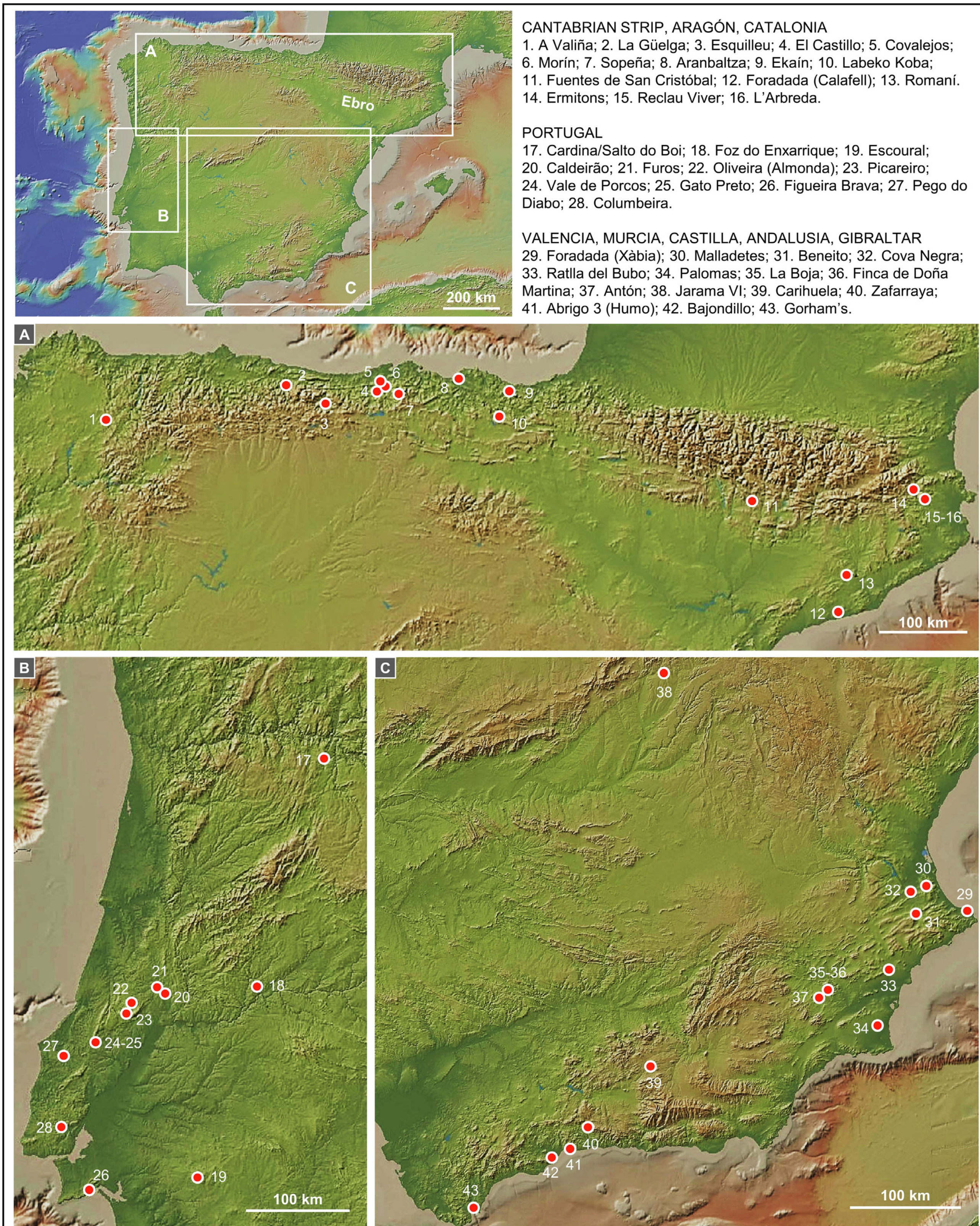

Fig. 1. Location of the Transition sites mentioned in the text. **A.** Northern Spain. **B.** Portugal. **C.** Eastern, central, and southern Spain. Relief map: Global Multi-Resolution Topography Synthesis (https://www.gmrt.org/GMRTMapTool/) (Ryan et al., 2009).

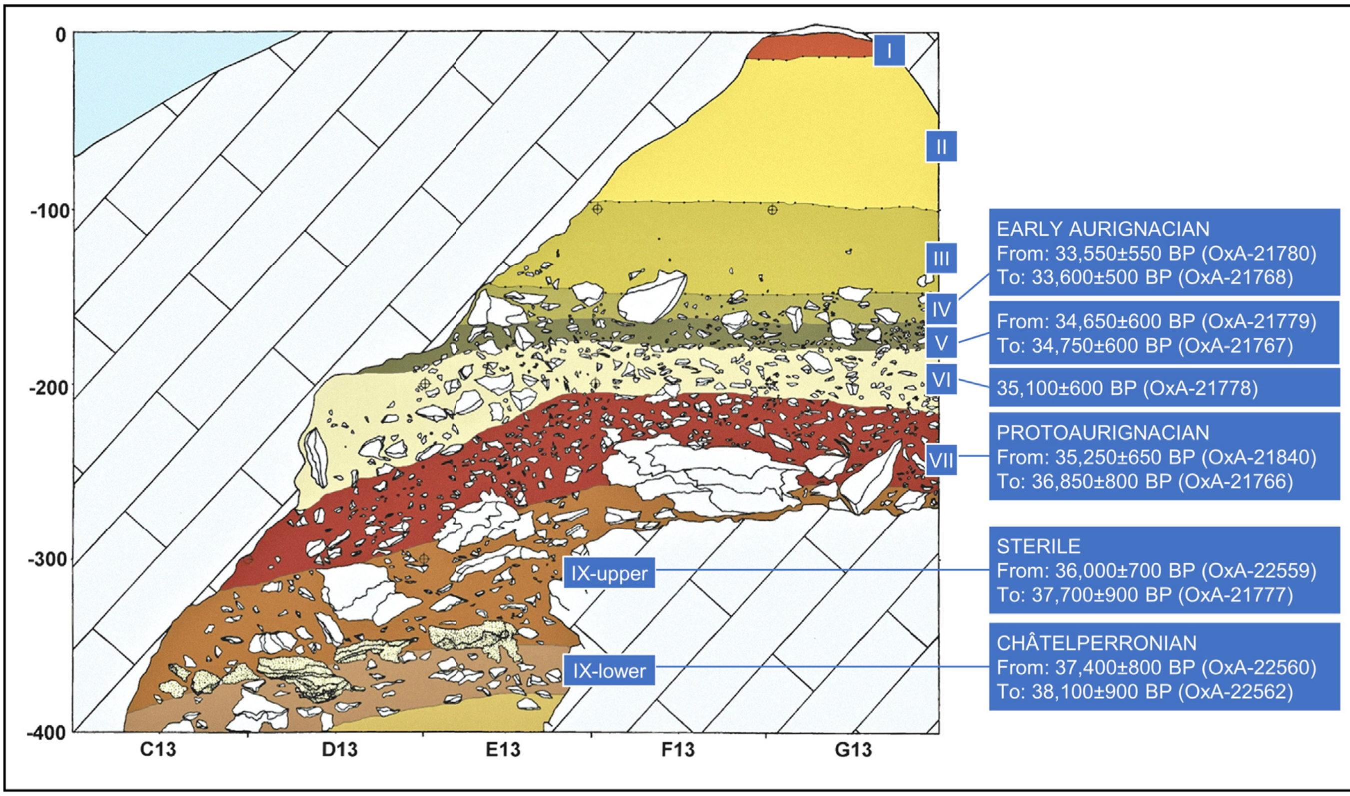

Fig. 2. Labeko Koba. Stratigraphy and dating. After Rios-Garaizar et al. (2012a) and Wood et al. (2014), modified.

(OxA-19967) and 20,810 ± 110 BP (OxA-19246), corroborating both my assessment and Mallol et al.'s (2010) conclusion that uppermost Unit B of the geological succession (comprising archaeological layers 3–11) is significantly disturbed by cryoturbation processes.

Persistence of the Middle Palaeolithic into the time range of the Protoaurignacian might also be inferred from the date published by Maroto et al. (2012) for level XII of the cave site of Sopeña (Miera, Cantabria): 35,500 +650/-800 BP (GrA-39761). The site, however, is a cave bear den, and the sample was an unidentified bone. Even though the associated stone tools are of undeniable Mousterian affinities, there is no reason to believe that the dated bone reflects the activity of humans rather than bears. Since, the interpretation of this site has been further complicated by additional results for two samples from level XII and one from level XI (the latter considered to belong in an undefined early Upper Palaeolithic), each dated both with and without ultrafiltration (Pinto-Llona and Grandal-d'Anglade, 2019). In only one case, however, did both sub-samples provide a statistically identical result: level XII sample SPÑ02-17/07-87758-I6.NXII, dated by Beta-470472 and Beta-470469, and which a mean pooled radiocarbon age of 44,353 ± 362 BP can be calculated from using the algorithm in Calib 8.1 (Stuiver and Reimer, 1993). The implication of this result is that at least one, if not all of the following, must be true: the non-ultrafiltrated GrA-39761 result reflects incomplete decontamination; level XII is a palimpsest spanning some ten millennia; vertical post-depositional displacement in connection with the stratigraphic discontinuity observed at the interface between levels XI and XII precludes dating-by-association of their archaeological components; all of the available dates for levels XI and XII are inaccurate. Be it as it may, Sopeña cannot be used in support of the regional Middle Palaeolithic having persisted into the timespan of the Châtelperronian or the Aurignacian.

2.2. The Châtelperronian

Level IX-lower of the Basque cave site of Labeko Koba (Arrasate, Gipuzkoa) constitutes uncontroversial, techno-typological proof of the Châtelperronian extending into Iberia. The integrity of the assemblages of stone tools and faunal remains is warranted by the *c.* 50 cm-thick, sterile, or near-sterile deposit (levels IX-upper and VIII) separating it from the Protoaurignacian in level VII (Arrizabalaga and Altuna, 2000; Arrizabalaga et al., 2003) (Fig. 2).

Another site, Cueva Morín (Villaescusa, Cantabria), provides corroborating evidence; despite lacking sedimentological entity and corresponding to no more than a thin, soliflucted, and cryoturbated contact zone between levels 11 (Mousterian) and 8–9 (Protoaurignacian) (Laville and Hoyos, 1994), level 10 of this cave yielded a number of Châtelperron points. My 2006 review argued that the sequence's formation process implied a degree of stratigraphic mixing at the elevation of level 10, as intimated by the few Mousterian and Aurignacian diagnostics found therein and by the Châtelperron points in level 9; yet the evidence from Morín demonstrated that bearers of a Châtelperronian technology were present in Cantabria in the time interval, between Mousterian and Protoaurignacian, when one might expect them to be there indeed. Further support for this notion was provided by El Castillo cave (Puente Viesgo, Cantabria), a major site featuring a >15 m-thick stratigraphic succession that spans the whole of the Upper Pleistocene (Cabrera and Bischoff, 1989); here, a minor Châtelperronian component was suggested to exist in the "Aurignacian Delta" level of Obermaier's early twentieth-century excavation of the site (Zilhão and d'Errico, 1999; 2003).

Two recent additions to the corpus are in the Basque Country: the open-air site of Aranbaltza (Barrika, Euskadi), and level Xa of

Fig. 3. Châtelperron points from northern Spain. **A.** Aranbaltza. **B.** Cova Foradada (Calafell). After Morales et al. (2019) and Rios-Garaizar et al. (2012b), modified.

the cave site of Ekaín (Deva, Gipuzkoa), both undated. The lithic assemblage retrieved in the former is large (>2000 items) and characteristic in both technology and typology, with 12 typical Châtelperron points among its 272 retouched tools (Rios-Garaizar et al., 2012b) (Fig. 3A). The lithic assemblage retrieved in level Xa of Ekaín is very small (11 items only) but includes two Châtelperron points, one complete and one fragmentary (Rios-Garaizar et al., 2012a). The typological rationale underpinning the level's chronostratigraphic assignment to the Châtelperronian is supported by its position in the sequence: under level IXb, an Early Aurignacian context whose entity and integrity are supported by a number of refits (Rios-Garaizar, 2011).

At Labeko Koba, no ambiguity exists in the association between the samples used for dating and the archaeological context they are intended to date. Yet, the first batch of results for the Châtelperronian turned out to be much younger than expected: the oldest (Ua-3324, 34,215 ± 1265 BP) placed it in the range of 36.2–41.4 ka, while the youngest (Ua-3034, 26,575 ± 505 BP; 29.9–31.6 ka) fell squarely in the time range of the Gravettian. In line with the stratigraphy-has-precedence principle, my 2006 review argued for incomplete sample decontamination to be the culprit and the reported results to be minimum ages only. Redating of the sequence proved that such was indeed the case: using ultrafiltrated collagen, four statistically indistinguishable ages, overlapping at 1σ between 41.6 and 42.7 ka ago, i.e., within the right chronostratigraphic ballpark, have been obtained for level IX-lower (Wood et al., 2014) (Fig. 2).

New dating work was also carried out at Morín, using charcoal samples collected from extant stratigraphic profiles (Maroto et al., 2012). The results corroborate the caveats outlined in my 2006 review; they confirm that the sediments from Protoaurignacian levels 8 and 9 contain inherited, reworked, and intrusive material, as the ages obtained for them — 40,060 ± 350 BP (OxA-19084) and 33,430 +250/-230 BP (GrA-33891), respectively — came out in reverse order and are inconsistent with regional chronostratigraphy. In this context, whether the sample used to date Morín level 10 was associated with the Châtelperronian material therein found is questionable. In addition, the sample was pre-treated with only the first step of the ABA protocol, and so the result obtained (29,380 +260/-240 BP; GrA-33823) is likely to be no more than a minimum age; it must be rejected as a Châtelperronian date on that count too.

My 2006 review noted that Morín and Castillo marked the westernmost edge of the Châtelperronian's geographic span. Claims existed for the technocomplex to be represented in Galicia, at the cave site of A Valiña (Castroverde, Lugo) (Villar and Llana, 2001), but, as also argued by others (Maíllo-Fernández, 2007), the evidence derives from dates obtained on bone from a carnivore den and the few associated artefacts' techno-typological affinities with the Châtelperronian are far from evident. Now, a data point 100 km westward of Morín is provided by Zone D of the cave and rock-shelter site of La Güelga (Ñarciandi, Asturias) (Menéndez et al.,

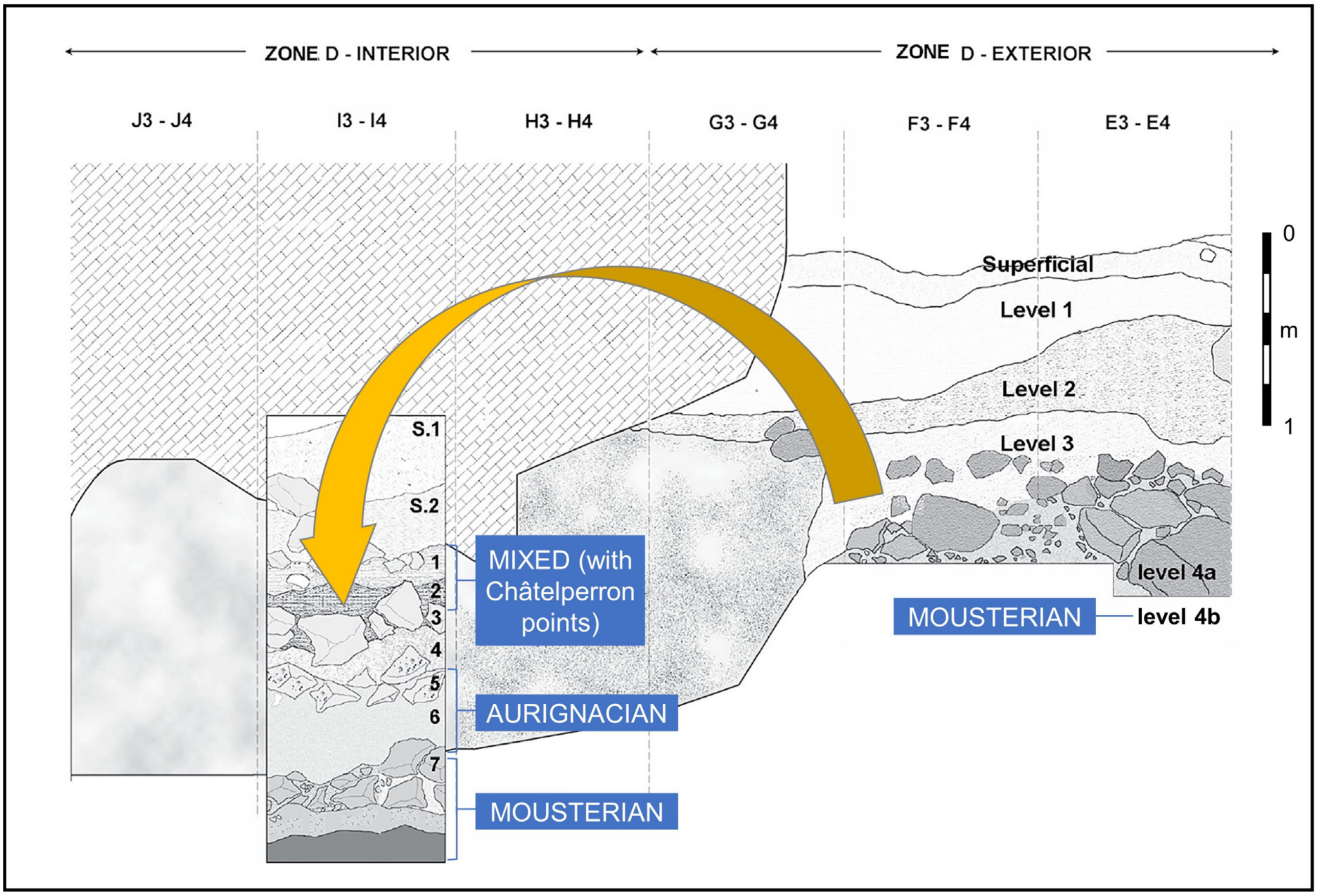

Fig. 4. La Güelga. Correlation between the Exterior and Interior trenches of the site's zone D. After Jordá et al. (2013), modified.

