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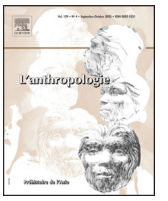

Original article

Chronology of the early Pleistocene Orce and Huéscar sites (Baza Basin, SE Spain)

Chronologie des sites d'Orce et de Huéscar du Pléistocène inférieur (Bassin de Baza, Sud-Est de l'Espagne)

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ABSTRACT

The Baza Basin (SE Spain) preserves one of the most complete continental records of the European early Pleistocene and is central to debates on the timing of the first human dispersals into Western Europe. This study provides an updated chronological and biochronological framework for the key sites of Orce (Fuente Nueva-1, Venta Micena, Barranco León and Fuente Nueva-3) and the nearby locality of Huéscar-1. We integrate large and small mammal biostratigraphy with paleomagnetism and published numerical dating (ESR, U-series, and cosmogenic nuclides) to refine the temporal succession of faunal assemblages spanning the middlle Villafranchian to the Epivillafranchian. Fuente Nueva-1 is placed near the middle–late Villafranchian transition (ca. 2.1–2.0 Ma). Venta Micena records a derived post-Dmanisi fauna best dated to ca. 1.6–1.5 Ma. Overlying layers at Barranco León and Fuente Nueva-3, which have yielded lithic artefacts, cut-marked bones, and a human deciduous tooth, are slightly younger (ca. 1.5–1.3 Ma), documenting the earliest well-dated human presence in Western Europe. Faunal changes between Venta Micena and these sites indicate increasing environmental openness and aridity and the replacement of mesodont caprines by more hypsodont forms, together with equid diversification. Huéscar-1 represents a later Epivillafranchian community (ca. 1.07–0.8 Ma), characterized by more generalized taxa linked to the Early–Middle Pleistocene Transition. The combined evidence supports a diachronous sequence of faunal turnovers and confirms that hominins reached southwestern

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Europe before the return of suids at the onset of the Early-Middle Pleistocene Transition, constraining the ecological context of the earliest European populations.

Mots clés :
Biochronologie
Paléomagnétisme
Datation numérique
Villafranchien supérieur
Épivillafranchien

RÉSUMÉ

Le bassin de Baza (SE de l'Espagne) conserve l'un des enregistrements continentaux les plus complets du Pléistocène inférieur européen et constitue une référence majeure pour la chronologie des premières dispersions humaines en Europe occidentale. Cette étude propose un cadre chronologique et biochronologique actualisé pour les principaux gisements d'Orce (Fuente Nueva-1, Venta Micena, Barranco León, Fuente Nueva-3) ainsi que pour le site voisin de Huéscar-1. Nous combinons les données biostratigraphiques des grands et petits mammifères avec le paléomagnétisme et les datations numériques publiées (ESR, séries de l'uranium, nucléides cosmogéniques) afin de préciser la succession des faunes du Villafranchien moyen à l'Épivillafranchien. Fuente Nueva-1 se situe près de la transition entre le Villafranchien moyenet le Villafranchien supérieur (ca. 2,1–2,0 Ma). Venta Micena enregistre une faune dérivée postérieure à Dmanisi, dont la datation la plus précise se situe entre ca. 1,6 et 1,5 Ma. Les niveaux sus-jacents de Barranco León et Fuente Nueva-3, qui ont livré des industries lithiques, des ossements portant des traces de découpe et une dent déciduale humaine, sont légèrement plus récents (ca. 1,5–1,3 Ma) et documentent de la présence humaine la plus ancienne et la mieux datée d'Europe occidentale. Les changements faunistiques entre Venta Micena et ces sites indiquent une ouverture et une aridité progressive des milieux, avec le remplacement de caprinés mésodontes par des formes plus hypsodontes parallèlement à une diversification des équidés. Huéscar-1 correspond à une communauté épivillafranchienne plus récente (ca. 1,07–0,8 Ma), dominée par des taxons plus généralistes liés à la transition entre le Pléistocène inférieuret le Pleistocène moyen. L'ensemble des données confirme une succession diachronique de renouvellements fauniques et indique que les homininés ont atteint le sud-ouest de l'Europe avant le retour des suidés au début de l'Épivillafranchien.

1. Introduction

The preservational completeness of the latest Miocene to Pleistocene paleobiological continental record of the Baza Basin (Andalusia, SE Spain) is probably the best of Europe (Maldonado-Garrido et al., 2017; Martínez-Navarro et al., 2018). In this context, the Orce sub-basin, situated in the northeastern sector of the Baza Basin, is worldwide known by its exceptional Early Pleistocene stratigraphic series, which also records the earliest evidence of human presence in Western Europe at the sites of Barranco León, with an estimated chronology of 1.43 Ma (Toro-Moyano et al., 2013) and Fuente Nueva-3 (Martínez-Navarro et al., 1997; Oms et al., 2000), dated between 1.5 and 1.2 Ma (Álvarez-Posada et al., 2015).

Once the debate on the *short chronology* (defended by Roebroeks and Kolfschoten, 1994) vs. the *long chronology* was overcome, thanks to the findings during the eighties and nineties of the XX Century of several early Pleistocene human records in Southern Europe, especially at the sites of Orce and Atapuerca in Spain, the discussion was focussed on the chronology of the first human colonization of Europe, which was increasing in time year per year, especially after the findings of Dmanisi, in Georgia, at the gates of the European Continent, dated to 1.85–1.77 Ma (Dźaparidze et al., 1989; Lordkipanidze et al., 2007, among others). The race to find the first European began, and the debate on the early Pleistocene human fossil record in Southern and Western Europe started to be a permanent and hotly topic of discussion. The research on the early Pleistocene sites of Orce, discovered for the science on the summer of 1976 by the team led by Prof. J. Gibert, started to be in the centre of the debate.

The study of the faunal assemblages of Orce, situated in the *cul-de-sac* of the Iberian Peninsula, the westernmost region of Eurasia, is crucial for understanding the first human colonization of Europe. Now, we know that the dispersal of humans out of Africa was coincident with the dispersal in Europe of some large mammal species of African origin, which normally dispersed via the bottleneck of the Levantine Corridor. The fossil record in this area shows that early Pleistocene faunas of Holarctic and African origins are mixed here. This is especially evident at Ubeidiya (Israel), a site dated between 1.6 and 1.2 Ma (Tchernov, 1986; Martínez-Navarro et al., 2009, 2012a). However, only very few species of African origin were able to cross the Taurus mountains across Anatolia and disperse into the European continent (Martínez-Navarro and Palmqvist, 1995, 1996; Martínez-Navarro, 2010; Martínez-Navarro and Rook, 2025).

