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The oldest human fossil in Europe dated to ca. 1.4 Ma at Orce (Spain)

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ABSTRACT

The Orce region has been one of the best late Pliocene and early Pleistocene continental paleobiological records of Europe. It is situated in the northeastern sector of the intramontane Guadix-Baza Basin (Granada, Andalusia, southern Spain). Here we describe a new fossil hominin tooth from the site of Barranco León, dated to ~1.4 Ma (millions of years ago) by a combination of Electron Spin Resonance (ESR), paleomagnetic and biochronologic methods. While the range of dates obtained from these various methods overlaps with those published for the Sima del Elefante hominin locality (1.2 Ma), the overwhelming majority of evidence points to an older age. Thus, at the moment, the Barranco León hominin is the oldest from Western Europe.

Introduction

The date of the earliest human occupation of Europe has been recently challenged by new paleontological and archaeological evidence from both longitudinal extremes of the continent. The Georgian site of Dmanisi has provided an important collection of lithic artefacts and very significant fossils of early *Homo*, ca. 1.8 Ma (millions of years ago) (Vekua et al., 2002; Lordkipanidze et al., 2007; Ferring et al., 2011), the Spanish site of Sima del Elefante, in Atapuerca, has yielded some lithic artefacts and a mandibular fragment dated to ~1.2 Ma (Carbonell et al., 2008), the Italian site of Pirro Nord (1.3–1.7 Ma) (Arzarello et al., 2009), and the French sites of Lézignan-la-Cèbe and Pont-de-Lavaud (1.57 and ~1.1 Ma, respectively) (Crochet et al., 2009; Despriée et al., 2010) have provided some lithic artefacts. Here, we report the finding of a first deciduous molar of early *Homo* dating back ~1.4 Ma from Orce, which was found in direct association with assemblages of lithic artefacts and large mammal bones (Oms et al., 2000b; Toro-Moyano et al., 2009; Martínez-Navarro et al., 2010).

The tooth comes from level BL-D (previously referred to as BL-5; i.e., Martínez-Navarro et al., 2005), square J54, of the section at Barranco León, a tributary creek of the Orce river, in the northeast of the Plio-Pleistocene lacustrine deposits of the Guadix-Baza Basin (Vera, 1970; Sanz de Galdeano and Vera, 1992; Fernández et al., 1996)

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(Fig. 1). The Barranco León section spans the middle terrigenous member (lowest part of section in Fig. 1) and the upper 'Silty Calcareous Member' of the Baza Formation (Vera et al., 1985; Oms et al., 2000a, 2011), which is dominated mainly by limestones, sandstones, carbonate silts and dark mudstones, deposited in a lake with an alternation of slightly saline and saline waters (Anadón et al., 1994; Anadón and Gabàs, 2009). The excavated layers of the BL section show sediments associated with a swampy environment, except level D, which shows fluvial features and encloses the archaeological level (see further details in Oms et al., 2011). Level BL-D contains abundant remains of early Pleistocene large and small mammals, including *Ursus* sp., *Canis mosbachensis*, *Lycaon lycaonoides*, *Vulpes* cf. *praeglacialis*, *Pachycrocuta brevirostris*, *Meles* sp., *Stephanorhinus hundsheimensis*, *Equus altidens*, *Equus sussenbornensis*, *Hippopotamus antiquus*, *Bison* sp., *Hemitragus* cf. *albus*, *Praemegaceros verticornis*, *Metacervocerus rhenanus*, *Oryctolagus* cf. *lacosti*, *Mimomys savini*, *Allophaiomys* aff. *lavocati*, *Allophaiomys* sp., *Apodemus* aff. *mystacinus*, *Histryx* sp., *Galemys* sp., Erinacenae indet., *Crocidura* sp., *Sorex minutus*, and *Sorex* sp. (Agustí and Madurell, 2003; Furió-Bruno, 2003; Martínez-Navarro et al., 2010 and references there in), and stone artefacts (Oms et al., 2000b), which are broadly similar to other African and European lithic assemblages assigned to the Oldowan Industry Complex, or Mode I technology, characterized by a low degree of standardization (i.e., simple core forms and debitage).