2018). This addition suggests that the Châtelperronian range may indeed have encompassed the entire extent of the shores of the Bay of Biscay, from the French Aquitaine in the North to Galicia in the West.

La Güelga is also interesting in that the site was initially thought to be an instance of the Châtelperronian occurring stratigraphically above the Aurignacian (Menéndez et al., 2005). The base of the deposit in question (levels 5–9 of the Interior trench of Zone D) is a normal Aurignacian-over-Mousterian sequence sealed by boulders denoting an episode of overhang collapse (levels 3–4); these boulders are overlain by stratigraphic units that yielded a few Châtelperronian points (levels 1–2). Dating of the sequence with ultrafiltrated collagen produced a set of five statistically indistinguishable results for level 5 that fall in the range of the Early Aurignacian and are consistent with regional chronostratigraphy (Menéndez et al., 2018). The single result for level 2 — 40,300 ± 1200 BP (OxA-27958) — is in good accord with the Châtelperron points therein found; however, levels 1–2 also yielded burins, retouched blades, sidescrapers, denticulates, and Levallois flakes. This heterogeneous composition suggests that levels 1–2 correspond to a reworked deposit commingling material of disparate industrial affinities, consistent with the geoarchaeological study's conclusion that said levels are reworked along a slope (Kehl et al., 2018): in all likelihood, what we have here is redeposition in the cave's Interior area of the upper part of the stratigraphic sequence once found in the adjacent Exterior area (Fig. 4). This hypothesis is consistent with the fact that only the base of the extant Exterior sequence, Mousterian level 4b, is an *in situ* deposit — one that is (a) topographically above the Aurignacian deposit of the Interior area and (b) dated to the same range as the latter's Mousterian level 9 (>45.3 ka ago).

At the opposite end of the Châtelperronian's geographic distribution at this latitude, it has been claimed that level A of the Abric Romaní (Capellades, Barcelona), well-known to represent a palimpsest of different Upper Palaeolithic occupations capping the site's long and impressive sequence of Middle Palaeolithic habitation floors, included no less than 29 Châtelperron points (10 typical and 19 atypical) (Camps and Higham, 2012). However, as shown by Vaquero and Carbonell (2012), the claim rests on an error of classification; those 29 items are not Châtelperron points, and the contrast between the lithics that Camps and Higham illustrate with drawings and the photos of the same objects provided by Vaquero and Carbonell suffice to dismiss the former's typological attributions.

This spurious reference apart, the evidence for the Châtelperronian in Catalonia was restricted, until recently, to a small number of diagnostic Châtelperron points: two from Ermitons; and at least two and four, respectively, from the close-by rock-shelters of Reclau Viver and L'Arbreda (Serinyà, Girona). However, these specimens came not from individualised stratigraphic units reflecting discrete, representative occupations: the Ermitons pieces were found in Middle Palaeolithic level IV; those from Reclau Viver came from a

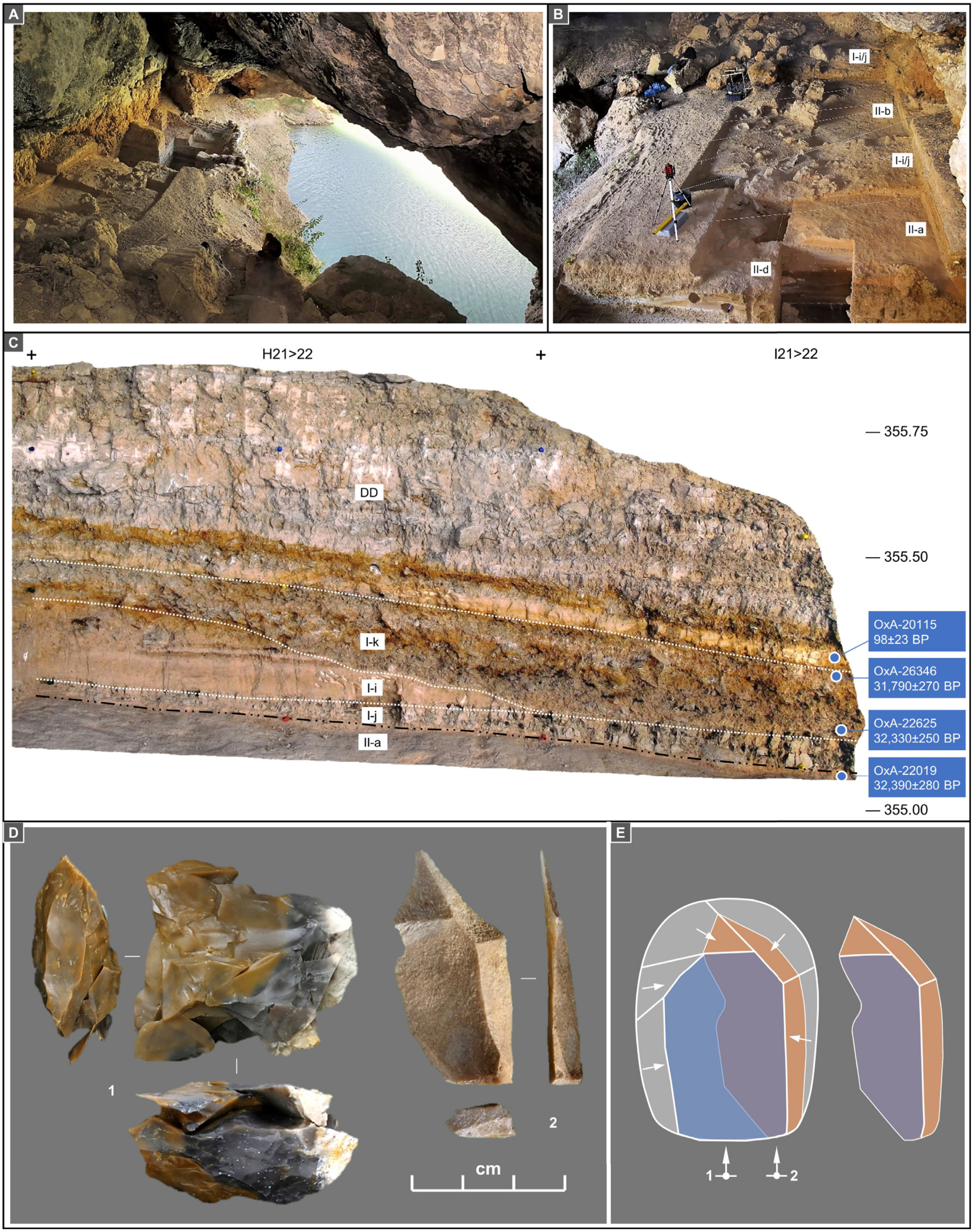

Fig. 5. Cueva Antón. **A.** Overview of the excavation (at the end of the 2012 field season). **B.** The fluviatile units exposed under Middle Palaeolithic layer I-k (at the end of the 2011 field season). **C.** Stratigraphic profile representing the AS1 sub-complex and associated ABOx-SC dating results (elevations are in m asl). **D.** Diagnostic lithics from layer I-k: 1. centripetal core for small flakes (J19-4), with refits; 2. laminar Levallois flake (H21-8; lateral removal after the extraction of a preferential flake in a Levallois recurrent reduction sequence). **E.** Schematic of the reduction sequence leading to the extraction of H21-8.

>80 cm-thick "Aurignacian" deposit dated to between 30,190 ± 500 BP (OxA-3726), at the top, and 40,000 ± 1400 BP (OxA-3727), at the base; and the L'Arbreda items had been excavated at the interface between Protoaurignacian level H and immediately underlying Mousterian level I. My 2006 review argued that, notwithstanding, Châtelperron points had index fossil significance and, therefore, presence of the type at those three sites sufficed to conclude that, even though the context of the finds was ambiguous or mixed, the Catalonian Upper Palaeolithic did begin with a Châtelperronian phase. An alternative view was that the specimens in question bore no more than superficial similarity to the Châtelperron point and simply represented an aspect of the variation seen in other types of backed implements commonly found in regional Mousterian assemblages (Garcia Garriga et al., 2012; Maroto, 2001-2002).

The identification of a discrete Châtelperronian level at the cave site of Foradada (Calafell, Tarragona), situated along the coast about half-way between Barcelona and Tarragona, has now settled the debate (Morales et al., 2019). Its level IV yielded a set of eight Châtelperron points (Fig. 3B) associated with an unpierced marine shell (*Steromphala varia*) and a pedal phalanx of the imperial eagle (*Aquila adalberti*) bearing cut-marks consistent with extraction of the claw for symbolic purposes. The radiocarbon dates obtained on charcoal samples, however, are significantly younger than expected, ranging from 31,900 ± 200 BP (Beta-414539) to 34,570 ± 240 BP (Beta-435465). These results were obtained on samples pre-treated with the ABA protocol, but another two, obtained on samples for which the AOx-SC protocol was followed, are no older.

Explaining the Foradada dating anomaly is not easy. At first glance, the comparison between the ABA and Ox-Sc results would seem to suggest that incomplete decontamination is not an issue and, therefore, that dissociation between the dating samples and the archaeology they were supposed to date is where the problem resides. For instance, the ages could reflect the presence of charcoal particles introduced post-depositionally, during the interval represented by the major stratigraphic discontinuity separating Châtelperronian level IV from Aurignacian level IIIc above. Noteworthy is also that, if both units appear in direct contact through most of the excavated area, elsewhere at the site they are separated by an up to 50 cm-thick travertine platform — level TP-2. Thus, it cannot be ruled out that, because of the intense carbonate precipitation occurring at the site through the time interval represented by that travertine, the dated samples contained exogenous carbon the pre-treatment protocols failed to remove completely. This hypothesis is consistent with the fact that the ages obtained for level IIIc are also younger than expected for its archaeological content (which, based on the presence of two split-base bone point fragments, belongs in the Early Aurignacian). Moreover, in level IIIc, the difference between the ABA and ABOx-SC results for sub-samples of the same sample is significant (up to 1500 years). With available information, the parsimonious reading of the Foradada results is that they are minimum ages only.

2.3. The Aurignacian

Labeko Koba also produced new, ultrafiltrated collagen results for the site's Protoaurignacian and Early Aurignacian occupations (levels VII and IV-VI, respectively) (Wood et al., 2014) (Fig. 2). The ages obtained are consistent internally, i.e., in terms of age/depth, as much as externally, i.e., with the wider chronostratigraphic framework (Banks et al., 2013a, 2013b). This consistency supports my proposition that the Labeko Koba sequence be considered as the standard reference to assess the Transition in northern Iberia (Zilhão, 2006b, 2007, 2011). It is against this standard that we need to look into the claims, based on radiocarbon results obtained at El Castillo and Covalejos (Piélagos, Cantabria), that an Aurignacian or Aurignacian-like Upper Palaeolithic could have emerged in northern Spain well before 41–42 ka.

At El Castillo, a long-standing hypothesis has been that level 18 of the late 20th-century excavation of the cave's porch represents a "Transitional Aurignacian" in which one would find Upper Palaeolithic technological innovations developing within a Middle Palaeolithic substrate; a number of charcoal samples would date this context to as early as 42.6–45.6 ka ago (e.g., OxA-2477, 41,100 ± 1100 BP) (Cabrera-Valdés and Bischoff, 1989; Cabrera et al., 2001). In fact, that level is a Mousterian deposit in which the few Upper Palaeolithic-like artefacts reflect either intrusion or palimpsesting (Zilhão and d'Errico, 1999, 2003); to take it as the equivalent of Obermaier's 1 m-thick "Aurignacian Delta" deposit and assume that the latter's truly diagnostic Aurignacian tools are of the age indicated by the new excavations' radiocarbon-dated charcoals is therefore unwarranted. Indeed, Obermaier himself noted that a conspicuous Mousterian component existed in his Aurignacian Delta, which he divided into an upper part rich in split-based points and a lower one rich in sidescrapers. Analysis of the stone tools from levels 16–22 has also questioned the "transitional" nature of the core reduction systems employed in the Mousterian levels found below level 18 (Pastoors and Tafelmaier, 2013).

To test these contradicting views, Wood et al. (2018) dated a number of cut-marked bone samples from both the new and the old excavations, as well as a split-based point antler blank from the latter. They used ultrafiltrated collagen and, for level 18, obtained five results between 42,700 ± 1600 BP (OxA-22403) and 46,000 ± 2400 BP (OxA-21973), leaving no doubt that it is a Middle Palaeolithic deposit. They further showed that Obermaier's Aurignacian Delta conflates remains left behind by more than one occupation: minimally, one from the Early Aurignacian and one from the Mousterian, represented by, respectively, OxA-21713 (the antler blank; 35,000 ± 600 BP, 38.9–41.3 ka) and OxA-22018 (42,100 ± 1500 BP; 42.7–47.2 ka).

At Covalejos, the Aurignacian is found in level C, but the two available dating results, both on non-ultrafiltrated collagen, are inconsistent: 32,840 +280/-250 BP (GrA-24200), on bone, and 37,940 +400/-350 BP (GrA-33877), on a tooth (Sanguino and Montes, 2005; Yravedra-Sainz de los Terreros et al., 2016). Given that immediately underlying level D is Mousterian and yielded significantly older, non-ultrafiltrated collagen results (e.g., 43,050 +750/-550 BP; GrA-33811), it is likely that a many millennia-long hiatus exists at the site. In addition, taphonomic analysis of the bone assemblages has shown that, according to a number of indicators, level C falls in the "carnivores first" mode of carcass access. Whether the age indicated by GrA-33877 (41.9–42.5 ka) is a minimum age only, and whether it reflects human or carnivore activity must therefore remain open issues; this dating result cannot be used to support that an earlier-than-expected Aurignacian exists in the region's archaeological record.

At the other end of the Cantabro-Pyrenean cordillera, charcoal results for the basal part of L'Arbreda's level H (e.g., AA-3781, 39,900 ± 1300 BP, 42.0–45.0 ka) once provided a counterpart for the precocious age of El Castillo's "Transitional Aurignacian"

(Bischoff et al., 1989). My 2006 review argued that, even though no reason existed to suspect the accuracy of the ages, their stratigraphic association with the Aurignacian lithics was questionable. The reasons were threefold. Firstly, the deposit was excavated in arbitrary horizontal spits eventually shown to cut across stratigraphic boundaries; therefore, when used for the assemblages of artefacts and faunal remains, the “level” labels were post-excavation constructs whose equivalence to the units defined by observation of the excavation trench's profiles was hypothesis, not fact. Secondly, L'Arbreda's so-called “Upper Sequence” (archaeologically, Mousterian-to-Solutrean) was a slope deposit with a significant dip whereby, outward, Mousterian level I was found topographically above the interior area the samples from level H had been taken from. Thirdly, this configuration implied a significant probability of inherited material being present in level H. Based on these observations and the index fossils represented, I argued that the anomalous ages reflected problems of sample association and that levels I, H and G were to be interpreted as recording successive occupations occurring in the same order as and coevally with their counterparts elsewhere in northern Spain and neighbouring France — Mousterian followed by Châtelperronian, Protoaurignacian, and Early Aurignacian, the whole capped by an Evolved Aurignacian.

Using ultrafiltrated collagen, Wood et al. (2014) measured the age of samples of anthropogenically modified bone from levels G (three), H (eight) and I (four). As a test of the validity of my alternative interpretation, the verdict is clear: the level G results came out fully within the expected range; the level H results are no older than 36,000 ± 700 BP (OxA-21784; 39.8–42.0 ka) and span the Protoaurignacian-to-Early Aurignacian interval (though a couple reflect the presence of items of Aurignacian II age in the “level H” set of faunal remains); of the results for level I, one, dated twice, fell in the range of the Evolved Aurignacian (possibly a minimum age only, but almost certainly reflecting unrecognised post-depositional disturbance), two fell in the range of the Châtelperronian (and of the previously available charcoal dates for overlying level H), and only one yielded an age unambiguously within the timespan of the Mousterian (44,400 ± 1900 BP; OxA-21702). In short: L'Arbreda fits the regional chronostratigraphic pattern, and Bischoff et al.'s (1989) earlier-than-expected Protoaurignacian dates measured the age of inherited material indeed.