In this paper we describe the early Pleistocene mammalian faunas from the Baza Basin, especially those from the sites cited above, which are the most excavated up to date: (i) discussing on the species origin and the chronology of each site in the context of geochronological data; (ii) comparing them with the late Villafranchian and Epivillafranchian records from other sites of Europe and Western Asia; and (iii) discussing on their relationship with the human dispersal events into the Eurasian continent (Rook and Martínez-Navarro, 2010; Bellucci et al., 2015).

2. The Villafranchian and Epivillafranchian records of the Baza Basin: Orce and Huéscar

The term Villafranchian was described in reference to the fossil large mammal faunas contained in the fluviatile and lacustrine sediments from Villafranca d'Asti, Piedmont, Italy (Pareto, 1865). It comprises a timespan of 2.5 million-years, from the Late Pliocene (ca. 3.6 Ma) until the late Early Pleistocene (1.1 Ma), the base of the Jaramillo normal subchron. This European biochronological unit is divided in Early Villafranchian (from 3.6 to 2.6 Ma), Middle Villafranchian (from 2.6 to 2.2–2.1 Ma), and Late Villafranchian (from 2.2–2.1 to 1.1 Ma) (Rook and Martínez-Navarro, 2010; Madurell-Malapeira et al., 2014). The late Villafranchian is followed by the Epivillafranchian, which spans until the Early-Middle Pleistocene transition (0.8–0.7 Ma) (Madurell-Malapeira et al., 2014; Bellucci et al., 2015; Martínez-Navarro and Rook, 2025).

Although the Baza Basin has a mostly complete Plio-Pleistocene fossil record, with early Ruscinian (MN14) assemblages recorded at several sites but especially at the Baza 1 site (Ros-Montoya et al., 2017). The late Ruscinian (MN15) is well recorded at the Huéscar sites (Mazo et al., 1985), particularly at the Canal de San Clemente site (Martínez-Navarro et al., 2006). The early Villafranchian is only represented at the basin by several layers with small vertebrates (see Maldonado-Garrido et al., 2017). Finally, the Orce series records the best early Pleistocene assemblages of the basin, including the Middle Villafranchian site of Fuente Nueva-1 (FN-1) and several Late Villafranchian sites, which are particularly well recorded around most of the stratigraphic series in the triangle formed by Orce and its two hamlets, Fuente Nueva and Venta Micena, with particular interest in the paleontological site of Venta Micena (VM), and the archaeological sites of Fuente Nueva-3 (FN-3) and Barranco León (BL). The known faunal assemblages are completed by the latest early Pleistocene site of Huéscar-1 (Hu-1), which records the Epivillafranchian (Table 1, Fig. 1).

3. Fuente Nueva-1 and the late Middle Villafranchian

This locality was first published by Moyà-Solà et al. (1987), with a faunal list dominated by the presence of *Mimomys* spp., *Apodemus dominans*, *Castillomyscrusafonti*, Leporidae indet., Carnivora indet., *Gazella borbonica*, and *Equus stenonisvireti*. Later on, Gibert et al. (2002), after a small systematic excavation, published the following faunal list: *Castillomys crusafonti* ssp., *Apodemus dominans*, *Mimomys* cf. *reidi*, *Equus stenonis*, Rhinocerontidae indet., *Gazella borbonica*, *Soergelia* spp., Bovidae indet. 1, *Cervus* cf. *perrieri*, Cervidae indet., *Lynx* cf. *issiodorensis*, *Pachycrocuta perrieri*, *Canis* spp., and Carnivora indet. small size.

The latter faunal list displays some inconsistencies, including the presence of *Soergelia*, which has not been recorded at any other European site with a chronology older than 1.8 Ma. This finding suggests that it may have been mistaken with other bovid species. In any case, this paper addressed the importance of FN-1, a site that has not been well appreciated because it is very old as to preserve evidence of human presence. In addition, the record of *Canis* (if this record proves correct, as its determination is only based on the presence of a canine, which was not figured or measured) at FN-1 would indicate a transition from the Middle to the Late Villafranchian, but the evidence is not conclusive. Following this imprecise faunal list, and based on paleomagnetic and stratigraphic data, Scott et al. (2007) situated FN-1 in a chronology close to 1.5 Ma, thus younger than Dmanisi, which is impossible based on its vertebrate assemblage. Later on, and based on the same data, Gibert et al. (2024) suggested that FN1 is chronologically situated just above the Olduvai normal paleomagnetic subchron (1.7–1.5 Ma).

In their study of the Orce paleomagnetic series, Oms et al. (1996) situated FN-1 in the subchron 2r1n (Reunión), between 2.14–2.08 Ma.

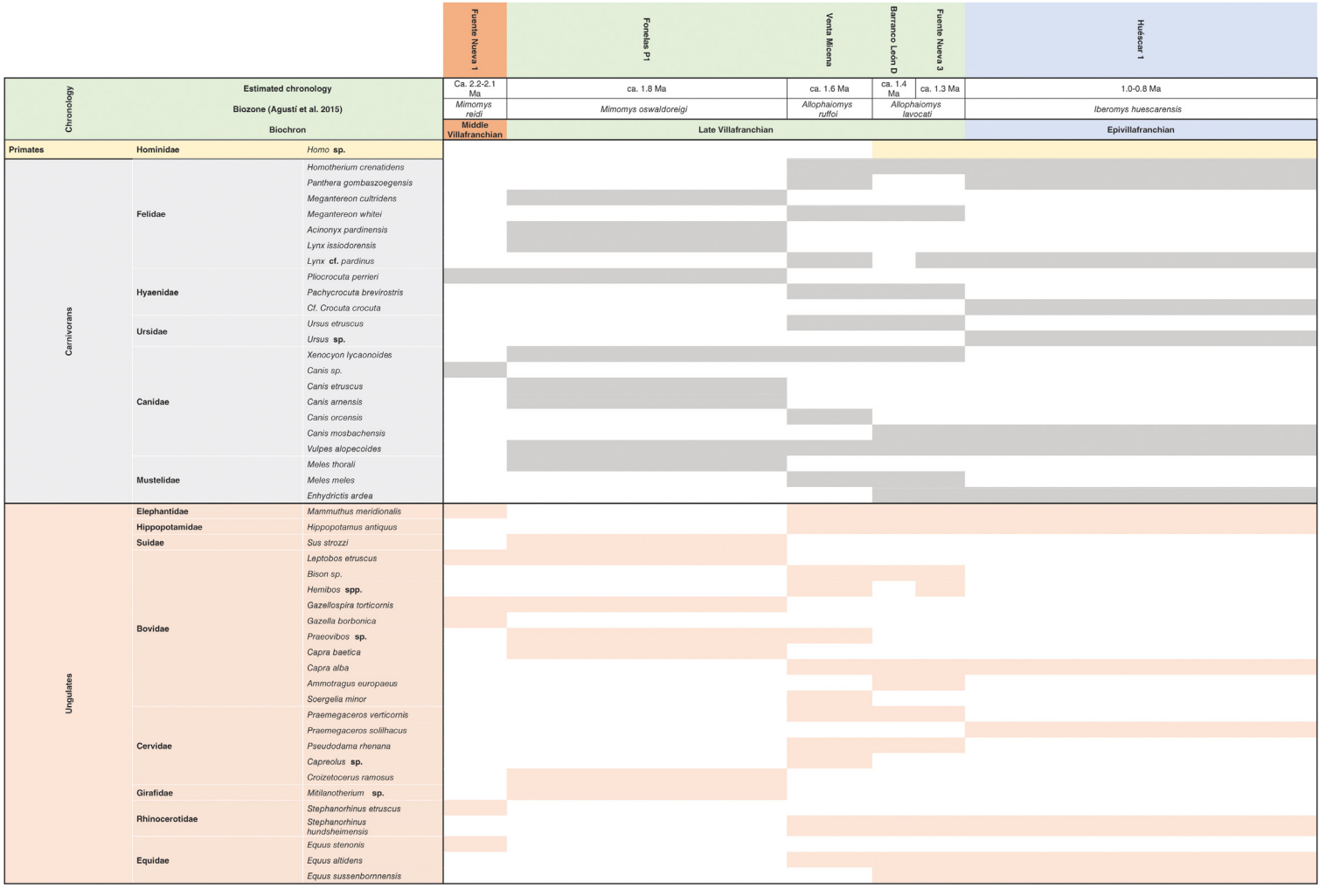
According to the new biochronological data preliminarily published by Ros-Montoya et al. (2016), who reported on the presence of *Stephanorhinus etruscus* and *Gazellospira torticornis* in FN-1, the age of this site would probably be close to the chronology proposed by Oms et al. (1996).