Paleoanthropology

The human specimen, BL02-J54-100 (Fig. 2), is a complete crown of an isolated lower left first deciduous molar (dm_1). It is heavily worn on the occlusal surface (category 5 according to Molnar, 1971). Roots are missing due to resorption, suggesting that the tooth was shed ante-mortem. A distal wear facet is present at the contact with dm_2. The occlusal outline is oval and slightly asymmetrical. It presents the five main cusps. The protoconid is the largest and it is mesially displaced, followed by the metaconid, the hypoconid and finally the entoconid. The distal bifurcation of the central groove sets the limits of a small hypoconulid. At the dentine and pulp cavity level the hypoconulid is only hinted as a faint elevation (Fig. 2). A well developed lingual groove and less developed buccal grooves are present. Mesial cusps represent the major part of the crown, and they are connected by a mid-trigonid crest. The tooth exhibits a strong mesial marginal ridge, prolonged by a vestigial paraconid, separated from the metaconid by a deep V-shaped groove that opens towards the lingual face. This feature is present in *Australopithecus* and *Homo*, such as KNM-ER 820, KNM-ER 1507 and the Zhoukoudian specimens (Weidenreich, 1937; Wood, 1991), and absent in *Paranthropus*. BL02-J54-100 exhibits a tuberculum molare in the mesiolingual angle, expanding onto the root trunk, but less developed than that found in the dm_1 from Gran Dolina-TD6, Atapuerca (Bermúdez de Castro et al., 1999) (Fig. S1). The presence of the tuberculum molare, the relative expansion of the mesial cusps and mesial marginal ridge, and the enlargement and relative position of the protoconid are classical diagnostic features in the genus *Homo* (Hillson, 1996; Keyser et al., 2000) (Fig. S1).

Overall, BL02 is a large tooth although there is a great overlap with other group's dm_1 dimensions (Table 1 and Fig. S2). The mesiodistal (MD) diameter is close to the mean of *Paranthropus robustus* and *Australopithecus afarensis* but it also falls within the range of variation of African, Asian and European early Pleistocene *Homo* as well as *Homo heidelbergensis* and the Middle Paleolithic *Homo sapiens* sample. The buccolingual (BL) diameter is also close to the mean of *P. robustus* and *A. afarensis* and larger than that of any of the studied groups except for *Paranthropus boisei* and *Homo antecessor*. The crown computed area falls within the range of variation of *P. robustus*, *A. afarensis* and *H. heidelbergensis*. The highest values of the *Homo* sample are represented by the European early and middle Pleistocene fossils such as Arago 66, ATD6-94 and Barranco León, together with the Neanderthal specimens from Teshik-Tash and Shanidar VII (Fig. S2).

Archaeology

The lithic assemblage at Barranco León is composed of 1244 artefacts (Fajardo, 2008), including 26 cores, 185 whole flakes, 78 flake fragments, 759 waste flakes or débris, 17 retouched pieces, 92 angular fragments, 12 modified cobbles (including hammerstones) and 75 unmodified materials (cobbles and stones).

Flint, limestone and quartzite compose the raw material of the lithic assemblage. Jurassic formations situated approximately 3 km south of the site contain several primary sources of good raw material, while several flint sources in secondary deposits of alluvial and colluvial origin were also found near the site (Toro-Moyano et al., 2009, 2011).

Humans knapped at the Barranco Leon D site. Two sets of refitted flint pieces were identified. The first set is composed of four pieces: one core and three flakes (see Fig. 3a). Although it is not complete, the first and the last stages of the reduction sequence are present. The first stage shows the application of the orthogonal technique with no preparation of the striking platform; cortical surfaces and previous negative scars were used as striking platforms. The last stage is composed of the exhausted nucleus with ventral face exploitation of a flake showing the economy of good quality raw materials. The second refitting set is formed by pieces involuntarily detached during the knapping process.

Two main techniques were used for knapping: hard-hammer percussion and direct unipolar and bipolar techniques (axial and non-axial using an anvil). The choice of these techniques is related to the texture and quality of the raw material. The cobbles and tabular fragments of flint were destined for the production of flake cutting edges, while the less frequent limestone artefacts include cores, battered hammerstones and debitage.

The primary goal of the Barranco León knappers seems to have been obtaining small flakes, perhaps to fulfill immediate needs including rapidly cutting meat of large herbivore carcasses. The proportion of flakes, together with the high frequencies of débris (61.01%), broken and whole flakes, and angular fragments (28.54%), which sum up to 89.55% of debitage elements in the whole assemblage, and the refitting pieces show that the debitage was in situ. Although all stages of core reduction are presented, the most abundant are from the final stages of flaking. The proportion of retouched artefacts (1.37%) is low and does not show stylistic standardization. These are basically light-duty retouched pieces (see Fig. 3b).

The striation marks and polished areas (Toro-Moyano et al., 2003) on the lithic material (Fig. 3c) are similar to those reported in well-known African and European assemblages such as Olduvai Gorge, Koobi Fora or Monte Poggiolo (Keely and Toth, 1981; Sussman, 1987; Peretto et al., 1998). These marks suggest that the tools were used on a variety of materials.