3. To the South

Recall that, in eastern, central, southern, and western Iberia, my 2006 review argued that the Transition consisted of the replacement of a late-persisting, Neandertal-associated Mousterian by a Modern-associated Evolved Aurignacian. Others argued for the Middle Palaeolithic to have persisted even longer: Bicho et al. (2015), de la Peña (2013), and Marreiros and Bicho (2013), for instance, proposed that those regions' earliest Upper Palaeolithic was the Gravettian, while Finlayson et al. (2006, 2008) envisaged Neandertals persisting in Gibraltar until as late as the LGM (Last Glacial Maximum). Conversely, Wood et al. (2013) questioned the persistence pattern altogether, arguing that the dating evidence was of insufficient quality to support that, south of the Ebro drainage, the Transition was out of phase with the rest of Europe. More recently, Cortés-Sánchez et al. (2019) argued for the Aurignacian to emerge in Malaga (Andalusia) even earlier than in the Franco-Cantabrian region, a stance since endorsed for Portugal by a group of authors who, until then, had been keen promoters of the notion that the Upper Palaeolithic of the country had not begun until some ten millennia later, with the Gravettian (Haws et al., 2020).

Confused? You probably are, and not with no reason.

The good news is that at least one aspect of the controversy — whether, beyond the Ebro, the Upper Palaeolithic began with the Aurignacian or the Gravettian — seems to have been settled. A consensus now exists that the Aurignacian extended into Andalusia and Portugal. As the Châtelperronian remains unknown and no claims to its identification have ever been forthcoming, the debate now has a much narrower focus. The key questions are: How early is these regions' Aurignacian? How late is their Late Mousterian? Do these technocomplexes overlap in any manner, spatial or temporal, of archaeological significance?

3.1. *The Late Mousterian*

After discussing all the possible instances of a late-persisting Mousterian, my 2006 review concluded that a significant number were to be rejected due to insufficient or inaccurate dating. That rejection has since been corroborated for the cave sites of Cova Negra (Xàtiva, Valencia), Cueva del Boquete de Zafarraya (Alcaucín, Málaga), and Gruta Nova da Columbeira (Bombarral, Portugal) (Eixea et al., 2020; Villaverde Bonilla and Eixea Vilanova, 2017; Wood et al., 2013; Zilhão et al., 2011).

I had retained ten other cave sites as worthy of consideration: Jarama VI (Valdesotos, Guadalajara), Sima de las Palomas de Cabezo Gordo (Torre Pacheco, Murcia), Cueva de la Carihuela (Piñar, Granada), Cueva Bajondillo (Torremolinos, Málaga), Complejo del Humo (Abrigo 3; La Araña, Málaga), Gorham's Cave (middle part; Gibraltar), Lapa dos Furos (Tomar, Portugal), Gruta da Oliveira (Torres Novas, Portugal), and Gruta da Figueira Brava (Setúbal, Portugal). Of these:

- The Jarama VI sequence is now known to be significantly older; even uppermost level 1, previously assigned to the Upper Palaeolithic (Jordà, 2001), is in fact Middle Palaeolithic (and has been dated by radiocarbon to >50.2 ka; Kehl et al., 2013; Ruiz et al., 2020; Wood et al., 2013).
- At Palomas, the evidence remains inconclusive (Trinkaus and Walker, 2017; Walker et al., 2008). The loose deposits capping the excavated sequence (Unit A) contain Middle Palaeolithic stone tools and fragmentary Neandertal remains, and the ages obtained by luminescence and U-series D/A (Diffusion/Adsorption) on bone set a maximum age of 45.3 ka ago for the base of that deposit. Radiocarbon dates on burnt bone found higher-up suggest that the middle of Unit A dates to 39.6–40.1 ka (e.g., OxA-15423, 35,030 ± 270 BP). Even though the accuracy of burnt bone dates has been questioned (Zazzo, 2014), 50 cm more of sediments that also contain nothing but Middle Palaeolithic stone tools and Neandertal remains are found above the elevation of the radiocarbon-dated samples; it is therefore likely, but by no means certain, that Unit A does extend beyond 40 ka ago.
- For Carihuela, Carrión et al. (2019) published a series of new radiocarbon results based on coprolites or on organic carbon extracted from a range of materials. The coprolite results show significant reworking of the upper part of the stratigraphic succession, with little to no agreement between age and associated industry (e.g., “Bronze Age” levels with specimens dated to *c.* 18 ka, or “Final Middle Palaeolithic” levels with specimens dated to 21–22 ka). Most of the other results were obtained on samples of bulk sediment, sediment and bone, or sediment and charcoal. However, as shown by the Gruta da Nova da Columbeira experiment (Zilhão et al., 2011), such types of samples are inevitably biased by younger carbon introduced through soil formation processes. The only potentially reliable result is Poz-45194, obtained on charcoal from the base of unit IV in section I of Chamber III: 39,800 ± 1200 BP (42.1–44.8 ka). Lithics of

Middle Palaeolithic affinities are found higher-up in unit IV; the age of such levels remains, however, uncertain, and, at their elevation, assemblage homogeneity and stratigraphy integrity are in any case problematic. Thus, currently, only palaeoenvironmental correlation based on pollen analysis supports persistence of the Middle Palaeolithic beyond 42 ka at Carihuela; overall, the evidence remains inconclusive, as Carrión et al. (2019) indeed acknowledge.

- Bajondillo appeared in my list because of an AMS date of "*c.* 34 ka" for level 14 of the sequence reported by Cortés-Sánchez et al. (2005: Fig. 5). However, that paper provided no further detail, and no mention of that result exists in subsequent publications.
- At "Abrigo 3" (Complejo del Humo), level 17 represents the latest Middle Palaeolithic. Preliminary reports mentioned a TL (thermoluminescence) date of *c.* 35 ka for level 23, a thick flowstone found *c.* 1.5 m lower down. That this TL result represented a maximum age for level 17 has since been contradicted by radiocarbon dating to 40,730 ± 310 BP (42.6–43.6 ka; OxA-16803) of a mussel shell from level 18 (Ramos Fernández et al., 2011–2012). This result is not inconsistent with the notion that level 17 post-dates the 40–42 ka interval, but whether such is indeed the case remains an open issue.
- Level IV of the trench excavated 1997–2005 in the back of Gorham's Cave (Gibraltar) yielded a series of dating results that Finlayson et al. (2006) took for evidence that Neandertals persisted locally until at least 28 ka ago. As shown by Zilhão and Pettitt (2006), the series is stratigraphically inconsistent and includes results of questionable provenience, association, and chemical reliability. In Stringer and Barton's 1990s excavation of the middle part of the cave, however, a hearth remnant was identified at the contact between Contexts 18 and 16; designated Context 24, this hearth yielded a burnt pinecone bract dated to 32,280 ± 420 BP (35.6–37.7 ka; OxA-7857) (Pettitt and Bailey, 2000). The associated stone tool assemblage is, however, poor; a quartzite denticulate is the only retouched specimen. Together with similar dating results obtained from trenches further inside the cave (Pettitt et al., 2002), Context 24 supports persistence of the Middle Palaeolithic in the area beyond *c.* 38 ka ago, i.e., into the time range of the Early Aurignacian. However, such a support must be qualified, as the evidence is insufficient for full confidence in the charcoal samples' cultural association to be possible.
- At Furos, a large, typical Levallois flake was retrieved in level 3 of the succession. A maximum age for the poor assemblage represented by this flake is provided by underlying level 4, an archaeologically sterile unit radiocarbon dated on a bulk sample of land snail shells to 34,580 +1160/-1010 BP (ICEN-473). Additional dating is required to rule out the possibility that this result is a minimum age only.
- At Oliveira, uppermost Middle Palaeolithic layer 8 yielded a substantial, techno-typologically unambiguous stone tool assemblage. Mutually consistent ages in the 37–38 ka interval were obtained by radiocarbon and U-series D/A dating on samples of, respectively, burnt, and unburnt bone (Hoffmann et al., 2013; Marks et al., 2001). Since, however, OSL dating of the deposit and the constraining U-series ages obtained for the flowstone capping the archaeological succession have shown that the Oliveira deposit is entirely of Last Interglacial age (Zilhão et al., 2021b).
- At Figueira Brava, the previously available radiocarbon result, obtained on a bulk sample of limpet shells, has been shown to vastly underestimate the true age of the deposit. Based on U-series dating of interstratified or stratigraphically constraining flowstone, corroborated by OSL dating of the sediments themselves, the site's archaeology is entirely of Last Interglacial age (Zilhão et al., 2020).

The persistence pattern remains unfalsified in a few of the sites listed above, but the supporting evidence is ambiguous. The case therefore now rests principally on four sites whose dating and stratigraphic context are robust. In three, the archaeological remains are found in sediments accumulated by riverside dynamics: Cueva Antón (Mula, Murcia), Cardina/Salto do Boi (Vila Nova de Foz Côa, Portugal), and Foz do Enxarrique (Vila Velha de Ródão, Portugal). The fourth is a cave site: Gruta do Caldeirão (Tomar, Portugal).

3.1.1. Cueva Antón

This large cave/rock-shelter cavity harbours a *c.* 3 m-thick fluviatile deposit (Fig. 5A-B): complex AS (Archaeological Succession), a remnant of the 5–7 m level of the River Mula terrace staircase. The lower part (sub-complexes AS2-AS5) dates to MIS (Marine Isotope Stage) 5a. The upper part (sub-complex AS1), separated by a paraconcordant unconformity, is of MIS 3 age and reflects a deposition environment of alluvial floodplain alternating and ending with wall degradation and runoff: lenses of fine, sandy-silty alluvium deposited during low-energy inundation events form the base of AS1 (layers I-i, I-j, II-a, II-c, and II-b); the top (layers I-g, I-h, and I-k) is an unconsolidated breccia of small, angular limestone fragments with a clayey silty matrix reflecting continued, but episodic and very low-energy inundation of the site (Fig. 5C). Layer I-k yielded a small Mousterian assemblage, for which a maximum age is provided by the ABOx-SC date obtained on juniper charcoal collected in immediately underlying alluvial layer II-a: 32,390 ± 280 BP (36.2–37.4 ka) (Angelucci et al., 2013, 2018; Burow et al., 2015; Zilhão et al., 2010a, 2016, 2017).

The result for layer II-a is part of a fully age/depth-consistent set of four ABOx-SC results for layers I-k, II-a, and II-b; their accuracy and stratigraphic association are uncontested. Even though acknowledging that such is the case, Wood et al. (2013) have expressed reservations as to the nature of the I-k assemblage (Fig. 5D-E): owing to its "small size and largely undiagnostic nature," one would not be allowed to use it as evidence for the late survival of Neandertals. Since, however, the complete assemblage has been published; it remains small, but a number of the last blanks extracted prior to discard of an exhausted core have been refitted onto it (Zilhão et al., 2017). This refit unit illustrates application of the Levallois core reduction method, and the diagnostic nature of Levallois reduction is unquestionable: in western Europe, it constitutes a hallmark of the Middle Palaeolithic, and is altogether unknown in unmixed Châtelperronian and Aurignacian assemblages (Bachellerie, 2011; Teyssandier and Zilhão, 2018).

The refitting evidence and the site's formation process warrant the stratigraphic integrity and the chronological homogeneity of layer I-k. Short of questioning the accuracy of the ABOx-SC radiocarbon dating of sub-complex AS1, something for which no evidence exists, and no one ever proposed, Cueva Antón documents persistence of eastern Spain's Middle Palaeolithic until at least 37.4 ka ago.

3.1.2. Cardina/Salto do Boi

Cardina is a large platform dominating a meander of the River Côa located adjacent to and upstream of a rhyolite dike, the Salto do Boi (Ox Leap). It was here, in 1995, that discovery of a rich Gravettian-to-Magdalenian sequence first provided an immediate archaeological context for the valley's open-air Palaeolithic rock art (Zilhão et al., 1995).

Under the known colluvial sequence, recent and ongoing excavation work has exposed a 3.5 m-thick succession of alluvial sediments comprising four layers, designated Geoarchaeological Field Units (GFUs): GFU 5-GFU 8. This deposit reflects relatively stable floodplain conditions, and the refitting work shows that the vertical dispersion of the original occupation contexts does not exceed 20 cm. In the context of overbank inundation, the explanation for the scatter lies in the rise of groundwater levels and the rapid decrease of water-flow energy at the end of the sedimentation process (Aubry et al., 2020).

The last Middle Palaeolithic occupation is represented in UA 11 of GFU 5, where UA refers to the arbitrary 5 cm spits into which each GFU was subdivided for excavation. Below UA 11, GFU 5 comprises another 27 such spits, i.e., *c.* 1.5 m of sediment across which stone tool technology is rather stable: the raw materials used are local (milky and translucent quartz, rhyolite, quartzite pebbles) and regional (rock crystal), core reduction proceeds mostly via discoid (centripetal, unifacial) and polyhedral methods geared to the production of flake blanks, and retouch is infrequent (a few notches, denticulates, and sidescrapers).

In UA 10, chert and silcrete from distant sources in the northern Meseta and central Portugal appear for the first time and do so alongside blades and bladelets extracted from prismatic and carinated cores. The techno-typological composition of the *c.* 50 cm-thick ensemble of spits from UA 1 to UA 10 of GFU 5 warrants assignment to the Aurignacian because a Caminade scraper and a few Dufour bladelets were found in UA 2-UA 9. The homogeneity of this somewhat vertically scattered assemblage is supported by refitting and the distribution of twenty-eight items of a diagnostic raw material (filonian, fine-grained jasper).

The luminescence ages for GFU 5 were obtained on feldspar grains using a multi-grain, pIRIR — post-IR (Infrared) IRSL (Infrared Stimulated Luminescence) — protocol whereby the pIRIR signal was measured after IR stimulation at 50 °C and at 225 °C and the final ages were corrected for anomalous fading. For UA 10 (sample 172211), 153 cm bd (below datum) and UA 12 (sample 172210), 161 cm bd, the ages are, respectively, 33.6 ± 2.0 and 39.5 ± 1.8 ka. The latter age provides a *terminus post quem* for the latest Middle Palaeolithic in UA11. Overall, the results point to significant discontinuity at the Middle/Upper Palaeolithic boundary, which age/depth modelling constrains to the interval between 34.0 ± 2.0 and 38.4 ± 1.9 ka.

These ages are fully consistent with the evidence from Cueva Antón. This is the more so because Cardina's site formation process

Table 1
Radiocarbon chronology of the Transition in Iberia. Stratigraphically reliable results obtained using ultrafiltration of collagen (for bone samples) or the ABOx-SC protocol (for charcoal samples). Results were calibrated with IntCal20 using Calib 8.1 (Reimer et al., 2013, 2020).

SITE	SAMPLE	LAYER	LAB #	AGE BP	CAL BP	SOURCE
CANTABRIA, BASQUE COUNTRY						
CHÂTELPERRONIAN						
Labeko Koba	Bone	IX-lower	OxA-22563	37800 ± 900	42917–41042	(a)
			OxA-22562	38100 ± 900	43113-41160	(a)
			OxA-22561	38000 ± 900	43009-41160	(a)
			OxA-22560	37400 ± 800	42652-40912	(a)
			OxA-22564	37900 ± 900	42962-41100	(a)
PROTOAURIGNACIAN						
Labeko Koba	Bone	VII	OxA-21793	35400 ± 650	41612-39309	(a)
			OxA-X-2314-43	36500 ± 750	42271–40142	(a)
			OxA-21766	36850 ± 800	42442–40414	(a)
EARLY AURIGNACIAN						
Labeko Koba	Bone	IV	OxA-21768	33600 ± 500	39630–37016	(a)
			OxA-21780	33550 ± 550	39694–36874	(a)
		V	OxA-21779	34650 ± 600	41066–38100	(a)
			OxA-21767	34750 ± 600	41144–38346	(a)
		VI	OxA-21778	35100 ± 600	41347–39118	(a)
El Castillo	Bone	Aurignacian Delta	OxA-21713	35000 ± 600	41328–38943	(b)
VALENCIA, MURCIA, PORTUGAL						
LATE MOUSTERIAN						
Cueva Antón	Charcoal	I-k top	OxA-26346	31790 ± 270	36697–35476	(c)
		I-k base	OxA-22625	32330 ± 250	37197–36159	(c)
		II-a	OxA-22019	32390 ± 280	37374–36179	(c)
		II-b	OxA-21244	32890 ± 200	38184–36681	(c)
Gruta do Caldeirão	Bone	L	MAMS-41871	36490 ± 390	42028–40886	(d)
		M	MAMS-33905	31900 ± 170	36669–35844	(d)
		Unit 5	MAMS-41874	33810 ± 290	39500–37665	(d)
		Unit 6	MAMS-41876	32890 ± 260	38465–36536	(d)
EVOLVED AURIGNACIAN						
Cova de Malladetes	Charcoal	XIII	VERA-6510ABOxSC	32080 ± 350	37164–35617	(e)
			VERA-6511ABOxSC	32400 ± 360	37650–36022	(e)
		XIVA	VERA-6513ABOxSC	33600 ± 500	38822–36376	(e)
			VERA-6514ABOxSC	33370 +410/-390	39273–37012	(e)
La Boja	Charcoal	OH19	VERA-6157ABOxSC	33179 +482/-455	39234–36645	(f)
			VERA-6557ABOxSC	33230 +400/-380	39196–36894	(g)
		OH20	VERA-5855ABOxSC	33170 +470/-450	39221–36651	(f))
Lapa do Picareiro	Bone	FF	MAMS-42276	32340 ± 140	36985–36295	(h)
		GG	Wk-32219	32997 ± 263	38768–36732	(h)
			Wk-41258	32063 ± 336	37113–35635	(h)
			MAMS-42277	33910 ± 160	39502–38401	(h)
			MAMS-42281	33790 ± 190	39399–37884	(h)
			MAMS-44445	33880 ± 160	39477–38320	(h)

(a) (Wood et al., 2014); (b) (Wood et al., 2018); (c) (Zilhão et al., 2016); (d) (Zilhão et al., 2021a); (e) (Villaverde et al., 2021); (f) (Zilhão et al., 2017); (g) this paper; (h) (Benedetti et al., 2019; Haws et al., 2020).