4. Venta Micena: the most representative Late Villafranchian paleontological site of Western Europe

This paleontological site was found by J. Gibert, J. Agustí and N. Sánchez in July 1976. It is a 80–120 cm thick horizontal stratum of white micritic limestone (99% of pureness)that outcrops over an extension of more than 2.5 km showing a continuous presence of fossil large mammals. It preserves a surface of more than 1 km^2 (i.e., > 1.000.000 m^2) that is filled by fossil remains of large vertebrates. This means that Venta Micena probably represents one of the largest and richest paleontological sites of the world, similar to the Late Pleistocene La Brea tar pits of Los Angeles in California. The faunal list includes 22 species of large mammals: *Mammuthus meridionalis*, *Stephanorhinus hundsheimensis*, *Equus altidens*, *Hippopotamus antiquus*, *Praemegaceros* cf. *verticornis*, *Pseudodamarhenana*, *Capreolus* spp., *Bison* spp., *Hemibos* aff. *gracilis*, *Praeovibos* spp., *Soergelia minor*, *Hemitragus albus*, Caprini indet., *Ursus etruscus*, *Xenocyon lycaonoides*, *Canis orcensis*, *Vulpes alopecoides*, *Meles* spp., *Homotherium crenatidens*, *Megantereon whitei*, *Panthera* cf. *gombaszoegensis*, and *Lynx* spp. (Moyà-Solà et al., 1987; Martínez-Navarro, 1991; Martínez-Navarro and Rook, 2003; Martínez-Navarro et al., 2011, 2021; Ros-Montoya, 2010; Rodríguez-Gómez et al., 2017a; among others). Apart from these species, the following small vertebrates must be added: *Testudo* spp., *Pelophylax* cf. *perezi*, *Asoriculus gibberodon*, *Galemys pyrenaicus*, *Galemys* spp., *Allophaiomys ruffoi*, *Eliomys intermedius*, *Hystrix major*, *Apodemus* aff. *mystacinus*, *Apodemus sylvaticus*, *Castillo myscrusafonti*, *Oryctolagus* cf. *lacosti*, and *Prolagus calpensis* (Agustí et al., 2015; Maldonado-Garrido et al., 2017).

This site was first excavated in 1976, and later there were two excavation seasons in 1979 and 1982, following no systematic methodology of excavation. Later on, it has been methodologically excavated in different intermitent periods. During the

Table 1
Large mammals record of the most significant Early Pleistocene localities from the Guadix-Baza Depression at Orce (Fuente Nueva 1 [latest Middle Villafranchian], Venta Micena, Barranco León level D, and Fuente Nueva 3 [Late Villafranchian]), Huéscar (Huéscar 1 [Epivillafranchian]), and Fonelas (Fonelas P1 [base of the Late Villafranchian]). This last site has been included here because, although the earliest Late Villafranchian is recorded in the Orce series at sites like Barranco de los Conejos, the neighbour locality of Fonelas P1 has a much better large mammals record.
Données sur les grands mammifères des localités les plus importantes du Pléistocène inférieur de la dépression de Guadix-Baza : Orce (Fuente Nueva-1 [Villafranchien moyen terminal], Venta Micena, Barranco León niveau D et Fuente Nueva-3 [Villafranchien supérieur]), Huéscar (Huéscar-1 [Épivillafranchien]) et Fonelas (Fonelas P1 [base du Villafranchien supérieur]). Ce dernier site a été inclus car, bien que le Villafranchien supérieur le plus ancien soit présent dans la série d'Orce, sur des sites comme Barranco de los Conejos, la localité voisine de Fonelas P1 présente des données sur les grands mammifères beaucoup plus riches.