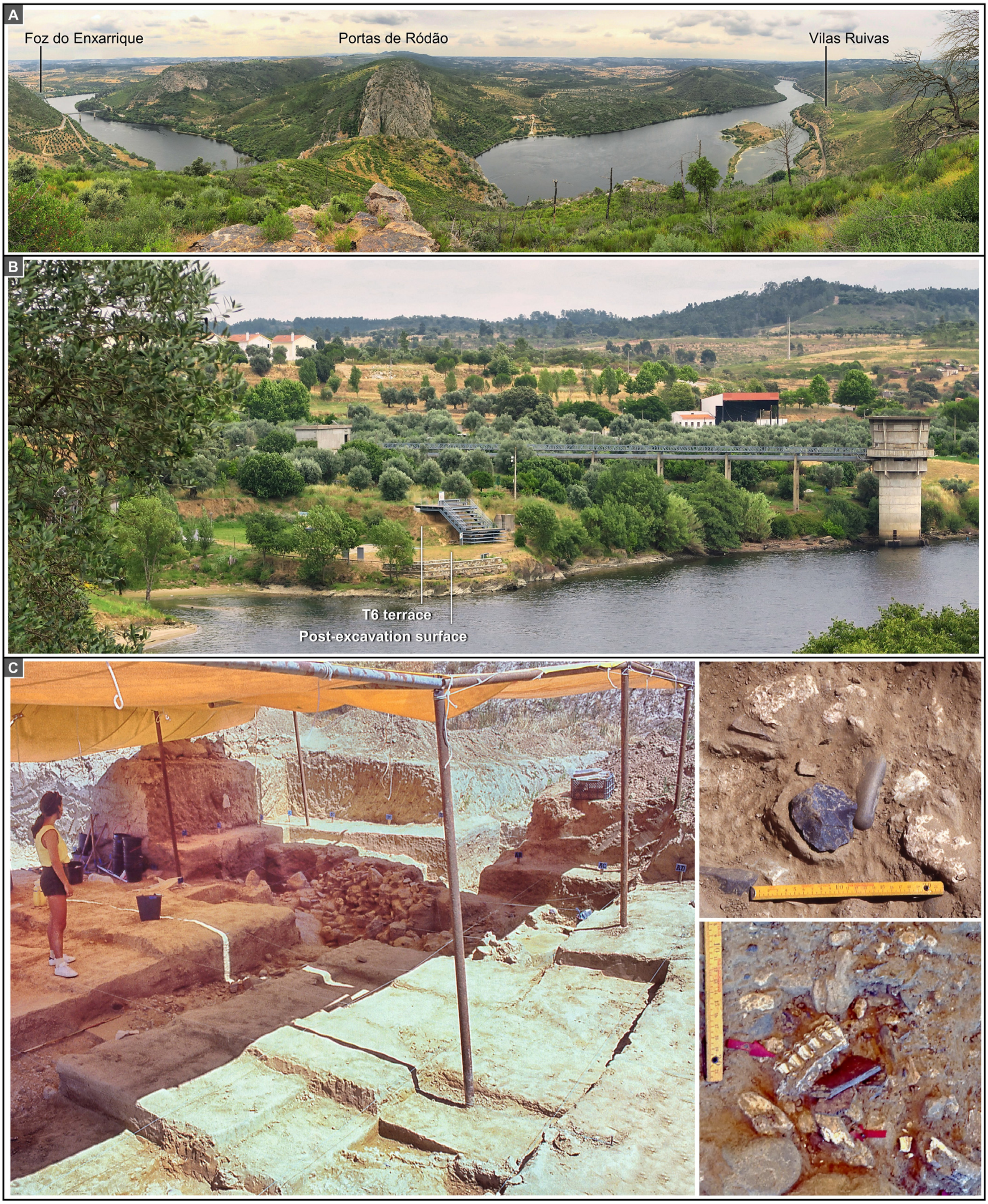

Fig. 6. Foz do Enxarrique. **A.** The Ródão Gates, with indication of the Middle Palaeolithic sites associated with the staircase of Tagus River terraces (Foz do Enxarrique, with T6; Vilas Ruivas, with T5). **B.** View of Foz do Enxarrique (June 2021); the archaeological level extends under the deposit protected by the metal structure put in place in the context of the area's post-excavation landscaping. **C.** The site during the 1991 field season and finds exposed *in situ* at the interface between the UU and LU beds: excavation of the X-AD/33–42 grid units (left); quartzite centripetal core (top right); tooth row of an herbivore (bottom right).

implies that some degree of incomplete bleaching must characterise the dated populations of feldspar grains. For instance, samples 172206 (193 cm bd, GFU 17, 51.0 ± 2.4 ka) and 172210 (161 cm bd, GFU 11, 39.5 ± 1.8 ka) span some ten millennia across *c.* 30 cm of deposit, whereas stone tool refitting connects finds from GFU 12 with GFU 15 and GFU 16, i.e., across 20 of those 30 cm. It is reasonable to assume that a counterpart of the spread seen among the deposit's stone tool component will have been the upward displacement of sediment particles that overbank inundation removed from extant surfaces; mixed with those transported in suspension, such particles would have redeposited anew by decantation after little, if any exposure to sunlight.

Under Aubry et al.'s (2020) age/depth model, the Middle Palaeolithic would have persisted in the Côa Valley until at least 42.2 or 40.3 ka (depending on whether we take the older limit of the interval at the 95.4 % or the 68.3 % level of probability). However, given the possibility of incomplete bleaching, the multi-grain luminescence results upon which the model is built could feasibly represent overestimates of the true age of the dated deposits. This is the more so since, (a) prior to correction for fading, the feldspar ages are *c.* 10 % younger (Aubry et al., 2020: Table 1), (b) the fading rate lies in the range of 1–2%/decade, i.e., in the range of laboratory background noise, and (c) whether correction of the pIRIR(225) signal is required in such cases is contentious (Buylaert et al., 2012; Roberts, 2012; Vasiliniuc et al., 2012; Zilhão et al., 2021b). Put another way, the parsimonious interpretation of the data from Cardina/Salto do Boi is that, in all likelihood, the site's last occupation by Middle Palaeolithic people post-dates 40–42 ka.

3.1.3. *Foz do Enxarrique*

Like Cardina, Foz do Enxarrique is located on a platform formed by alluvial accumulation immediately upstream of a major streambed choke, in this case the quartzite ridge forming the Tagus valley's Portas de Ródão (Ródão Gates) (Fig. 6A). Excavated between 1982 and 2002, the archaeological horizon is found within an alluvial terrace of the local staircase, 10 m above pre-damming river level; initially designated T5 (Cunha et al., 2008), this terrace is now known as T6 (Cunha et al., 2012, 2019) (Fig. 6B).

In the type-section exposed in the main area of the site, T6 comprises two beds: at the base, LU (Lower Unit), which is *c.* 40 cm-thick and consists of clast-supported boulder and pebble gravels; above, UU (Upper Unit), which is *c.* 5.60 m-thick and consists of a fine, silty/sandy sediment. The UU bed has been subdivided into three layers: top (to a depth of *c.* 4.55 m), made up of sandy silts; middle (*c.* 4.55–5.40 m below surface), made up of very fine to fine sands with some thin, interbedded gravel lenses; and lower (*c.* 5.40–5.60 m below surface), made up of fine sands containing faunal remains and an abundant and unquestionably Middle Palaeolithic stone tool assemblage (Fig. 6C). The >10,000 artefacts document use of the Levallois and Discoid methods to exploit locally available quartzite river cobbles (Berruti et al., 2016; Raposo, 1995).

Due to the saturation of the OSL signal from quartz, luminescence dating of the sequence used feldspar grains. The ages initially obtained were calculated with the IRSL protocol and constrained the accumulation of T6 and, hence, of the archaeological level within it, to between 31.6 ± 1.3 and 38.5 ± 1.6 ka (Cunha et al., 2008). Using a different protocol, where a pIRIR signal is measured at 290 °C and final ages are assumed not to need correction for anomalous fading, Cunha et al. (2019) have now published somewhat earlier ages for the same samples: 44 ± 3 (5.50 m below surface) and 43 ± 4 ka (5.30 m below surface), at the base of UU, in association with the archaeological horizon; and 37 ± 2 ka, in the upper part of UU, 90 cm below the surface.

The archaeological remains are found within a stretched, discontinuous, and deformed lobe that dips and thickens towards the river margin, packaged within a homogeneous, massive matrix devoid of lamination or bedding. Such a context suggests a sequence of events whereby the riverside accumulation of alluvial sands was followed by human occupation of the thusly formed beach and mass flows eventually reworked and moved downslope the sedimentary bodies and their archaeological content.

This site formation process implies a degree of heterogeneity in the luminescence properties of the measured feldspar grains, which the reworking process will have completely bleached only in part; most will have been incompletely bleached, or even not at all. Consequently, one would expect two populations of bleached grains to be present in the sampled sediment: one reflecting the age of deposition, another reflecting the age of redeposition. As Cunha et al. (2019) did not employ single-grain analysis, do not report on overdispersion, and are omissive on the statistical models used to calculate the final ages, the potential impact of sample heterogeneity is difficult to assess.

With current evidence, the *c.* 43–44 ka ages are best interpreted as reflecting the time of sedimentary deposition, not the time of human use. Put another way, the results for the base of the UU bed provide a maximum age for the archaeological horizon, while the 37 ± 2 ka result for the bed's upper part provides a minimum age. Based on these data, the parsimonious view would seem to be that this episode of terrace formation in the valley of the River Tagus is part of a wider Iberian pattern and broadly coeval with those post-dating 40–42 ka documented in the valleys of the River Mula of Murcia and the River Côa of Portugal — with attendant implications for the age of Foz do Enxarrique's Middle Palaeolithic occupation.

3.1.4. *Gruta do Caldeirão*

Excavated 1979–88, this cave site has been in the literature mostly because of its thick Solutrean deposit and overlying funerary context of the Cardial culture (western Europe's first farmers) (Zilhão, 1992, 1993b, 1997, 1993b). The Transition is recorded in the basal levels of the trenches excavated in the Entrance (i.e., the extant porch; Fig. 7A) and the Back Chamber (in the cave's interior; Fig. 7B) (Zilhão, 2006b). An updated and detailed discussion can be found in Zilhão et al. (2021a). The key points are summarised in the following.

In the Back Chamber, the evidence comes primarily from square P11, where the Middle Palaeolithic deposit, layers L-P, could be excavated down to bedrock over a thickness of *c.* 1.2 m. In the Entrance, the Middle Palaeolithic begins *c.* 50 cm below surface and the finds are contained in units 5–6, which, in a limited part of the test trench, could be excavated over a thickness of *c.* 1 m. In both sectors, a marked discontinuity separates the latest Middle Palaeolithic from the earliest Upper Palaeolithic — the K/L boundary, associated with cut-and-fill features, in the Back Chamber, and the unit 4/unit 5 boundary, associated with carbonate cementation, in the Entrance.

On both sides of the K/L boundary, faunal remains are abundant, but primarily carnivore-accumulated, and stone tool assemblages, although small, contain diagnostic lithics warranting their technocomplex attribution (Fig. 8). Layers L-P and units 5–6 yielded sidescrapers as well as Levallois cores and debitage. A characteristic carinated core found at the base of unit 4 of the Entrance is diagnostic of the Aurignacian, whose representation at the site is corroborated by a Dufour bladelet retrieved in the Back Chamber at the interface between layers L and K; the dating of the latter's upper part to the 30.4–33.3 ka interval provides a *terminus ante quem* for this fleeting Aurignacian use of the site.

Layers L-M and units 5–6 have been dated by radiocarbon, while five single-grain, quartz OSL ages have been obtained for the sequence of layers K–O. In both sectors, the radiocarbon results

Fig. 7. Gruta do Caldeirão: the site. **A.** The entrance (1980), and the S-Q20 > 19 stratigraphic profile at the end of the 1988 field season (orthorectified image). **B.** The cave interior: from left to right, excavation of the Solutrean levels in the Corridor sector (1985), overview of the Back Chamber (1987), and the P11 > 10 stratigraphic profile (1988; orthorectified mosaic and drawing). Elevations are in cm bd.

display inversions. In the Entrance, the ages obtained are 32,890 ± 260 BP (MAMS-41876, 36.5–38.5 ka), for a sample from unit 6, and 33,810 ± 290 BP (MAMS-41874; 37.7–39.5 ka) for a sample from unit 5. In the Back Chamber, layer M has been dated to 31,900 ± 170 BP (MAMS-33905; 35.8–36.7 ka) and layer L to 36,490 ± 390 BP (MAMS-41871; 40.9–42.0 ka; another result for this layer is several millennia younger, of the same age as the layer K samples, and represents intrusion).

Reworking in association with cut-and-fill features is the plausible explanation for the inversions because all of the radiocarbon-dated samples underwent an ultrafiltration pre-treatment, none had been prepared with glues or consolidants, the collagen's quality indicators are good, and the measured ages are quite removed from the method's limit of applicability. Indeed, the stone tool assemblages associated with the K/L boundary reveal a few comparable anomalies: for instance, layer K yielded a few quartz items of clear Middle Palaeolithic affinities (a Levallois flake, a denticulate, and a sidescraper).

This view is supported by the age/depth consistency of the OSL ages, which range from 37.7 ± 2.8 ka for layer K to 58.4 ± 3.8 ka for layer O, demonstrating the overall stratigraphic integrity of the Back Chamber's Middle Palaeolithic deposit. As is clearly the case with the comparable anomalies found either side of the major stratigraphic discontinuity separating Magdalenian layer Eb and

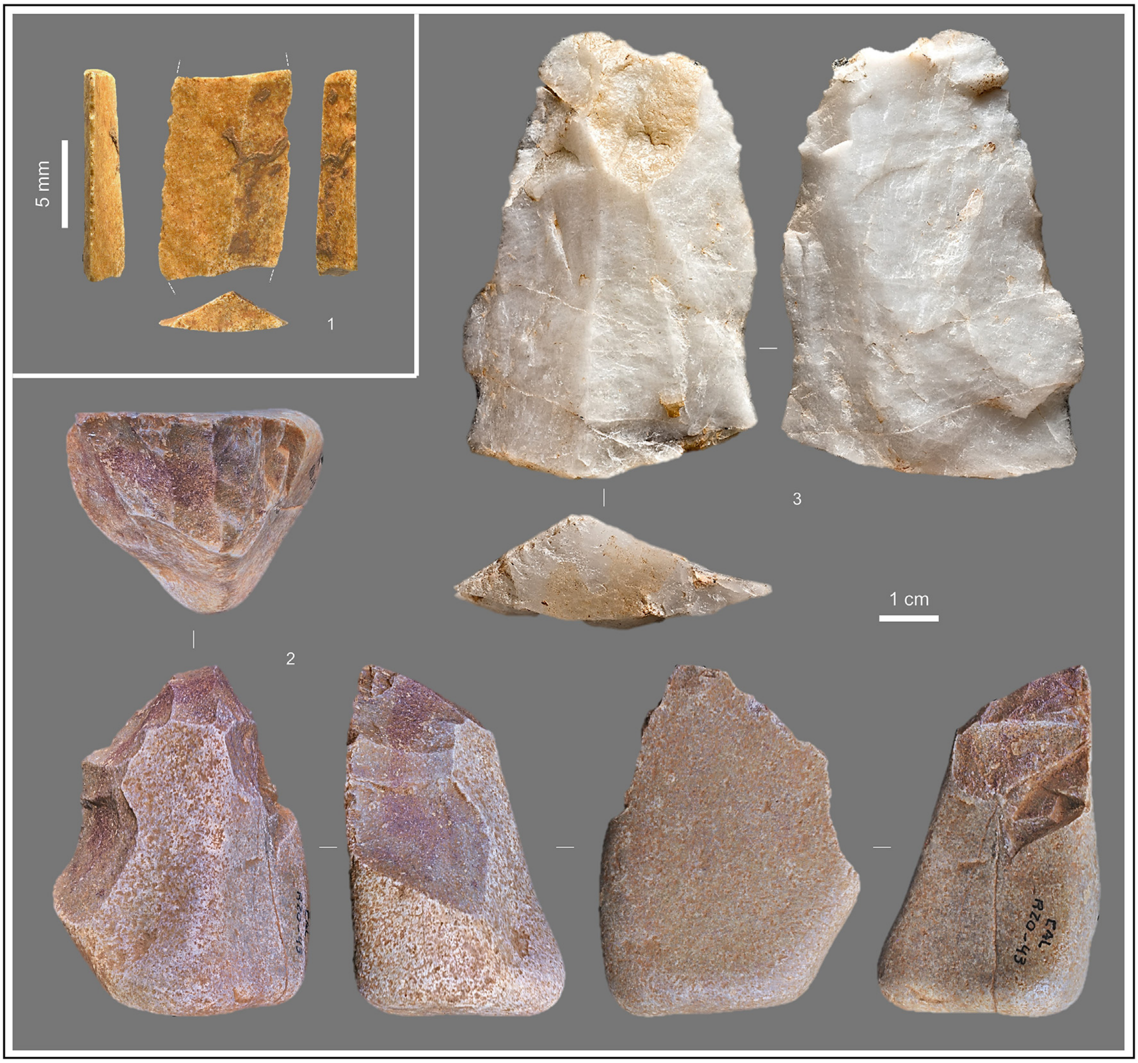

Fig. 8. Gruta do Caldeirão: diagnostic lithics. 1. Dufour bladelet (water-sieve find from the K/L interface); 2. Carinated core (unit 4 of the Entrance trench); 3. Quartz sidescraper (layer L).

Upper Solutrean layer Fa (Fig. 7B), the few inversions seen in Caldeirão's radiocarbon dating record are to be interpreted as earlier-than-expected results reflecting the presence of inherited items.

Bayesian modelling of the dating results obtained for the succession supports these interpretations. Even if the radiocarbon ages for the Middle Palaeolithic are excluded from consideration, the 95.4 % probability interval calculated for the K/L boundary is 32.2–38.9 ka. Including the radiocarbon dates and treating layers L-N and units 5–6 as a single phase to account for the inversions, that interval changes, but barely: to 33.9–38.6 ka. A similar outcome is obtained using rates of sedimentation derived from the combined consideration of the OSL and radiocarbon ages for the Pleistocene succession as a whole. Using as a fixed point the OSL sample for layer M (37.9 ± 2.3 ka), half-way through the deposit bounded by the K/L and N/O discontinuities, all rate-of-sedimentation scenarios that are consistent with dating and stratigraphic constraints imply a *terminus post quem* of 39.0 ka for the end of the Middle Palaeolithic at the site.

The evidence from both trenches therefore places Caldeirão's uppermost Mousterian levels well within the time range during which the Protoaurignacian and the Early Aurignacian were present in Asturias, Cantabria, and Catalonia. This dating framework is consistent with the palaeoclimate inferences derived from the MS (Magnetic Susceptibility) study of the site's sequence (Ellwood et al., 1998; Zilhão, 1997). The interval of mild, warm conditions implied by the MS values for layers L-N supports correlation with the long period of rather temperate climate that southern and western Iberia witnessed between the onset of GI (Greenland Interstadial) 12 (46,860 years ago) and the end of GI 8 (36,580 years ago), which only the brief cold spell of GS (Greenland Stadial) 9 (38,220–39,900 years ago), associated with HS (Heinrich Stadial) 4, punctuated in any significant manner (Rasmussen et al., 2014; Sánchez Goñi et al., 2009).

3.2. The Evolved and the Late Aurignacian

In eastern, southern, and western Iberia, my 2006 review found sound evidence for the Aurignacian to be represented at the cave sites of Cova de Malladetes (a.k.a. Mallaetes; Barx, Valencia), Cova Beneito (Muro del Comtat, Alicante), Cueva Bajondillo, and at the open-air site of Gato Preto (Rio Maior, Portugal). That contention was further supported by preliminary reports (stratigraphic sequences, lithic assemblages, and radiocarbon dates) from two other

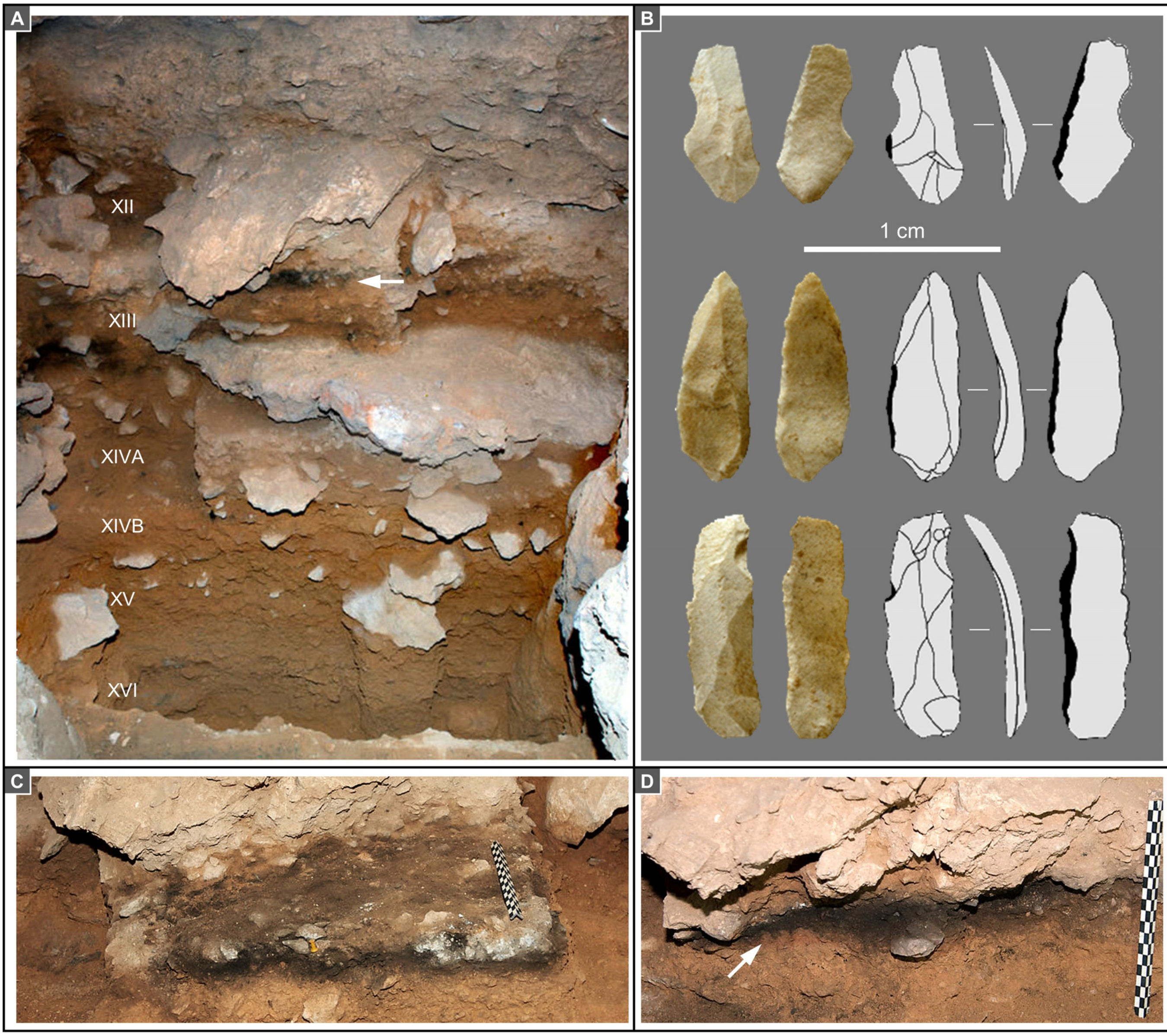

Fig. 9. Cova de Malladetes. **A.** Stratigraphic profile of the Zone III trench (2016–17); the arrow indicates the position of the hearth shown in panels C–D. **B.** Dufour bladelets from level XII. **C-D.** The hearth in level XIII (exposed, and after sectioning; the arrow points to the rubefaction band observed below the charcoal and ash layer). After Villaverde et al. (2021), modified.

sites, Cova Foradada (Xábia, Alicante) and Rattla del Bubo (Muro del Comtat, Alicante) (Casabò, 2001, 2014, 2014; Iturbe Polo and Cortell Pérez, 1992). The characteristics of the stone tool assemblages placed these occurrences in the Evolved Aurignacian.

The technological features of the single-component assemblage retrieved in the open-air site of Vale de Porcos (Rio Maior, Portugal) (e.g., the fact that most carinated cores are of the "burin" rather than the "scraper" type) supported assignment to the later, final phase of the technocomplex. Such a Late Aurignacian would also be represented by layer 2 of the cave site of Pego do Diabo (Loures, Portugal), which yielded a small set of a particular sub-type of Dufour bladelets: elongated, robust, bilaterally pointed by a form of alternate retouch that, on the ventral side, is semi-abrupt and invasive. I further pointed out that the Pego do Diabo sub-type also occurred in mixed or reworked contexts capping Middle Palaeolithic deposits at Cueva de Zafarraya and Gruta do Escoural (Montemor-o-Novo, Portugal).

With regards to the Late Aurignacian, suffice is to mention here that dating of Pego do Diabo using the ultrafiltration protocol has since corroborated a chronology in the range of 34.2–35.3 ka, while refitting and in-depth technological analysis of the Vale de Porcos assemblage corroborated the initial assignment (Aubry et al., 2006; Zilhão, 2006a; Zilhão et al., 2010b). In eastern and southern Spain, persistence of the Aurignacian into the 35–36 ka interval is otherwise shown by the ages obtained for level XVIC of Cova de les Cendres (Teulada-Moraira, Alicante) and OH (Occupation Horizon) 15 of the rock-shelter of La Boja, in the Rambla Perea (Mula, Murcia), <2 km NE of Cueva Antón (Villaverde et al., 2019; Zilhão et al., 2017). The Pego do Diabo sub-type was not identified in these two Spanish contexts, but the latter's bladelet tool assemblages are small (seven items in total, in both cases) and so variability in functional or other site-specific factors is an explanation for this difference that cannot be ruled out at present.

The key developments of recent years point in conflicting directions. The high-resolution, well-dated stratigraphic sequences spanning the Evolved and the Late Aurignacian of La Boja (Zilhão et al., 2017) and Cova de les Malladetes (Villaverde et al., 2021) strongly support the Ebro Frontier pattern, which is seemingly contradicted by claims that an Early Aurignacian is present at Lapa do Picareiro (Alcanena, Portugal; Haws et al., 2020) and Cueva Bajondillo (Cortés-Sánchez et al., 2019). At the latter site, the age of the assemblage is even claimed to be earlier than in northern Spain and supportive of scenarios of long-term regional sympatry with the Middle Palaeolithic. Given their prominent role in current debates, the following discussion will be restricted to these four sites.

3.2.1. *Cova de Malladetes*

First and quite extensively excavated in the 1940s, the stratigraphic layout of this Palaeolithic sequence stems from two test trenches open in 1970 (Fortea and Jordá, 1976). In the East Trench (Zone II), below a Gravettian package (levels VIII-X), an ensemble lacking backed items (levels XI-XIV) yielded a conventional radiocarbon date on charcoal placing it at the end of the Aurignacian timespan: 29,690 ± 560 BP (KN/I-926) (for level XII). Occupation of the site at that time was otherwise indicated by a large, massive-based bone point, characteristic of the Evolved Aurignacian, found in the basal levels of the 1940s excavations.

In 2016–17, to further refine and better date the Early Upper Palaeolithic of Malladates, a new trench, Zone III, was opened from the extant east profile of Zone II, which was excavated back *c.* 1.2 m, over its entire width (*c.* 2.5 m), and down to a depth of *c.* 4.4 m (Villaverde et al., 2021). The Transition stratification revealed in the process consists of a *c.* 65 cm-thick Aurignacian ensemble (levels XII, XIII, XIVA) overlying a >70 cm-thick, very poor ensemble containing charcoal and lithics of technologically undetermined affinities (levels XV-XVI); a sterile, *c.* 16 cm-thick deposit of fine sandy silts (level XIVB) separates the two ensembles (Fig. 9A). Five different hearths were found at different elevations within the *c.* 30 cm-thick level XIII, and another at the base of level XIVA (Fig. 9C-D). The dating of six charcoal samples associated with these Aurignacian hearths used an ABA pre-treatment and yielded a stratigraphically consistent set of ages, corroborated by ABOx-SC dating of sub-samples.

Bayesian modelling of the results constrains the Malladetes Aurignacian to the 34.1–39.1 ka interval, consistent with the presence of the Roc-de-Combe sub-type among the small assemblage of 12 Dufour bladelets from Zone III (the low number reflecting the small size of the trench; in level XIII, several large boulders restricted the excavatable area to 1 m^2 only). Most came from uppermost level XII (Fig. 9B), dated to 30,100 ± 280 BP (VERA-6508), in the range of the Late Aurignacian (and statistically indistinguishable from the 1970 conventional result obtained in adjacent Zone II); level XIII yielded a single such bladelet; three were found in level XIVA. The ages obtained for levels XIII and XIVA range between 32,080 ± 350 BP (VERA-6510ABOxSC) and 33,370 +410/-390 BP (VERA-6514ABOxSC), fully within expectations for an Evolved Aurignacian. It is likely that the massive-base antler points from the 1940s belong in this occupation phase.

The good preservation of the hearth features, the consistent age/depth relationship of the dating results, and the presence of Dufour bladelets through levels XII-XIVA bear witness to the stratigraphic integrity and homogeneously Aurignacian nature of the sequence. Nothing that might hint at earlier phases of the technocomplex exists among the finds made in the much larger deposit, in both area and volume, previously excavated elsewhere at the site to elevations below that reached in 2016–17. Therefore, the human occupation documented in level XV of Zone III is, in all likelihood, a Middle Palaeolithic one, and the age of 36,180 +570/-530 BP (40.2–43.0 ka; VERA-6515ABOxSC) obtained for a hearth therein excavated is consistent with the inference.

These observations imply that level XIVB spans the GI 8-GI 10 interval, i.e., the times of Ebro Frontier. Under the model's premises, this level's archaeological sterility must reflect temporary human abandonment of the area due to temperate tree reforestation of low and mid-altitude karst areas. Consistent with this notion, the charcoal of angiosperms spikes in level XIVB, reaching 30 %, more than sixfold the second highest value recorded above (in Aurignacian levels XII-XIVA) or below (in levels XV-XVI). Therefore, in the mountains of the Mondúver Massif, where Malladetes is located, karst cavity sedimentation would not have been arrested at this time, only significantly slowed down: in the Zone III trench, to *c.* 4 cm/millennium, against *c.* 20 cm/millennium both above and below.

3.2.2. *La Boja (Rambla Perea)*

Zilhão et al. (2017) provide detailed presentation of the high-resolution stratigraphy revealed by the excavation of this rock-shelter's Transition levels, whose general outline is replicated, albeit lacking in chronometric information, at the adjacent site of Finca de Doña Martina. Here, I provide an update on La Boja's latest Mousterian and earliest Aurignacian occupations that includes information acquired during the last three years of fieldwork (2016–18). The chronology of the Transition levels is based on the radiocarbon dating of charcoal, which followed a protocol whereby corroboration of the results obtained with the standard ABA pre-treatment was acquired via the dating of sub-samples processed with the ABOx-SC or AOx-SC protocols.

As previously described, the relevant stretch of the La Boja succession comprises, from top to bottom, the following phases (Figs. 10 and 11): Late Aurignacian, corresponding to OH15-OH16 and defined by the appearance, alongside the characteristic Dufours, of marginally backed bladelets (Fig. 12, no. 6); Evolved Aurignacian, corresponding to OH17–OH20, with large blades, Dufour bladelets, and carinated or nosed scrapers (Fig. 12, nos. 2–5); IL (Intermediate Level) 4, corresponding to the archaeologically sterile sediment burying the thick, overhang-collapsed limestone mass sealing the basal infill; and OH21, the uppermost Middle Palaeolithic occupation, below the collapse. In the narrow space separating the fallen boulder from the shelter's wall, IL4 was significantly bioturbated. That was not the case outward, where the exterior lap of the deposit abutting the crest of the fallen rock mass was excavated in 2016–18 and revealed a thin, sparse occupation horizon sandwiched between the underlying stony surface and the immediately overlying OH20 sediment (Fig. 11). This new horizon was designated as OH21a and, accordingly, OH21 from the 2008–14 field seasons was renamed to OH21b.

OH21a yielded a small stone tool assemblage (N = 11). Nine are quartzite items: a denticulate (Fig. 12, no. 1), a retouch flake from that denticulate, six small flakes, and a chip. A limestone flake and a chert core of the Kombewa type were also found. A limited area in which the adjacent profile shows disturbance of the interface between OH21a and the overlying Aurignacian sequence yielded most (>80 %) of a set of 57 very small, intrsuive chert items (chippage, a mesial bladelet, half-a-dozen small flake fragments; <15 g in total); they probably relate to the knapping activities recorded in OH19–OH20 above. By its technological characteristics and the use of quartzite — a raw material that, in the Aurignacian, is either completely absent (in OH15 and OH19–OH20) or wholly marginal (in OH17 and OH16, where it represents 0.4 % and 0.06 % of the lithics, respectively) — OH21a clearly belongs in the Middle Palaeolithic.