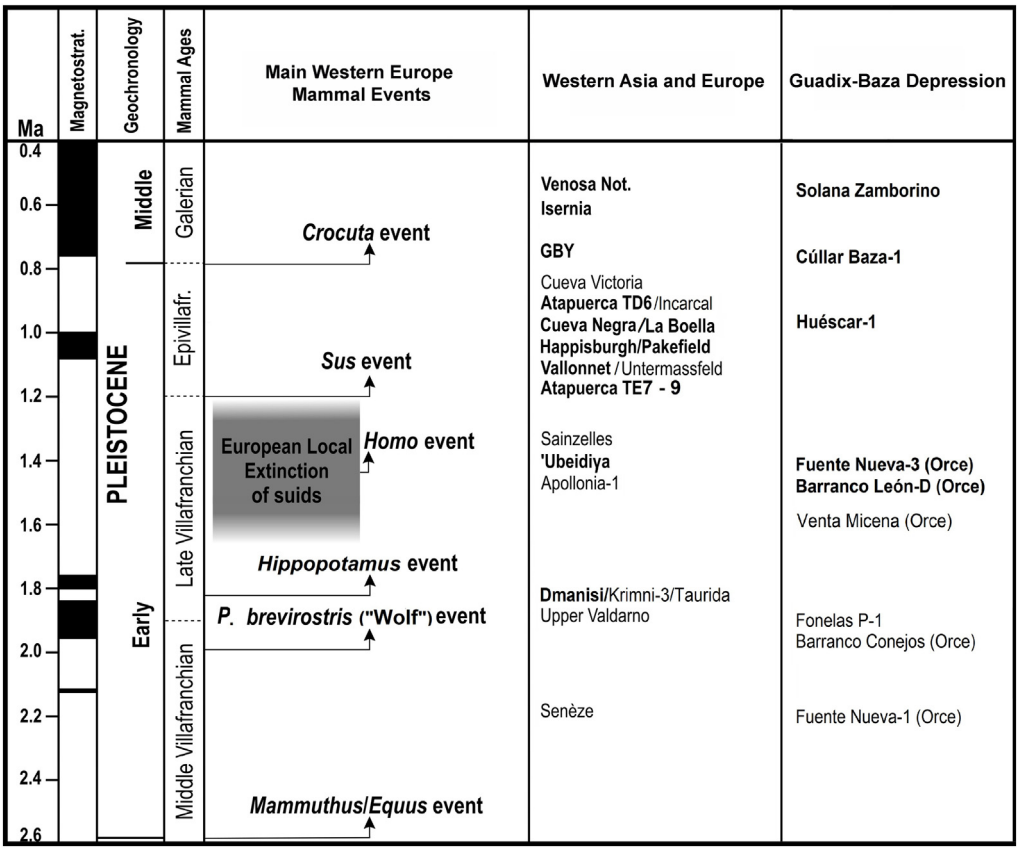


Fig. 1. Chronostratigraphic chart of the most significant sites from the Guadix-Baza Depression, in the general context of Europe and Western Asia (Sites with archaeological/paleoanthropological record are marked in bold).
Tableau chronostratigraphique des sites les plus importants de la dépression de Guadix-Baza, dans le contexte général de l'Europe et de l'Asie occidentale (Les sites ayant fait l'objet de fouilles archéologiques ou paléoanthropologiques sont indiqués en gras).

1982 season a cranial fragment (VM0) was found and ascribed to *Homo* spp. (Gibert et al., 1983). At that time, this remain would have represented the oldest human fossil of Eurasia. The finding was lately questioned and the fossil was re-ascribed to a horse (Agustí and Moyà-Solà, 1987; Moyà-Solà and Köhler, 1997; Palmqvist, 1997). This disagreement generated a shadow on the extraordinary paleontological heritage of Venta Micena, but also in all the Orce sites, and created a long-standing controversy on the humanity or not of fossil VM0, which is still alive in the local society of Orce and Granada. Finally, the polemic was scientifically solved when the cranial fragment VM0 was ascribed to a female of a ruminant without frontal appendices. The polemic resulted from the original misinterpretation of the cranial anatomy, as the bones initially considered as parietals were frontals and the lambdoid sutures were the coronal one (Martínez-Navarro, 2002, 2012). Then, at the moment, no human evidence has been found at Venta Micena.

The chronology of Venta Micena has been subject to different interpretations. During the eighties, based on the presence of the arvicolid *Allophaiomys pliocaenicus* (a synonym of *A. ruffoi*), the site was dated to a pre-Jaramillo normal event and included within the biozone MmQ2, which was created by Agustí et al. (1987), with a relative age close to 1.2 Ma.

In 1991, based on published biochronological data and unpublished magnetostratigraphic data provided by F. Semah, the site was dated to approximately 1.6 Ma by B. Martínez-Navarro in his PhD thesis (Martínez-Navarro, 1991).

This chronology has been questioned several times. Scott et al. (2007), based on magnetostratigraphic data and a very simplified and inaccurate interpretation of the biochronological record, affirmed that "the quarried strata (Venta Micena, Barranco León and Fuentenueva-3) are from a narrow time span ($^{<}$ 100 ka) starting before 1.3 Ma". Duval et al. (2011), based on a combination of biochronological and paleomagnetic data, compared with radiometric data from Atapuerca Sima del Elefante and proposed that there was an obvious chronology for Venta Micena comprised between 1.77 and 1.22 Ma. Moreover, the analyses of 5 fossil teeth of large mammals by a combined uranium series – electron spin resonance (US-ESR) dating approach resulted in an age estimate for the site of 1.37 ± 0.24 Ma, close to 1.4 Ma. Finally, Gibert et al. (2024), using very similar magnetostratigraphic data to those published by Scott et al. (2007) and based on a "Bayesian age-stratigraphic model", gave a chronology to Venta Micena of 1.32 ± 0.07 Ma (i.e., the same as in 2007).

What insights do the large mammals from Venta Micena provide? A detailed analysis of the site vertebrate record, species by species, reveals that all the taxa recorded at the site are derived forms of the same lineages recorded at the Caucasian site of

Dmanisi, with the exception of *Hippopotamus antiquus*, which is not recorded at the Georgian site. This clearly indicates that Venta Micena is younger than Dmanisi, and it is older than Barranco León and Fuente Nueva-3, as discussed below, with a chronology close to 1.6–1.5 Ma, as proposed by Martínez-Navarro (1991).

5. The Late Villafranchian sites of Barranco León and Fuente Nueva-3: the earliest record of human presence in western Europe

Barranco León and Fuente Nueva-3 preserve similar (or even identical) faunal assemblages. Therefore, they will be explained together in the present study.

Barranco León: This paleoanthropological site was found in the summer of 1983 by a team led by the late J. Gibert. It is situated equidistant between the town of Orce and the village of Fuente Nueva, and shows one of the best outcrops of the early Pleistocene stratigraphic series of Orce. It has been recently drilled, completing a stratigraphic series of more than 80 m (Santamaría Barragán et al., 2025). The fertile paleontological and archaeological layer is named as BLD, corresponding to the filling of a fluvial paleochannel (Arribas and Palmqvist, 2002), with conglomerates and gravels in the basal part (layer D1) and very thin sands in the upper one (layer D2), where most of the large mammals fossils, including a deciduous human tooth, lithic tools and cut and percussion marks on the large mammal bones are located (Toro-Moyano et al., 2013; Espigares et al., 2019).