OH19 and OH20 are very close in time and share a similar lithic

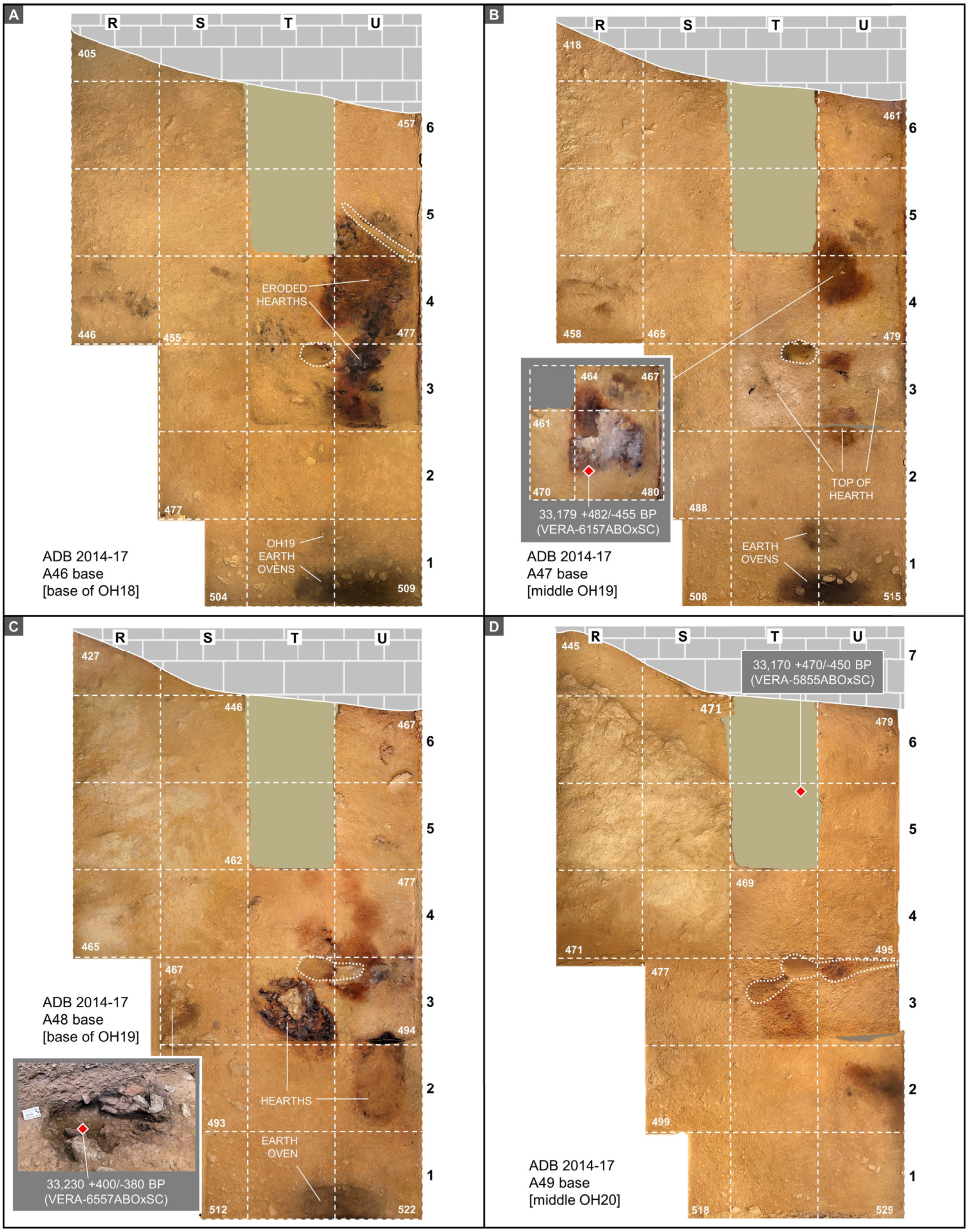

Fig. 10. La Boja: excavation of the Aurignacian levels. **A.** Décapage of the OH18/OH19 interface. **B.** Half-way through the excavation of OH19, at the base of the U/4–5 hearth (shown in the insert). **C.** Décapage of the OH19/OH20 interface; the insert is an oblique view over the partially disturbed hearth in R/S3. **D.** Half-way through the excavation of OH20. The shaded areas denote the test trench where bedrock was reached in 2013, and the red diamonds mark the position of the radiocarbon dated samples whose ages are shown; the dotted lines delimit burrows. A46-A49 are spit designations. Elevations are in cm bd.

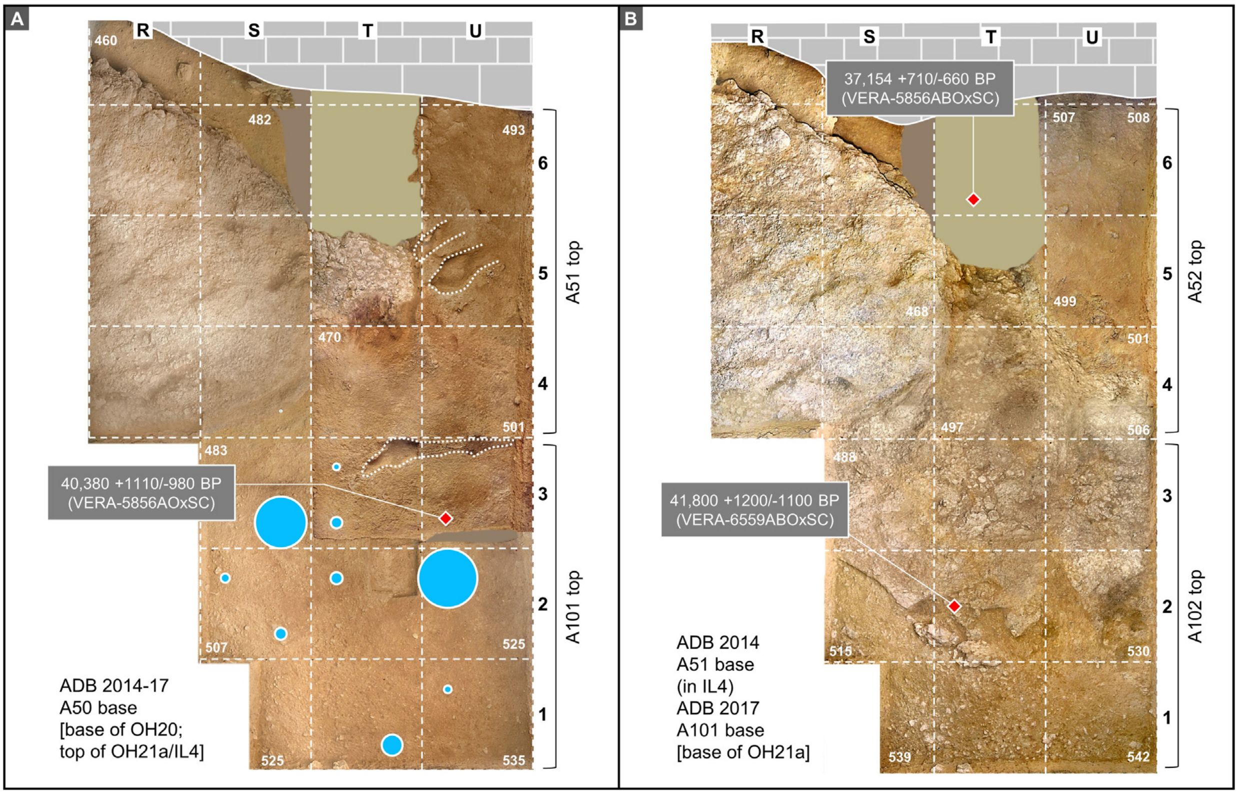

Fig. 11. La Boja: the uppermost Mousterian. **A.** Décapage of the interface between OH20 and OH21a/IL4; the bubble plot represents the distribution, by weight (total = 49.02 g), of the Middle Palaeolithic items in OH21a (N = 11). **B.** Base of OH21a. The shaded areas denote the test trench where bedrock was reached in 2013. The red diamonds denote the radiocarbon dated samples whose ages are shown; the dotted lines delimit burrows. A50-A51 and A101-A102 are spit designations. Elevations are in cm bd.

production system. However, in OH19, the intensive reduction and small size of the stone tools suggest short stays during which chert volumes brought in as ready-made blanks or finished tools were systematically recycled prior to discard. These inferences are consistent with the number of hearth features (Fig. 10B-C), whose excellent preservation suggests either coeval use or consecutive episodes separated by short intervals that, due to the high sedimentation rates, were nonetheless enough for a protective layer of sediment to accumulate. Conversely, in OH20, the large size of the items and the representation of all phases of the *chaîne opératoire* suggest transient passages during which chert volumes collected en route were processed for the extraction of quality blanks that were either exported or, if failed at set-up, discarded with no further labour investment. These inferences are consistent with the limited evidence for fire across OH20's excavated surface (Fig. 10D).

The radiocarbon ages obtained for OH19–OH20 — e.g., the OH20 result of 33,170 +470/-450 BP (36.7–39.2 ka; VERA-5855ABOxSC) — date the emergence of the Evolved Aurignacian in the region. For OH21a, the age obtained for a sample from the upper part of IL4, 15 cm below, sets a *terminus post quem* of 41,800 +1200/-1000 BP (VERA-6559ABOxSC). This age is statistically indistinguishable from the result of 40,380 +1110/-980 BP (VERA-6646AOxSC) obtained for a sample from OH21a itself, while an age of 47,500 +2500/-1900 BP (VERA-6561AOxSC) has been obtained for OH21b, below the collapsed rock mass. Therefore, the sediment that eventually buried the latter, creating a flat surface and thereby rendering the place amenable for habitation once again, accumulated at a rate of *c.* 10 cm/millennium — i.e., with the same pace documented, by both radiocarbon and OSL, for the Upper and Middle Palaeolithic sequences found above and below (Angelucci et al., 2018; Zilhão et al., 2017). Throughout, all episodes of stasis were minor; during such episodes, low-energy sheetwash caused the scatterings of ash, charcoal and rubefacted sediment that characterise the less well preserved occupation surfaces (e.g., OH18; Fig. 10A), but the very preservation of their stratigraphic integrity demonstrates that sedimentation resumed before long.

Against this background, the duration — several millennia — of the hiatus separating OH21a from OH20 is striking. It can be explained as the by-product of (a) no sediment having accumulated at the site through the interval, (b) a significant chunk (minimally, some 30 cm) of the previously accumulated deposit having been removed by erosional processes prior to the time when people returned, or (c) some combination of both. Massive erosion is very much unlikely because the deposit remained overhang-protected throughout and, in areas of the site located well behind the dripline, erosion never had a major impact. For instance, the major climatic and environmental upheavals associated with the Tardiglacial-to-Holocene transition did not erase or truncate the Epimagdalenian horizon capping the Pleistocene succession. The latter is sealed by a modern soil containing Neolithic sherds, and the uppermost Pleistocene levels (Epimagdalenian and Upper Magdalenian) are themselves cut by an extensive rabbit warren containing charcoals dated to the middle of the Holocene. These observations suggest that the direct contact between Epimagdalenian and Neolithic observed at the site reflects a four millennia-long, Early Holocene hiatus in sedimentation rather than the erosional loss of a deposit of Mesolithic age. By analogy, the interface between OH20 and OH21a, seven millennia apart yet in direct contact, is likely to reflect the presence of a sedimentation hiatus rather more than erosional truncation — the more so since no evidence for the latter process can be gleaned from the exposures of the interface observable in extant stratigraphic profiles.

At the end of such a long hiatus, OH21a/IL4 formed the exposed surface of the rock-shelter infill when sedimentation resumed and

Fig. 12. La Boja: diagnostic lithics. 1. Quartzite denticulate (OH21a); 2. Dufour bladelet of the Dufour subtype (OH20); 3. Blade (OH20); 4. Refit demonstrating a multi-step reduction sequence for the production of bladelets from carinated cores set-up on long, thick blade blanks (OH20/IL4); 5. Dufour bladelet of the Roc-de-Combe subtype (OH17); 6. Marginally backed bladelet (OH16).

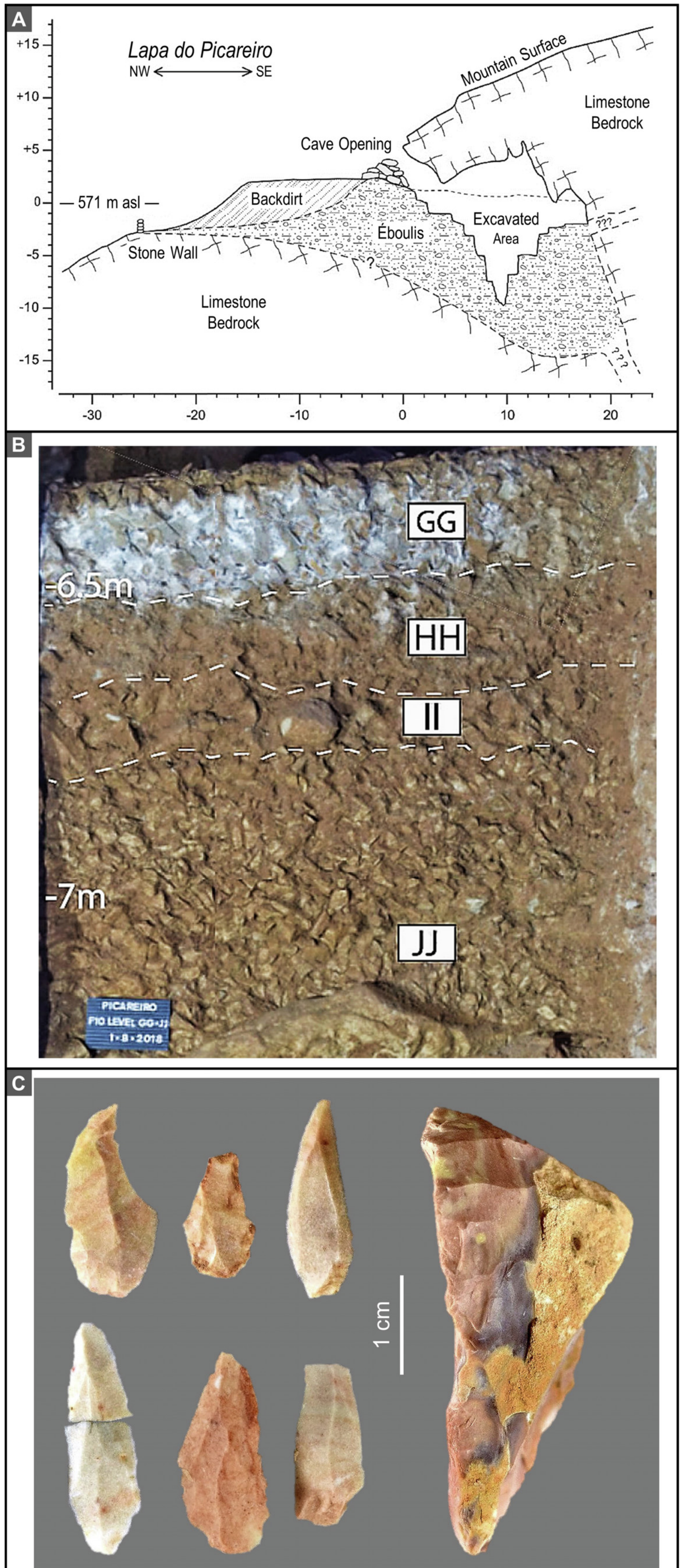

Fig. 13. Lapa do Picareiro: the site. **A.** Schematic geological setting and position of the excavation trench. **B.** Profile view of levels GG-JJ at the intersection between grid units F10 and F9 (elevations are in m bd; at *c.* 6.5 m, the base of level GG runs along 564.5 m asl). **C.** Lithics from level GG: unretouched bladelets and carinated core. After Benedetti et al. (2019) and Haws et al. (2020), modified.

OH20 began to accumulate. One would therefore expect their interface to be somewhat fuzzy and present two features: the existence at contact of a palimpsest lens intermingling artefacts and ecofacts of very different ages, potentially millennia apart; and subsurface intrusion affecting the sediments below. The latter is exemplified by the Aurignacian diagnostics (namely, typical carinated scraper/cores) from the inward lap of the IL4 deposit retrieved alongside a sample dated to 37,154 +710/-660 BP (VERA-5856ABOxSC; 40.9–42.5 ka); the apparent association is spurious, because the dated charcoal is environmental, not anthropogenic, and stone tool refitting demonstrates that the stone tools represent intrusions from the overlying, four millennia younger OH20 occupation (Fig. 12, no. 4). Palimpsesting is best illustrated by a thought experiment based on the very small chert debris related to OH19–OH20 that percolated into OH21a. Imagine that the accumulation of La Boja's Aurignacian had proceeded at a much slower rate, or that the excavation had failed to resolve the archaeo-stratigraphic interfaces with the required centimetre, if not sub-centimetre precision. In that case, discriminating between OH20 and OH21a would not have been possible, and the 2016–18 finds defining the thin OH21a lens would have been excavated as part of the OH20 horizon. Based on the dated charcoal, one might then be led to claim that this mixed context represented either a >42.4 ka “Early Aurignacian” (and one earlier than everywhere else, for that matter) or a “Transitional Aurignacian” combining legacy Middle and innovative Upper Palaeolithic technologies in association with a “transitional date” consistent with the “transitional technology.” In fact, such chimeric entities would be a mere by-product of post-depositional disturbance and insufficient resolution (of stratigraphy, or of excavation methods).

La Boja is therefore a doubly invaluable reference for the Transition in eastern Spain. Its waterproof dating record, based on robustly pre-treated samples of charcoal from several well-preserved hearth features, securely places the emergence of the region's Evolved Aurignacian occupation within the 36.7–39.2 ka interval. And the site illustrates well how easy it is for the hazards of formation process and post-depositional disturbance to generate illusory archaeological patterns that in fact represent the impact of geological, not cultural processes. Finally, OH21a brings additional support to the premise that, in Iberia, the late Middle and the early Upper Palaeolithic are so technologically distinct that, provided that diagnostics are found, assemblages can be securely assigned to one or the other even if very small.

3.2.3. Cueva Bajondillo

This site is a rock-shelter located in an urban setting, which limited access for research purposes. It was rescue-excavated in 1989; in 2000 and 2002, the Upper Pleistocene stratification exposed in the profiles was sampled for further analysis. The levels of relevance for the Transition are Bj/14-Bj/11. The Evolved Aurignacian affinities of the Bj/11 stone tool assemblage are uncontroversial, and Bj/14 belongs in the Middle Palaeolithic. In a restricted part of the site, these levels are separated by a lens of limited extent, Bj/13, at the top of which a fire feature has been differentiated as Bj/12 (Cortés-Sánchez, 2007a, 2007b, 2007b).

Recently, Cortés-Sánchez et al. (2019) have claimed that Bj/13-Bj/12 are Aurignacian and date to 40.6–44.8 ka. Contra, Anderson et al. (2019) and de la Peña (2019) have argued that there is nothing in those levels that might be construed as diagnostically Upper Palaeolithic, let alone Early Aurignacian or even Aurignacian *sensu lato*. Indeed, these levels' single, so-called “nosed scraper” (Cortés-Sánchez et al., 2019: Fig. 2) is clearly a misclassified item. Equally important, however, is that the association between the stone tool assemblage and the samples used to date it remains undemonstrated; were genuinely Aurignacian-like artefacts to one day emerge from Bj/13-Bj/12, the association question would still need to be posed because those levels' stratigraphic integrity is questionable.

In fact, prior to obtaining the recently published dating results, the excavator had consistently referred to Bj/13-Bj/12 as containing a solifluction-generated mix of Middle Palaeolithic and “Upper Palaeolithic-like” (sic) material. The following, taken from Cortés-Sánchez (2007b: 142–143), is a representative quote:

> “The Bj/13–12 assemblage is very small (353 items), and a reliable techno-typological analysis is therefore nonviable. However (…) substantial change is apparent in connection with the presence of various products indicative of Upper Paleolithic-like flaking (…). That said, these latter elements are associated with a not inconsiderable industrial component of Mousterian affinities.”

> “The contact between Bj/11 and Bj/12–13 is highly irregular due to solifluction processes, as is typical for a cold and humid environment. In this context, the mix of Mousterian and/or Aurignacian techno-typological attributes shown by the scarce material available to us is of difficult interpretation; therefore it seems logical to regard the available information as allowing us to go no further than acknowledging the possibility of mixing, as inferred from the analysis of the flaked stone tools.”

I have compiled elsewhere (Zilhão, 2021) an extensive list of comparable statements produced by the excavator between 1997 and 2010. These characterisations strongly suggest that the recently published dating results relate to the “not inconsiderable industrial component of Mousterian affinities” found in Bj/13–12 rather than to their putative, in fact undocumented Aurignacian component.

Cortés-Sánchez et al.'s (2019) claims are made *ex novo* with no discussion, or even acknowledgment, of the previous thirty years of consistent interpretation of Bj/13–12 as mixed, and devoid of supporting geologic or taphonomic data justifying the change of minds. I therefore see no reason to modify the concluding statement of the assessment of Bajondillo given in my 2006 review: “The Middle/Upper Paleolithic interface is fuzzy and post-depositionally disturbed, and great caution must be in order when interpreting the archaeological association and significance of (…) radiocarbon dates. With current evidence, use of [Bajondillo] to counter well-established patterns derived from more secure contexts is unwarranted.”

3.2.4. Lapa do Picareiro

This large cave site opens at *c.* 568 m asl (above modern sea level) (Fig. 13A). It features a Middle and Upper Palaeolithic archaeological stratification embedded in a succession of layers mostly made up of limestone fragments detached from the cave wall by cryoclastic spalling; the fine silt and clay matrix derives from soil-sediment inwash (Benedetti et al., 2019). The critical levels for the Transition are GG, HH and II (Fig. 13B). Based on stone tool technology (Fig. 13C) and Bayesian modelling of radiocarbon dates obtained on samples of ultrafiltrated collagen, these levels are claimed to belong in the Early Aurignacian and date to 41.1–38.1 ka ago (Haws et al., 2020). The modelling assumed that the GG-II ensemble represents a single, homogeneous behavioural package but nonetheless divided it into two phases: an earlier one, in the 40.6–42.4 ka interval, represented by level II; and a later one, in the 36.8–40.2 ka interval, represented by level GG. The beginning of the Aurignacian at Picareiro would thus fall in the time range of the Protoaurignacian of northern Spain, disproving Ebro Frontier and potentially vindicating the Bajondillo claims.

The first problem with these claims is that the date list and associated Bayesian model assign to level FF two results that,

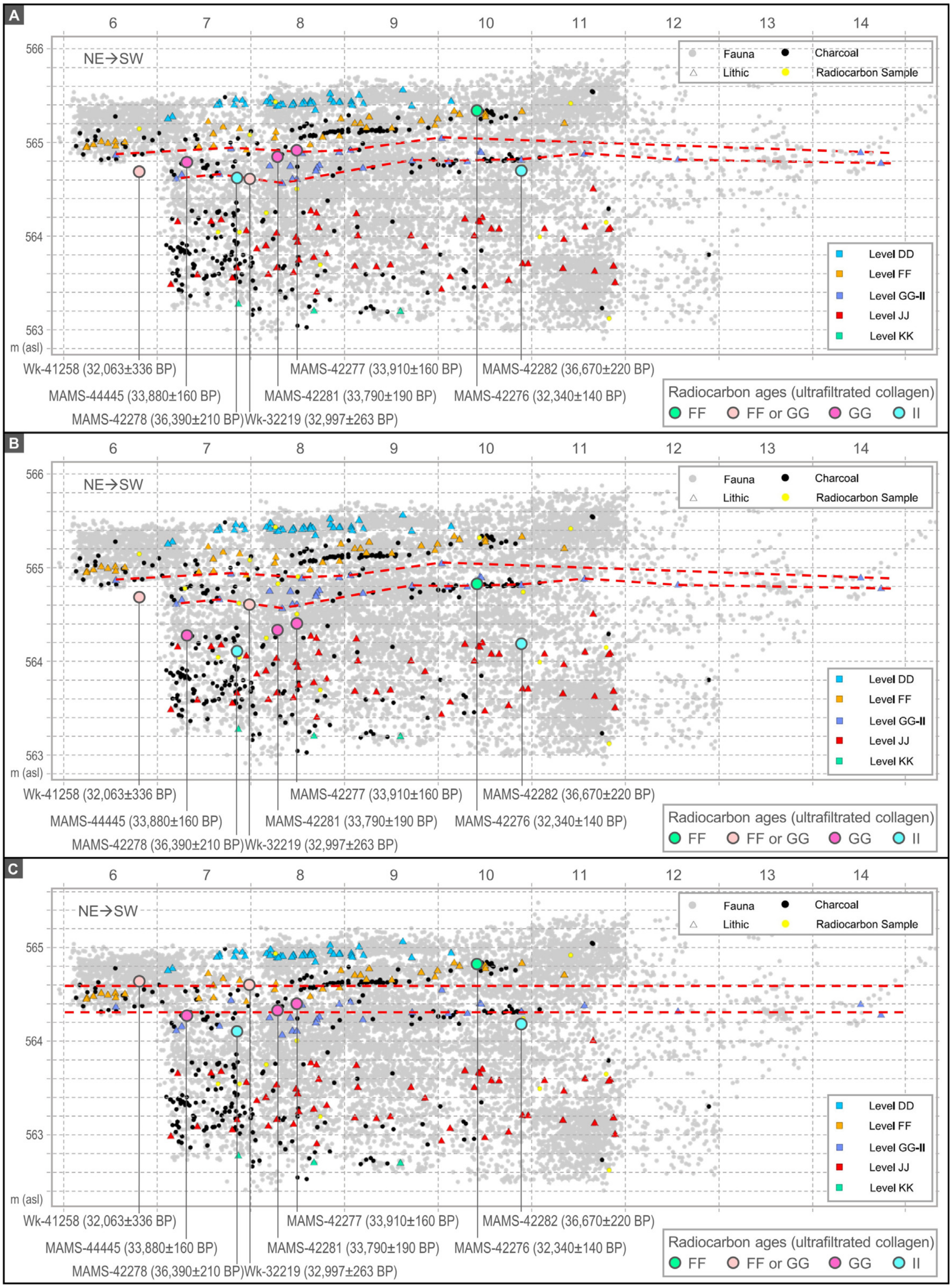

Fig. 14. Lapa do Picareiro: the dating. The bone samples from FF-II dated with collagen ultrafiltration projected on the cave's transversal axis. **A.** Correcting the position of Wk-32219 and Wk-41258 after Benedetti et al. (2019: Table 1). **B.** Applying the correction to all samples. **C.** Correcting the m asl scale. The dashed lines mark the upper and lower boundaries of GG defined by the lithics' colour coding (**A-B**) or in stratigraphic profiles (**C**). See text for additional explanation. After Haws et al. (2020: Fig. 3), modified.

according to Benedetti et al. (2019), were retrieved 6.40 m (Wk-32219; 32,997 ± 263 BP) and 6.33 m (Wk-41258; 32,063 ± 336 BP) bd, i.e., 564.60 m and 564.67 m asl, respectively (given the site datum's elevation, 571 m asl; Fig. 13A). This is *c.* 50 cm below where plotted in Fig. 3 of Haws et al. (2020) and squarely within the altitudinal range of the GG-II finds therein plotted. Indeed, Benedetti et al. (2019) explicitly provenanced Wk-41258 to GG, and no explanation has been provided for the inclusion of this sample among the “FF” samples of the Bayesian model (cf. Haws et al., 2020: Fig. 4 , Table S2).

The second problem concerns the inconsistencies in how the elevation of finds, samples, and stratigraphic units is reported. Fig. 14A assumes that the error with the two Wk samples is a one-off thing, corrects them, and redraws Haws et al.‘s scatterplot accordingly; when this is done, the set of results for GG-II no longer appears age/depth consistent. However, we have no information on the elevation bd of the set of MAMS dates; if they are affected by the same error, a question that one cannot but ask, then age/depth consistency is retained but all the samples would come from deposits found below, if not well below the putatively associated artefacts (Fig. 14B). The other possibility is that the error is systematic and affects the transformation into m asl of the elevation in m bd of all the finds in the scatterplot. This possibility is suggested by the discrepancy observed when comparing the upper boundary of the distribution of the items colour-coded as “GG” — all plotted above 564.6 m asl (i.e., above 6.4 m bd) — with the elevation— between *c.* 564.6 and 564.4 m asl (i.e., between *c.* 6.4 and 6.6 m bd) — of the upper boundary of level GG in the stratigraphic profiles illustrated by the sources (Benedetti et al., 2019: Fig. 4 ; Haws et al., 2020: Fig. 2C-E and S3) (cf. my Fig. 13B here). If such is the case, anchoring the scatterplot's vertical axis to the elevation of the two points for which the elevation bd is known (the Wk samples), as in Fig. 14C, suffices to correct the error. Doing so preserves the samples' age/depth relationship, reconciles their assigned provenance with the profiles' elevation data, and corroborates that the Wk samples are likely to belong in GG indeed. However, this solution to the problem introduces a mismatch with the colour coding used by the scatterplot to indicate the lithics' stratigraphic provenience, as most of the points coded as “GG-II” now plot below the lower boundary of GG. At first glance, this outcome is consistent with Haws et al.’s (2020) statement that “the earliest Aurignacian artefacts are distributed throughout the muddy matrix from the base of the large clasts of level GG through level II; ” from their Fig. 5 and Tables S4—S5 we know, however, that HH and II yielded no artefacts whatsoever and that all of the Aurignacian diagnostics came from GG. This information contradicts the Bayesian model's assignment of the two radiocarbon samples from layer II (MAMS-42282 and MAMS-42278) to an initial phase of the site's “Early Aurignacian,” which is also difficult to reconcile with their plotting below the stone tools colour-coded as GG-II (Fig. 14A—C).

The third problem concerns the origin of the dated bones, which has been described as follows: “A series of dates (…) on anthropically modified ungulate bones from the Late Middle and Early Upper Paleolithic levels is presented here (SI Appendix, Table S1 and Figs. S4—S6)” (Haws et al., 2020: 24415). This statement concerns all the MAMS samples from levels X-JJ, which all indeed appear to be of identical appearance; yet those from JJ-upper are “bones with percussion marks consistent with intentional butchery by humans” even though “lithic artefacts have not yet been found in this zone.” However, “consistent with intentional butchery” is not the same as “demonstrably anthropogenic.” Bearing in mind that artefacts were found neither in JJ-upper nor in HH or II, it is simply undemonstrated that the dated bones from these levels reflect human activity at the site; they could have been accumulated by carnivores or represent natural deaths (ibex, a taxon well represented in the faunal assemblage, shelters and often dies in caves). This is the more so if we bear in mind that animal bones are abundant across the entire thickness of the deposit, without interruption, whereas artefacts and charcoal are completely absent from the *c.* 40 cm between the base of GG and the top of JJ-lower (Fig. 14A—C). This pattern is strongly suggestive of humans being absent from the site through the four millennia or so of the corresponding interval's duration (*c.* 43—39 ka ago), strengthening the need for caution in the interpretation of the broken bones; it would be odd indeed that human usage of the site through such a long period of time left behind nothing else. Such caution cannot but be extended to the bones displaying similar breakage that were retrieved in levels such as GG, where the incursions documented by the scant artefacts must have been rather fleeting. Moreover, the faunal assemblages retrieved in the few late Middle and early Upper Palaeolithic cave deposits of similar characteristics (abundant animal bone, scant artefacts) known in Portugal (e.g., Buraca Escura, Caldeirão, Pego do Diabo; Aubry et al., 2001; Davis, 2002; Zilhão et al., 2010b) are all non-anthropogenic; there is no reason to think that Picareiro would have been unusual in this regard.

The fourth problem is that Haws et al. (2020) fail to heed Benedetti et al.’s (2019) conclusions about site formation. Given the dip of the stratification and the fact that debris flows are identified as a common deposition mechanism, the possibility that a given stratigraphic unit contains inherited material must be contemplated. A case in point are the sidescrapers found in level FF, based on which Benedetti et al. (2019) were led to speculate that FF might represent an interstratified Middle Palaeolithic occupation lens. Given that beds are clast-supported, forming a primarily openwork accumulation whose fine matrix represents the filling-in of voids, downward percolation of small elements would also have been inevitable, as indeed intimated by the ages obtained for charcoal samples that Haws et al. (2020) exclude from the modelling without explanation (e.g., Beta-247964 for level FF: 28,610 ± 300 BP; Benedetti et al., 2019).

If we can therefore conclude that the two results for level II provide a *terminus post quem* for the assemblage in GG, which of the latter's samples represent the age of the site's Aurignacian occupation is an open issue. Based on parsimony and consistency with the wider chronostratigraphic patterning, it should be Wk-41258 (35.6—37.1 ka) and Wk-32219 (36.7—38.8 ka), i.e., those that are in accord with (a) the Mula basin-derived timespan of 37.0—37.4 ka for the emergence of the Aurignacian in southern and western Iberia, and (b) the Middle Palaeolithic persisting beyond 39 ka at nearby Caldeirão. With regards to the other samples, the likeliest explanation is that they reflect the operation of the same kinds of site formation processes that ubiquitously affect the karst archives of the Transition in Iberia: palimpsesting, explaining the GG mix of different ages; and reworking, explaining FF's sidescrapers and charcoal date.

4. Discussion and conclusions

It is now clear that the Châtelperronian was indeed Neandertal-made and predates the Aurignacian rather than having persisted alongside it for many millennia. There should be no question either that, in northern Iberia, no Middle Palaeolithic isolates persisted into the time range of the Châtelperronian, let alone the Aurignacian.