Fuente Nueva 3: This site was discovered by two children, the brothers Santiago and Pablo Cristobal-Ninou, who showed it to Alain Bocquet, the owner of a neighbouring cave-house placed 100 m distant from the site. A. Bocquet showed the site to one of us (BMN) in May 1991 and, in December 1992, during the earthmoving for the installation of the electrical network in Fuente Nueva, we stopped the excavator machine when it was going to place a pole on the outcrop, leaving on the surface a significant amount of flint flakes and fossils of large mammals. The stratigraphy of the site was first described as composed by 15 stratigraphic layers (Turq et al., 1996; Martínez-Navarro et al., 1997). This stratigraphy was revised in Oms et al. (2011), who reduced the series to 12 layers grouped in three sedimentary cycles, from bottom to top, composed of four levels of nodular whitish limestones (layers 1, 4, 11, and 12) with evidence of paleoseismites, irregular yellowish marly levels predominantly composed of clays and silts (layers 2, 3, 6, 7, 8, 9, and 10), and one level of dark greenish fine and very fine sands (layer 5). Each of the three sedimentary cycles record shows dark-coloured marly lutites at the bottom, followed by sands with abundant iron oxides and carbonate nodules, completed by micro-karstified limestones with intraclasts and diagenetic markers at the top. The lowermost cycle is only represented by its upper part, layer 1; the middle cycle is recorded by layers 2 to 4, and the uppermost cycle records layers 5 to 12. Of these stratigraphic levels, layers 2, 3 and 5 preserve most fossils and tools unearthed from the site. These layers were deposited in a shallow lacustrine to swampy environment with variable depth, including sedimentary episodes associated with lakeshore conditions. All of these layers show variable thickness with irregular boundaries that evidence erosive processes, deformation structures, and earthquakes (Oms et al., 2011; Palmqvist et al., 2024).

The upper archaeological level of Fuente Nueva-3, where the presence of abundant hyaena coprolites is well documented, has been interpreted as a fossil latrine of the giant hyaena *Pachycrocuta brevirostris* (Espigares et al., 2023). More specifically, layer 5 has been interpreted as a quicksand level where elephants (*Mammuthus meridionalis*) and other megaherbivores were entrapped and scavenged by large carnivores, especially hyaenas (Palmqvist et al., 2024; Rodríguez-Gómez et al., 2024).

Apart from statistical differences in taxa abundance between the lower and upper archaeological levels, the composition of large mammals is homogeneous not only along all the stratigraphic series of Fuente Nueva 3, but is also like that of the level D of Barranco León, with no differences between both archaeological sites. It is composed by: *Homo* spp., *Mammuthus meridionalis*, *Stephanorhinus hundsheimensis*, *Equus altidens*, *Equus suessenbornensis*, *Hippopotamus antiquus*, *Bison* spp., *Hemibos* aff. *gracilis*, *Ammotragus europaeus*, *Hemitragus albus*, *Praemegaceros verticornis*, *Pseudodamarhenana*. *Ursus etruscus*, *Xenocyon lycaonoides*, *Canis mosbachensis*, *Vulpes alopecoides*, *Pachycrocuta brevirostris*, *Megantereon whitei*, *Homotherium crenatidens*, *Lynx* cf. *pardinus*, *Melesmeles*, and *Martellictis ardea* (Martínez-Navarro et al., 2003, 2010; Madurell-Malapeira et al., 2011; Rodríguez-Gómez et al., 2016; Medin et al., 2017; Bartolini-Lucenti and Madurell-Malapeira, 2020; Ros-Montoya et al., 2021). Furthermore, the following microvertebrates are recorded: *Squalius* aff. *cephalus*, *Squalius* aff. *pyrenaicus*, *Luciobarbus* aff. *sclateri*, *Discoglossus* cf. *jeanneae*, *Pelobates cultripes*, *Bufo bufo*, *Bufo calamita*, *Bufo* spp., *Hyla meridionalis*, *Pelophylax*cf. *perezi*, *Mauremys leprosa*, *Testudo* spp., *Emys orbicularis*, *Timon* cf. *lepidus*, *Dopasia* spp., *Coronella* cf. *girondica*, *Chalcides* cf. *bedriagai*, *Malpolon monspessulanus*, *Natrix maura*, *Natrix natrix*, *Rhinechis scalaris*, *Erinaceus* cf. *praeglacialis*, *Asoriculus gibberodon*, *Crocidura* spp., *Sorex minutus*, *Galemys* spp., *Allophaiomys* aff. *lavocati*, *Allophaiomys* spp., *Mimomys savini*, *Hystrix* spp., *Apodemus flavicollis*, *Apodemus mystacinus*, *Apodemus* aff. *mystacinus*, *Castillomys rivas*, *Oryctolagus* cf. *lacosti*, *Oryctolagus* spp., *Prolagus* spp. (Agustí et al., 2015, Maldonado-Garrido et al., 2017).

The chronology of Barranco León was initially based on biochronological data, which allows including it within the MnQ2 biozone, with a chronology similar to Venta Micena (Agustí et al., 1987). Later, once the magnetostratigraphy of the series was performed, and based on the arvicolid record, including *Mimomys savini*, the site was tentatively dated to an age close to 1.0 Ma (Oms et al., 2000). In 2013, in the publication of the fossil human tooth (Toro-Moyano et al., 2013), biochronological data were combined with paleomagnetism and with an age estimate obtained with electron spin resonance (ESR) dating applied to five samples of optically bleached quartz grains, which were extracted from the sediments separated 5 m from top to bottom in the stratigraphic series, and with a sample from layer BLD (sample ESR BL2) situated in the middle of the sampled stratigraphic series. This data provided the following results: ESR BL5 (top of layer E1, just above layer D2): 1.02 ± 0.09 Ma; ESR BL3 and BL4 (layer D2): 1.88 ± 0.19 Ma and 1.23 ± 0.12 Ma: ESR BL2 (layer D1): 1.46 ± 0.17 Ma; ESR BL1 (bottom: sampled 1.5 m below the base

of layer D1): 1.73 ± 0.17 Ma. These data suggested that sample ESR BL3 was oversized and, for this reason, it was discarded. As a result, the ESR weighted mean age of BLD, based on samples BL2, BL3 and BL4 from layer BLD, would be 1.43 ± 0.38 Ma (Toro-Moyano et al., 2013).

The first chronology of the stratigraphic layers of FN-3 was calibrated using a combined approach including biostratigraphy, based on the arvicolid record -which included *Mimomys savini* – and magnetostratigraphy (Martínez-Navarro et al., 1997). Years later, electron spin resonance (ESR) was also applied, providing an age of 1.19 ± 0.21 Ma (Duval et al., 2012). Similarly, Álvarez et al. (2015) used the cosmogenic nuclides technic, obtaining an age of 1.50 ± 0.31 Ma for the site.

In any case, the topographic positions of Barranco León and Fuente Nueva-3 are 6–7 m above the VM stratum. The small fauna of mammals, with the presence of *Allophaiomys ruffoi* in VM and *Mimomys savini* in BL and FN-3, suggests that BL and FN-3 are younger than VM. These results are corroborated by the large mammals record, where VM includes the mesodont caprine *Soergelia minor*, which is not present in BL and FN-3, as this ovibovine is substituted in these sites by an hypsodont caprine, *Ammotragus europaeus* (Moullé et al., 2004; Martínez-Navarro et al., 2010). Moreover, VM records only one equid, *Equus altidens*, while in BL and FN-3, two horse species, *Equus altidens* and *Equus suessenbornensis* (Alberdi, 2010), are documented. The presence of two equids in these sites, as well as the finding of a hypergrazing caprine in FN-3, indicates a more open environment with abundant grasses of low nutritional value in BL and FN-3 compared to VM, which would record more humid conditions and a higher quality forage for ungulates (Martínez-Navarro et al., 2010; Palmqvist et al., 2022b).

6. Huéscar-1 and the Epivillafranchian in the Baza basin

The Epivillafranchian is not recorded at any of the Orce sites, but it is present at the neighbouring site of Huéscar-1 (Hu-1) in the Baza Basin, found by E. Torrecillas at the beginning of the eighties. The depositional context of the archaeological layers corresponds to alluvial fans that prograded in an ephemeral lacustrine environment. The stratigraphic series shows a succession of paleo-channels, with an erosive base and fining-upward grain selection (i.e., the stratigraphy shows that particle size decreases with height, starting from conglomerates at the base to fine sands on the top) (Alonso-Diago et al., 2003).

The published list of large mammals includes *Canis mosbachensis*, Hyaenidae indet., *Ursus* spp., *Panthera gombaszoegensis*, *Homotherium* spp., *Enhydrictis* cf. *ardea*, *Equus altidens*, *Equus suessenbornensis*, *Stephanorhinus* ex gr. *Stephanorhinus hundsheimensis*, *Hipopotamus antiquus*, *Praemegaceros* cf. *P. solilhacus*, a member of Caprini Tribe identified as either *Capra* spp. or *Hemitragus*, and *Mammuthus meridionalis* (Mazo et al., 1985; Alberdi and Bonadonna, 1989; Ros-Montoya, 2010; Ros-Montoya et al., 2018). This is complemented with micromammals (Soricidae indet., *Eliomys quercinus*, *Apodemus* spp., *Castillomys crusafonti* ssp., *Mimomys savini*, *Iberomys huescarensis*, cf. *Microtus* (*Pitymys*) *gregaloides*, *Oryctolagus* spp., *Lepus* cf. *L. granatensis*, Leporidae indet.) (Mazo et al., 1985; Sesé, 1989; Cuenca-Bescós et al., 2014; Agustí et al., 2015), and an important bird assemblage (cf. *Tachybaptus ruficollis*, *Anas crecca/Anas querquedula*, *Anas platyrhynchos*, *Anas clypeata*, *Anas strepera*, *Anas* spp., *Netta rufina*, *Aythya ferina*, *Aythya nyroca*, *Aythya fuligula*, *Aythya* spp., *Perdix perdix*, *Crex crex*, and *Bubo bubo*), which is dominated by ducks that evidence a wetland environment, although other more terrestrial species are also present (Sánchez-Marco, 1989).

The biochronology of the site, based on the faunal record, was determined by the presence of the arvicolid rodents *Mimomys savini* and *Iberomys huescarensis*. The age of the site was constrained to between 1.07 and 0.8 Ma, which corresponds to the biochronological unit of the vole *Iberomys huescarensis* (Agustí et al., 2015), a species recorded at Atapuerca TD3/4-TD8 levels (Cuenca-Bescós et al., 2014), which have been dated from 1.13 ± 0.08 Ma to 900 ± 150 ka (TD3/4-TD5), and from 850 ± 140 to 730 ± 130 ka (TD7) (Moreno et al., 2015). This vole species is also recorded in Terrassa (NE Spain) at Vallparadís Section layer EVT12 (placed within the Jaramillo normal paleomagnetic subchron) and EVT10-7, dated by ESR to 858 ± 87 ka (Duval et al., 2015), an age which is also corroborated by the assemblage of small mammals (Minwer-Barakat et al., 2011; Lozano-Fernández et al., 2015), or at El Chaparral in Southern Spain (age estimated between 0.9 and 0.78 Ma) (López-García et al., 2012). *Iberomys huescarensis* is absent at Barranco León or Fuente Nueva-3, but the other vole, *Mimomys savini*, is well represented at both Orce sites. No taphonomic reworking has been detected in the Hu-1 layers, including the large mammals, where a complete mandible of a derived form of *Mammuthus meridionalis* was preserved (Mazo, 1989; Ros-Montoya et al., 2018). However, an outstanding controversy emerged on the site chronology when Demuro et al. (2015) applied a combined dating approach based on extended-range luminescence and optically stimulated luminescence (OSL), which suggested an age comprised between 570 and 420 ka. In our opinion, although numerical methods must be considered for dating, the presence of a faunal assemblage composed of typically Epivillafranchian elements indicates that the chronology proposed for the site of 1.07–0.8 Ma is the most parsimonious one.

7. Discussion

7.1. The sites of Orce and the chronology of the arrival of **Homo** into Western Europe

The Orce sub-basin preserves one of the best and most complete stratigraphic record of the continental early Pleistocene of Western Europe. This record starts at the bottom of the Cañada de Vélez gorge with the site of Fuente Nueva-1, characterised by the presence of the hyaena *Pliocrocuta perreri* (Gibert et al., 2002; Ros-Montoya et al., 2016). This species points to a chronology close to 2.2–2.1 Ma (Oms et al., 1996), at the top of the Middle Villafranchian, or in the Middle to Late Villafranchian transition, as in Senèze, France (Crégut-Bonnoure et al., 2024).

The Middle to Late Villafranchian transition is marked in Western Europe by an important faunal turnover, with the successive arrival of new faunas during the Olduvai normal paleomagnetic subchron (ca. 2.0–1.8 Ma). This turnover, formerly defined as the "*Wolf event*" (Azzaroli, 1977, 1983; Rook and Torre, 1996), was related to the arrival into the European Continent of a modern assemblage of large canids of the genus *Canis* sensu lato, around 2.0 Ma, which was composed at that time by *Canis (Xenocyon) falconeri*, *Canis etruscus* and *Canis arnensis* (Bartolini-Lucenti and Rook, 2016; Bartolini-Lucenti et al., 2020; Martínez-Navarro and Rook, 2025). The arrival of these canids is diachronic, as several records of canids are known from earlier than the base of the Olduvai chron (i.e., at the French sites of Senèze, dated 2.2–2.1 Ma) (Argant, 2024; Delson et al., 2024), or at the site of Roca Neya, dated to 2.6 Ma (Bartolini-Lucenti and Spassov, 2022). As a consequence, Martínez-Navarro (2010) suggested to call this dispersal event as "the *Pachycrocuta brevirostris* event", following the terminology used by Torre et al. (1992), which was based on the huge record of this giant, short-faced giant hyaena and its high impact in the generation of fossil accumulations during the Olduvai, post-Olduvai and Jaramillo times after its colonization of Europe at around 2.0 Ma, as recorded at the site of Olivola (dated to 2.0 Ma) (Rook and Martínez-Navarro, 2010), and its extinction in Europe during MIS21 (Madurell-Malapeira et al., 2010, 2024).