Whether the rest of Iberia continued to be inhabited by Middle Palaeolithic Neandertals for significantly longer than Catalonia and the Cantabrian strip remains a contentious issue. However, south- and westward of the Ebro depression, the Evolved Aurignacian remains the earliest securely documented occurrence of an Upper Palaeolithic technological system. Based on European-wide patterns, one would expect the age of such occurrences to be to no earlier than the 38th millennium before the present time, which the high-resolution, age/depth consistent dating results for Malladetes and La Boja fully support. Conversely, the dating results for Cueva Antón, Cardina/Salto do Boi, Foz do Enxarrique, and Caldeirão imply persistence of the Middle Palaeolithic in eastern, central, southern, and western Iberia through the preceding four millennia. This evidence is summarised in Fig. 15, which plots the

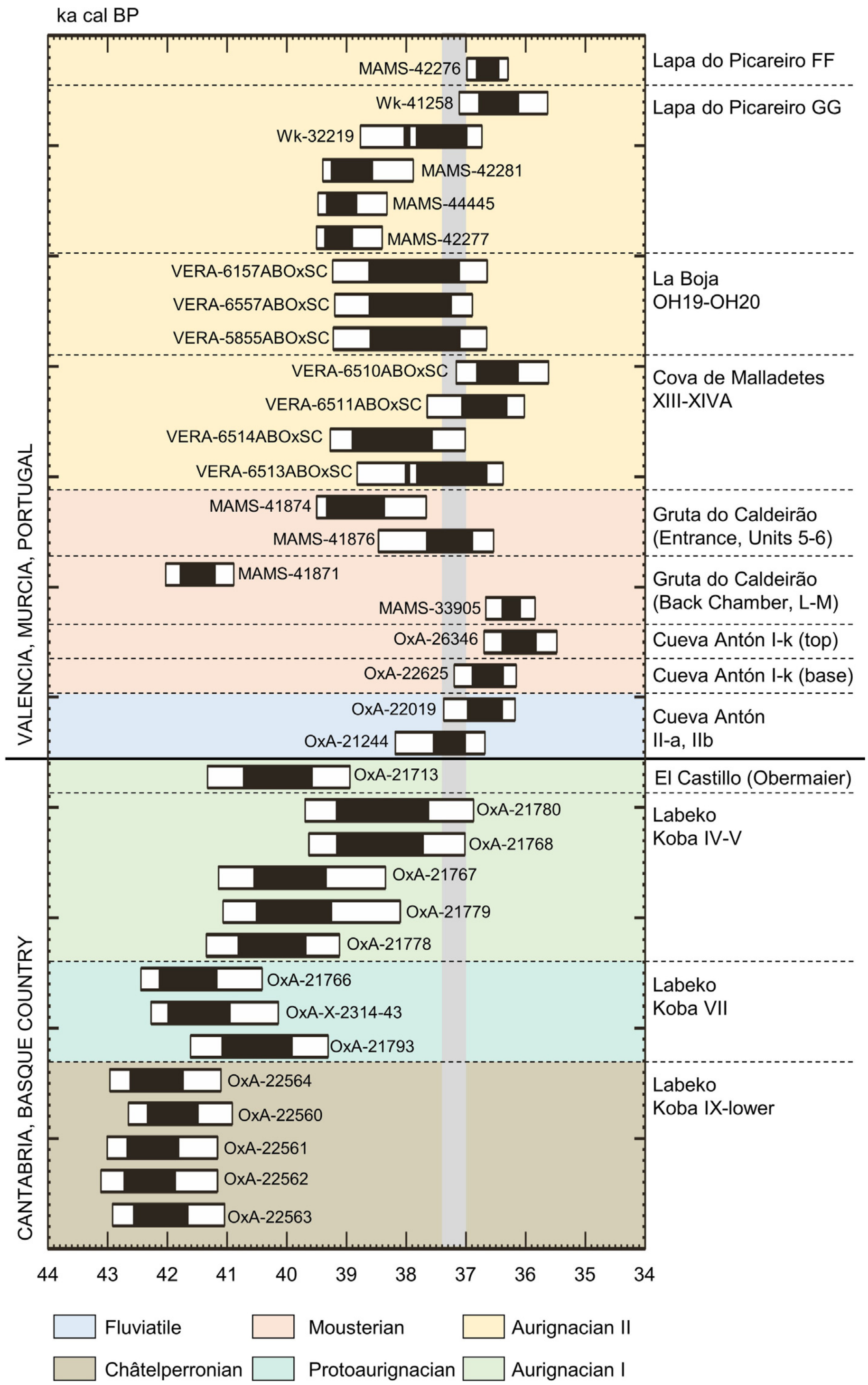

Fig. 15. The chronology of the Transition in Iberia. Block plot of the 95.4 % probability intervals of the calibrated radiocarbon ages in Table 1 (the black areas denote the 68.3 % probability interval). The grey band denotes the 37.0–37.4 ka interval to which the Mula basin sites (La Boja and Cueva Antón) constrain the Transition in eastern Spain.

radiocarbon ages for the key sites discussed here that have been obtained on robustly pre-treated samples (Table 1).

Dating error, caused by incomplete decontamination of samples close to or even beyond the range of radiocarbon remains an important issue in ongoing controversies. However, the generalised use of ultrafiltration and ABOx-SC and the progress made in the application of luminescence dating techniques are now working to significantly mitigate the impact of that problem. With regards to radiocarbon, the key point of contention is a strictly archaeological one: the relationship between a given sample and what that sample is supposed to date. One would have hoped that the clarification brought about by the redating of El Castillo and L'Arbreda would also have brought to the fore the importance of association issues, which, more recently, La Güelga has also highlighted; however, as other recent examples have shown (e.g., Bajondillo, Picareiro), this remains an unfinished business.

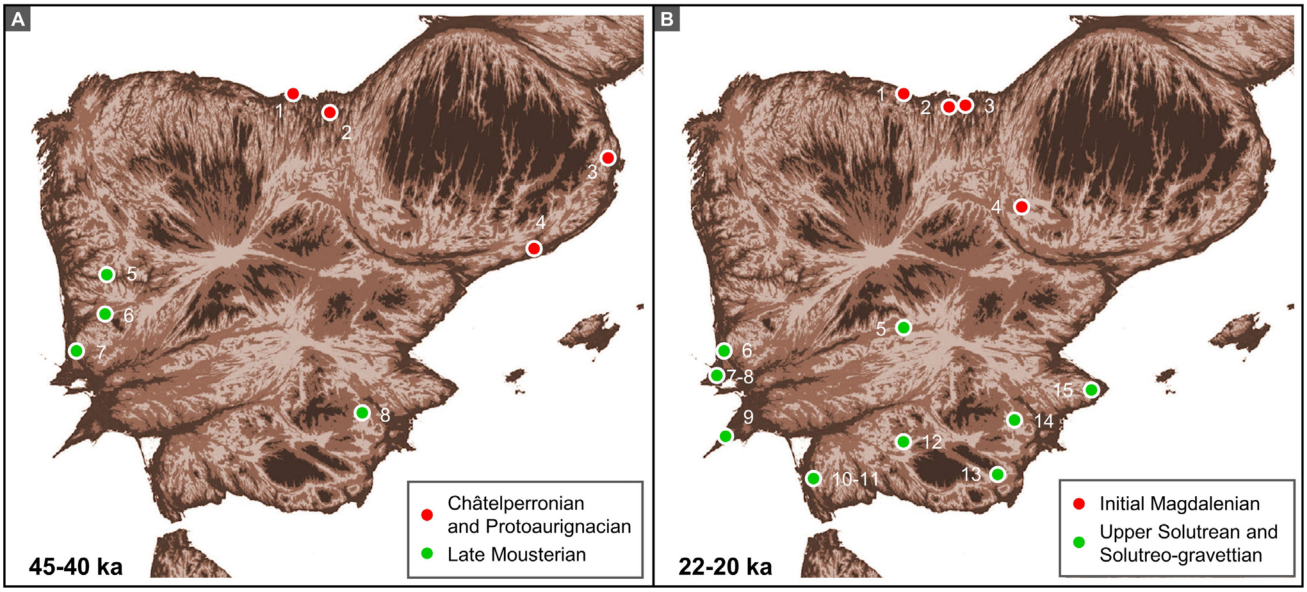

Fig. 16. Two aspects of the Ebro Frontier during the Upper Pleistocene of Iberia. The base map is Díaz del Río's (2020: Fig 2.2) friction-of-terrain cartogram (modified). **A.** During the Transition. Châtelperronian and Protoaurignacian: 1. Morín; 2. Labeko Koba; 3. L'Arbreda; 4. Foradada; Late Mousterian: 5. Cardina/Salto do Boi; 6. Foz do Enxarrique; 7. Caldeirão; 8. Antón. **B.** During the LGM. Initial Magdalenian: 1. Coímbre; 2. Rascaño; 3. El Mirón; 4. El Gato (after Straus, 2018). Upper Solutrean and Solutreo-gravettian (geographically representative sample of sites that yielded barbed-and-tanged or Parpallò points): 5. Arenero de Vidal; 6. Caldeirão; 7. Casa da Moura; 8. Salemas; 9. Vale Boi; 10. Higueral; 11. Fontanilla; 12. Pirulejo; 13. Ambrosio; 14. Finca de Doña Martina; 15. Parpallò (after Banks et al., 2009).

Ultimately, that controversies continue to revolve around taphonomic problems reflects the difficult and hard-to-deal-with Transition contexts encountered by Iberian archaeologists working in the karst domain. The large scale changes in global climate characterising the *c.* 37–42 ka interval significantly impacted those archives, as revealed by the well apparent scars they caused in all higher-resolution successions. Variable in kind, such impacts are ubiquitous in scope. Examples are the millennia-long hiatuses found at La Boja and Caldeirão, in both cases combined with significant, albeit localised post-depositional disturbance, or the marked slowdown of sedimentation apparent at Malladetes, where a corresponding deposit exists and has unambiguous entity, but is archaeologically sterile.

Interestingly, while the La Boja pattern suggests that, in rock-shelter contexts of eastern Spain, sedimentation would seem to have come to an almost complete halt during the *c.* 37–42 ka interval, it is the opposite in the case of the region's riverside contexts; as illustrated by the late MIS 3 deposit of Cueva Antón, coeval fluvial regimes featured mightier flows, leading to sediment accumulation picking up pace and potency. The same thing would seem to have happened in the valleys of the Côa and the Tagus, as documented at Cardina/Salto do Boi and Foz do Enxarrique. These examples suggest that it is in such fluvial archives that a definitive answer will eventually be found for the question of what happened to the Middle Palaeolithic people living beyond the Ebro when the Châtelperronian, first, and the Aurignacian, next, made their appearance in the Franco-Cantabrian region.

With current evidence, the hypothesis stands that the Middle Palaeolithic persisted for a few millennia, until the end of GI 8, only to be replaced by the Evolved Aurignacian, signalling the assimilation of Iberia's last Neandertals into the European-wide genetic and cultural pool created by the previous period of dynamic population interactions. This pattern has implications that extend way beyond the explanation of what happened in Iberian prehistory. If real and not an artefact of dating error or a biased record, it shows that, through Human Evolution, long-term intercontinental gene flow and cultural exchange could have been punctuated by extended periods of significant geographical isolation. Coupled with low population numbers, the occurrence of such prolonged periods of low-level interaction could explain why, despite the unity of the human species having been maintained through recurrent interbreeding, inter-population differences in morphology are so much more pronounced in the Lower and Middle Palaeolithic.

Explanations for the presence of the pattern during the *c.* 37–42 ka interval can be sought in the realms of biogeography and contingency. Collectively, the Pyrenean-Cantabrian cordillera, the Iberian System mountains, and the intervening Ebro River depression constitute a major physical obstacle to movement. Under adverse environmental circumstances this barrier effect would have been significantly enhanced — e.g., when mountain glaciers were present and arid-cold, semi-desert landscapes developed across the slopes at lower elevation, or, conversely, when trees expanded from cold-phase refugia during periods of climate amelioration, leading to the development of dense mountain forests. The *c.* 37–42 ka interval is a case in point because it witnessed a short spell of great aridity across the peninsula's Mediterranean façade, coincident with Heinrich Event (HE) 4, followed by much milder climate conditions during GI 8 — ones that, below 40° N, led to the formation of extensive tree-covered landscapes (Fletcher and Sánchez Goñi, 2008; Fletcher et al., 2010; Goñi et al., 2000; Sánchez Goñi et al., 2009; Sepulchre et al., 2007; Wolf et al., 2018).

The Phlegraean Fields caldera explosion, 39.9 ka ago (Fedele et al., 2007; Fitzsimmons et al., 2013; Giaccio et al., 2017; Silleni et al., 2020; Smith et al., 2016), may have temporarily boosted this frontier effect (Marti et al., 2016; Zilhão, 2009; Zilhão et al., 2017). For northern and western Europe, impacts would have been indirect and limited to short-term, worldwide "nuclear winter" effects. Across most of Italy and south-eastern Europe, which would seem to have been blanketed by the explosion's ash fall-out, food chains would have been disrupted, and the subsistence of hunter-gatherer communities severely compromised. To what extent and for how long carrying capacities were affected remains to be clarified but, for top-level predators, there can be little doubt that, in the regions that were directly hit, the explosion would have caused population crashes, if not extinctions. In adjacent territories, the emergence of such a sink would have had a significant consequence: release from the Eurasia-wide constraints of demographic pressure induced by the previous millennia of growth and assimilation, and creation of an outlet — the gradual repopulation of the areas that the explosion had turned into human deserts — for the shedding of any excess. For as long as the sink in central and south-eastern Europe remained unreplenished, pressure to expand westwards across the difficult terrain isolating the Iberian core from the rest of Europe would have ceased. Why the Neandertal/Modern admixture front eventually stalled at this point in space and time may therefore have been a consequence, at least in part, of such continent-wide demographic dynamics.

The implications for fate-of-the-Neandertals debates explain why Ebro Frontier attracted much attention. They also explain why the model has often been critiqued as proposing something entirely exceptional and, hence, something to be met with a healthy dose of scepticism. Another reason for this misconception is that, looking at Iberia based on our present-day world experience, we assess distance based on measurements of space. However, in a land without roads and at a time when people travelled on foot and did not have domesticated animals to transport their gear, equipment, and other possessions, such calculations are misleading, as powerfully illustrated by the friction-of-terrain cartogram in Fig. 16: in such circumstances, distance is a function of the time it costs to go from one place to another. In addition, bear in mind that relief is the only friction variable considered but, through late MIS 3 and MIS 2, semi-desert landscapes spread across the Ebro depression and the highlands of the Iberian System during harsher stadials, while their lower elevation mountainous terrain was colonised by temperate forest during milder interstadials; these fluctuations in vegetation cover would have enhanced the North-South barrier created by the Cantabrian, Iberian, and Pyrenean ranges.

It is therefore important to note here that the Ebro Frontier model builds upon biogeographic processes that, in Iberia, were in operation at several times during the Palaeolithic. This is well illustrated by the fact that, during MIS 3 and MIS 2, the typical cold-adapted fauna of the Eurasian steppe-tundra descended as far south as Barcelona — where it is represented *c.* 40 ka ago by the assemblage from Riera dels Canyars (Daura et al., 2013) — but failed to disperse into Valencia, Murcia, Andalusia, and Portugal. Whether, during the *c.* 37–42 ka interval, the Aurignacian peoples of the North coexisted with Mousterian Neandertals in the South remains controversial; but there can be little question that, during the preceding three millennia (*c.* 42–45 ka), a comparable separation existed, except that, then, the northerners were Neandertals too (albeit, Châtelperronian ones). Likewise, there is little question that, towards the end of the LGM, a similar cultural boundary separated for several millennia the Badegoulian and Early Magdalenian peoples of France from the Solutrean and Solutreogravettian peoples of Valencia, Murcia, Andalusia, and Portugal (Fig. 16). Knowing that, at the latitude of Valencia, 800 km separate the Atlantic from the Mediterranean, one might be puzzled to explain why the barbed-and-tanged or Parpallò bifacial point is found across the intervening geography but not in Catalonia, only 200 km north of the easternmost find locality of this Upper Solutrean index fossil. When the nature of the terrain is considered, however, it becomes clear why that is so: in terms of the time it takes to travel across on foot, Iberia is split in two halves of about the same size, and the territory encompassed by the distribution of the Parpallò point becomes *c.* 60 % smaller while the distance between Valencia and the Catalonian littoral remains the same (but would almost certainly increase significantly if the relief data were to be compounded with data on biomes and the extent of mountain glaciers).

The difficulty of the terrain to be crossed goes a long way to explain how much, how limited, or how intense, travel, communication, and exchange (of either genes or culture) can be. Social factors, however, also play a significant role, as shown by historical examples from the Arctic regions of eastern Canada (Graburn, 1979). Here, ethnographic accounts reveal that, through the 17th-18th centuries CE, little interaction existed across Indian/Inuit language barriers despite the overlapping of exploitation territories and the reliance on the same herds of migratory caribou; bilingualism was rare, mutual fear extreme, and regular trade, intermarriage, and co-residence unknown. The archaeological evidence supports that this pattern extended hundreds of years back in time, showing how low-density, small-scale hunter-gatherer societies may end up perceiving the other as “less than human” until such time comes as external circumstances force the *status quo* to change. Then, interaction, trade, and intermarriage eventually gain ground, with long-term consequences for the dilution of identitarian barriers based on language or “race.”

Future research may remain supportive of the Ebro Frontier model or bring about its falsification. Hopefully, whichever the case may turn out to be, the model will at least have been useful in highlighting that what is at stake goes beyond the comparison of sites, dates, and stone tools, and of their distributions. Such empirical data are the building blocks required to elaborate on what happened, and issues of accuracy and association doubtless will continue to deserve our full attention. But that should not detract from the fact that, ultimately, what we want to know is how populations interacted and how the outcome of that interaction can be explained using models derived from proper ethnographic analogy and operating at the historical rather than the evolutionary time scale.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This writing of this review was supported in part by FCT (Fundação para a Ciência e a Tecnologia, Portugal), via project ARQEVO (Archaeology and Evolution of Early Humans in the Western Façade of Iberia; PTDC/HAR-ARQ/30413/2017), and by the Government of Spain, via project HAR2017-85153-P (*Síntesis del Paleolítico medio y superior en Valencia y Murcia: aspectos cronológicos, paleoambientales, económicos y culturales*). I thank Pepe Carrión for his encouragement through the long two years of research and manuscript preparation. Lee Arnold, Thierry Aubry, Valentín Villaverde, and Pepe Carrión read parts of the original draft and contributed useful comments and information. Marianne Deschamps helped with the analysis of the lithics from the OH21a occupation horizon of La Boja. The research carried out since 2006 in the Mula basin sites of Murcia (Spain) has been of paramount importance in establishing the patterns summarised in this synthesis. I am hugely indebted to the dedicated work of all the colleagues and students who participated in the fieldwork and contributed to the publication of that project's results, and in particular to project co-directors Diego E. Angelucci, Valentín Villaverde, and Josefina Zapata. Any errors or omissions are my own.

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