Apart from the dogs and the giant hyaena mentioned above, the base of the Late Villafranchian, which corresponds in Italy to the Olivola and Tasso Faunal Units (FUs), is recorded in the Orce region by the earliest occurrence of the ovibovine muskox ancestor *Praeovibos* spp. at the site of Barranco de los Conejos, with an age estimate close to 1.8 Ma (Agustí et al., 2013, 2015), which is also recorded at the neighbouring site of Fonelas P1, with similar chronology, in the Western part of the Guadix-Baza Depression, which has an interesting earliest Late Villafrancian assemblage (Arribas et al., 2009; Bartolini-Lucenti et al., 2025). In Europe, the base of the Late Villafranchianis is well recorded in the Upper Valdarno Basin in Italy (Rook et al., 2013), Valea Graunceanului in Romania, Slivnitsa in Bulgaria, or Gerakarou in Greece (Spassov, 2024; Konidaris and Kostopoulos, 2024).

Just after the Tasso FU, dated to around 1.8–1.7 Ma, new species made their first appearance in Europe. The newcomers are first recorded at Dmanisi in Georgia (Vekua, 1995; Lordkipanidze et al., 2007), including the earliest record of the genus *Homo* in Eurasia. This assemblage also includes the giant hyaena *P. brevirostris* (Martínez-Navarro et al., 2025) and the sabertooth of African origin *Megantereon whitei* (Martínez-Navarro and Palmqvist, 1995, 1996; Palmqvist et al., 2007). Most of these newcomers arrived from Asia, such the buffalo *Bison georgicus*, the caprini *Soergelia minor*, and *Capra dalii*, as well as the spiral horn-core antelopes *Pontoceros ambiguous* and *Spirocerus* spp. (Moyà-Solà, 1987; Vekua, 1995; Kostopoulos, 1997; Bukhsianidze, 2005; Lordkipanidze et al., 2007; Martínez-Navarro et al., 2012b). A similar faunal assemblage, is also recorded at the Crimean site of Taurida Cave (Lavrov et al., 2022; Vislobokova, 2022; Lopatin, 2025) and at the site of Krimni-3 (Kostopoulos et al., 2023). The latter site is also characterised by the arrival of another African species, the giant aquatic megaherbivore *Hippopotamus antiquus* (Konidaris and Kostopoulos, 2024). This fauna dispersed into Western Europe, and derived forms from Dmanisi, which in Italy are included in the Italian Farneta FU, are present at the VM site in Orce, including the horse *Equus altidens*, the deer *Praemegaceros verticornis* (derived from *Praemegaceros obscurus*), *Soergelia minor*, *Capra alba* (derived from *Capra dalii*), and some carnivores such as the sabertooth *Megantereon whitei* or the lycaon-like *Xenocyon lycaonoides* (Martínez-Navarro and Palmqvist, 1995, 1996; Martínez-Navarro and Rook, 2003; Palmqvist et al., 2007; Rook and Martínez-Navarro, 2010; Bartolini-Lucenti et al., 2021; Palmqvist et al., 2022a; Fidalgo et al., 2024; Martínez-Navarro and Rook, 2025).

Above Venta Micena, at around 1.5–1.4 Ma, there is another small faunal turnover that involves the extinction of the mesodont caprine *Soergelia minor*, which is substituted by the hypsodont species *Ammotragus europaeus* (Moullé et al., 2004), and by the arrival of a second equid species, the large-sized horse *Equus suessenbornensis* (Alberdi, 2010; Martínez-Navarro et al., 2010) as well as most probably by the first arrival in Western Europe of the genus *Homo*, which is recorded at the sites of BL and FN-3 at ca. 1.4 Ma (Martínez-Navarro et al., 1997; Oms et al., 2000; Toro-Moyano et al., 2013). This suggests the development of more open, arid and seasonal environments in the Baza Basin (Palmqvist et al., 2022b; Fidalgo et al., 2024).

No younger sites with Epivillafranchian fauna are recorded in the Orce section above BL and FN-3. The beginning of the Epivillafranchian, which is related with the climatic transition of the Mid-Pleistocene Revolution (MPR) (Madurell-Malapeira et al., 2010, 2014; Konidaris, 2022), is marked in Europe by a new arrival of pigs, as explained below, and by a succession of other ungulate and carnivore species with more generalist adaptations that allowed them to survive in the new changing climatic and ecological conditions (Rodríguez-Gómez et al., 2017b). In this scenario, the large carnivorans characteristic of the Villafranchian (e.g., *Megantereon, Viretailurus*, *Ursus etruscusor Xenocyon*) co-existed before vanishing from the European ecosystems with the newcomers (*Panthera fossilis, Panthera pardus* and *Crocuta* spp.). Among ungulates, some of the species that are well recorded in the Orce sites were replaced by more generalistic and resilient herbivores (e.g., *Megaloceros savini*, *Pseudodama vallonnetensis* or *Bison schoetensacki*; Madurell-Malapeira et al., 2010, 2014, 2024; Madurell-Malapeira, 2025). As a result of this turnover, the newcomers progressively substitute the super-specialised Late Villafranchian faunas. Most of this new fauna is recorded at the site of Hu-1 (see Table 1 for the succession of the faunal assemblages of large mammals at the Guadix-Baza Depression). This Epivillafranchian fauna is well recorded, among others, at sites like Atapuerca TE7-9 levels (Huguet et al., 2025), Vallparadís Section in Terrassa (NE Spain) (Minwer-Barakat et al., 2011), or El Chaparral (López-García et al., 2012) in Spain, Vallonnet Cave in France (Moullé, 1992; Moullé et al., 2006), or Untermassfeld in Germany (Kahlke, 2020) (Fig. 1).

7.2. The disappearance of pigs in Europe and their return on the ecological landscape

During last two decades, a debate emerged on the interpretation of the Late Villafranchian faunal assemblages of Europe. It was focused on the extinction of pigs around all the continent for more than half million-years, from approximately 1.8 to 1.2 Ma (Martínez-Navarro et al., 2015, 2024). In the base of the Late Villafranchian (i.e., the Italian Olivola and Tasso FUs, dated to ca. 2.0–1.8 Ma) and before, the species of warty pig, *Sus strozzii*, is well recorded across Europe. This species vanished after 1.8 Ma

from the continent and has not been recorded from any of European site between 1.8 and 1.2 Ma (see reviews in Martínez-Navarro et al., 2015, 2024), although it survived in Asia, including the Levantine Corridor at the site of Ubeidiya (Geraads et al., 1986), which is dated between 1.6 and 1.2 Ma (Tchernov, 1986; Martínez-Navarro et al., 2009, 2012a).

Sus strozzii, the verrucosus pig, is well recorded in the Upper Valdarno in Italy (i.e., at Poggio Rosso: Mazza and Bertini, 2004), Senèze in France (Faure and Guérin, 2024), or the Guadix-Baza Depression at Fonelas P-1 in Spain (although this record was first ascribed to *Potamochoerus magnus* by Arribas and Garrido, 2008). Then, *Sus strozzii* disappeared from Europe until its reappearance at 1.2–1.1 Ma, when an evolved form of this species returned to the continent roughly coinciding with the return of more closed and humid environments at the base of the Jaramillo subchron (Cherin et al., 2020). This marked the end of the Late Villafranchian and the beginning of the Epivillafranchian (Martínez-Navarro et al., 2015, 2024; Bellucci et al., 2015). The oldest record of this new form of *Sus strozzii* is found at level TE7 from Sima del Elefante of Atapuerca, named there *Sus* spp. (Huguet et al., 2025) and is generally well recorded in most Epivillafranchian assemblages, such as Vallonnet in France (Moullé, 1992), Vallparadís Section in Spain (Cherin et al., 2020) or Untermassfeld in Germany (Guérin and Faure, 1997).

This hypothesis was questioned by Iannucci (2024, 2025), based on an incomplete distal fragment of a left fourth pig metatarsal, ascribed to *Sus* spp., from the French Central Massif site of Peyrolles, which was dated to 1.47 Ma by the $^{40}Ar/^{39}Ar$ method (Nomade et al., 2014). This suid fossil corresponds to the fossil collection excavated in the early XIXth Century by Jean Baptiste Croizet (Croizet and Jobert, 1828), which was sold to the Natural History Museum, London, in January 1848 (specimen labelled NHMUK PV OR 27621) (N.F. Adams, per. inf.). No data is known on the stratigraphic context or the exact geographical location from which the fossil was unearthed, as no reference to this finding has been published before. Based on the absence of data, Martínez-Navarro et al. (2024) concluded that although the bone specimen is certainly from a suid, the lack of information on the geographic context and stratigraphic position of the fossil invalidates Iannucci's hypothesis.

New findings seemed to challenge the Martínez-Navarro and co-workers hypothesis, such as the lower molar m_1, ascribed to *Sus* spp., from the Taurida Cave in Crimea (Lopatin, 2025), which is dated biochronologically to 1.8–1.6 Ma, or the Krimni-3 site in the Mygdonia Basin, Greece (Kostopoulos et al., 2023), where "a very fragile *Sus* molar has been located on the exposed surface […]; although the specimen was photographed, it was quickly destroyed by erosion, and it was not possible to collect. This finding […] fulfils both metrical and morphological features of *Sus strozzii*". Kostopoulos et al. (2023) also dated biochronologically the site in a time frame between 1.8 and 1.5 Ma. Both Taurida Cave and Krimni-3 have similar, if not the same, faunal assemblages to that of Dmanisi in the Caucasus, which suggests that they are close to 1.8–1.7 Ma. In addition, *Sus* spp. (cf. *Sus strozzii*) is recorded at Dmanisi by the presence of two teeth (one lower premolar and one incisor: M. Buhksianidze, per. comm.), showing the initial decadence of suids at the Dmanisi times in the middle latitudes of Europe. In fact, Dmanisi is the only site in the world that records the presence of hominins and suids, and in which human fossil bones and teeth are much better represented than those of pigs. If we consider that reproduction rate relates with fossilization probability (i.e., a higher number of individuals in the ecosystem would translate in more possibilities to increase the fossilization potential), humans have an extremely reproductive *k*-strategy, with a very low reproduction rate, while suids are the only Old World ungulate group with a reproductive *r*-strategy, having numerous litters (Martínez-Navarro et al., 2015, 2024). Then, if pigs are in the ecosystem, it would be expected that they are more abundantly fossilised than hominins. In fact, pigs are used as biochronological markers in Africa, where they use to be well recorded.

The earliest records of *Homo* in Western Europe, especially documented by Oldowan lithic tools, are in a chronology close to 1.5 Ma, such as those of Fuente Nueva-3 and Barranco León (Orce; ca. 1.4 Ma), and Alto de las Picarazas (Valencia; ca. 1.5–1.4 Ma) in Spain (Martínez-Navarro et al., 1997; Oms et al., 2000; Toro-Moyano et al., 2013; Vicente-Gabardá et al., 2016; among others). Then, we can affirm that the new arrival of pigs in Europe, which marks the beginning of the Epivillafranchian, is posterior to the arrival of the genus *Homo* in the continent, as documented at the Orce sites of Fuente Nueva-3 and Barranco León, where no suid occurrence has been found (Toro-Moyano et al., 2013). Following this reasoning, we suggest that both sites of Orce are chronologically older, around 200–300 ka, than level TE7 of Sima del Elefante in Atapuerca, where a form of *Sus* spp. is associated with early humans at 1.2–1.1 Ma (Huguet et al., 2025).

8. Conclusions

The Orce and Huéscar sites (Baza Basin) provide a uniquely continuous window into faunal and environmental dynamics during the European early Pleistocene. When evaluated through an integrated framework combining mammalian biochronology, paleomagnetism, and independent numerical dating, these sites document a coherent chronological sequence spanning the Middle Villafranchian to the Epivillafranchian. Fuente Nueva-1 represents one of the oldest well-characterized faunal assemblages of the Orce stratigraphic series, close to the Middle–Late Villafranchian transition, whereas Venta Micena records a slightly younger post-Olduvai community, which is composed largely of lineages already present at Dmanisi but showing a more derived evolutionary stage. This confirms that Venta Micena postdates the first hominin dispersals into the Caucasus while predating the earliest human settlements documented in Western Europe.

Barranco León and Fuente Nueva-3, stratigraphically positioned above Venta Micena, yield consistent archeological and paleontological evidence for hominin presence around ca. 1.5–1.3 Ma. Their faunal composition reflects a shift toward more open and seasonally variable environments, expressed in ungulate turnover, equid diversification and greater prevalence of grazing species. These ecological changes likely formed part of the broader environmental backdrop that facilitated hominin expansion into southwestern Europe.

Finally, Huéscar-1 records a younger Epivillafranchian assemblage, marking the transition toward more generalized and resilient mammal communities associated with the climatic reorganization that marked the Early–Middle Pleistocene Transition.

The absence of suids in the Orce hominin-bearing layers, contrasted with their reappearance in later Epivillafranchian contexts, reinforces the biochronological distinction between these phases. Altogether, the Baza Basin record demonstrates that hominins reached Western Europe during a specific interval of faunal and environmental restructuring, prior to the full establishment of Epivillafranchian ecosystems.

Disclosure of interest

The authors declare that they have no competing interest.

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