The lithic artefacts are found together with large mammal remains showing evidence of anthropic activity, including true spiral or helical fractures, impact points, flake scars and bone flakes (Binford, 1981; Shipman, 1981a,b; Johnson, 1985; Blumenschine and Selvaggio, 1988) (Fig. 3d–i).

Chronology

Electron Spin Resonance (ESR) dating was applied to optically bleached quartz grains extracted from the sediments. This method is based on the detection of paramagnetic centers, e.g., aluminium

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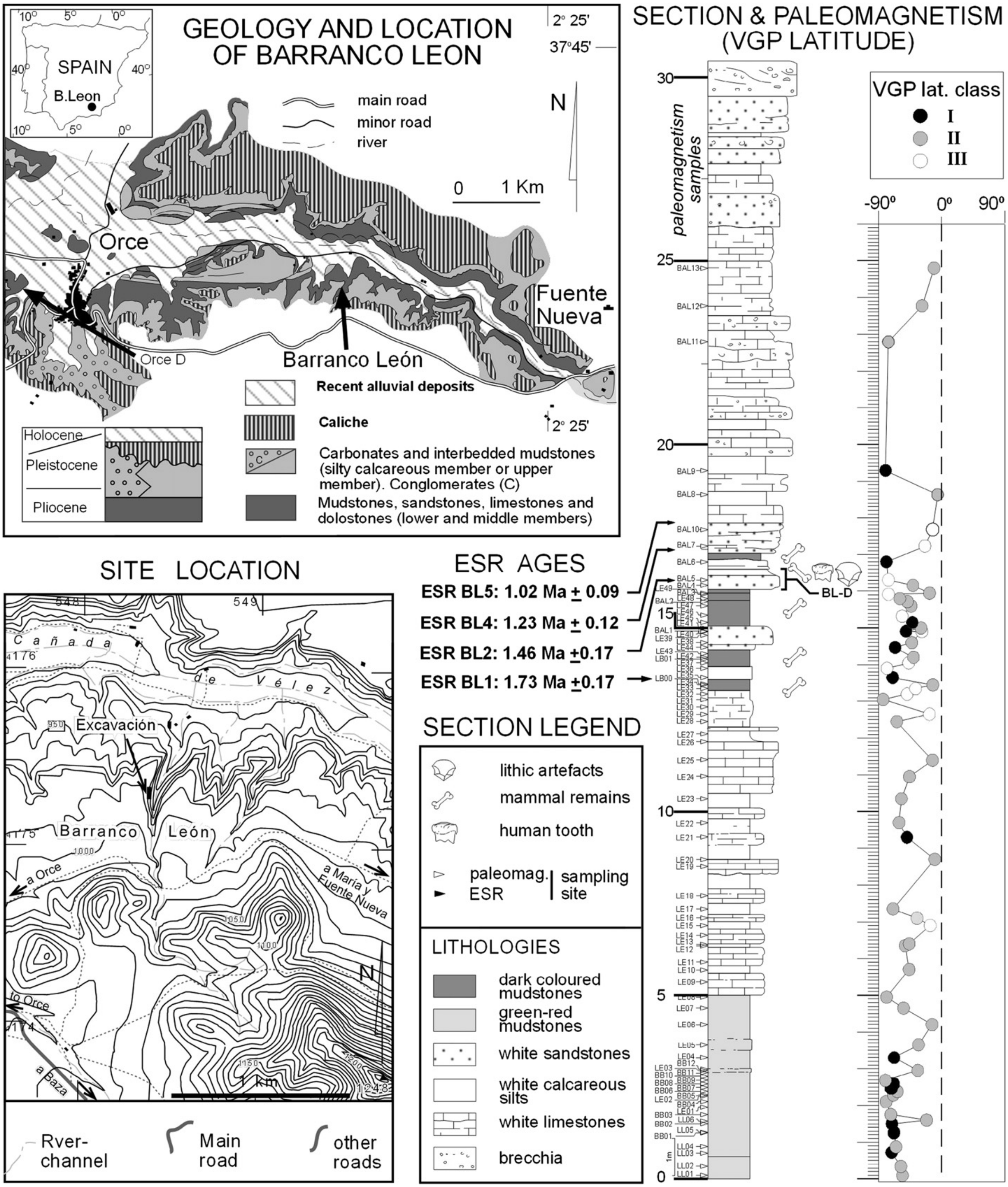

Figure 1. Barranco León site. Left: geological and geographical location. Right: section with paleomagnetic results and ESR ages in the middle.

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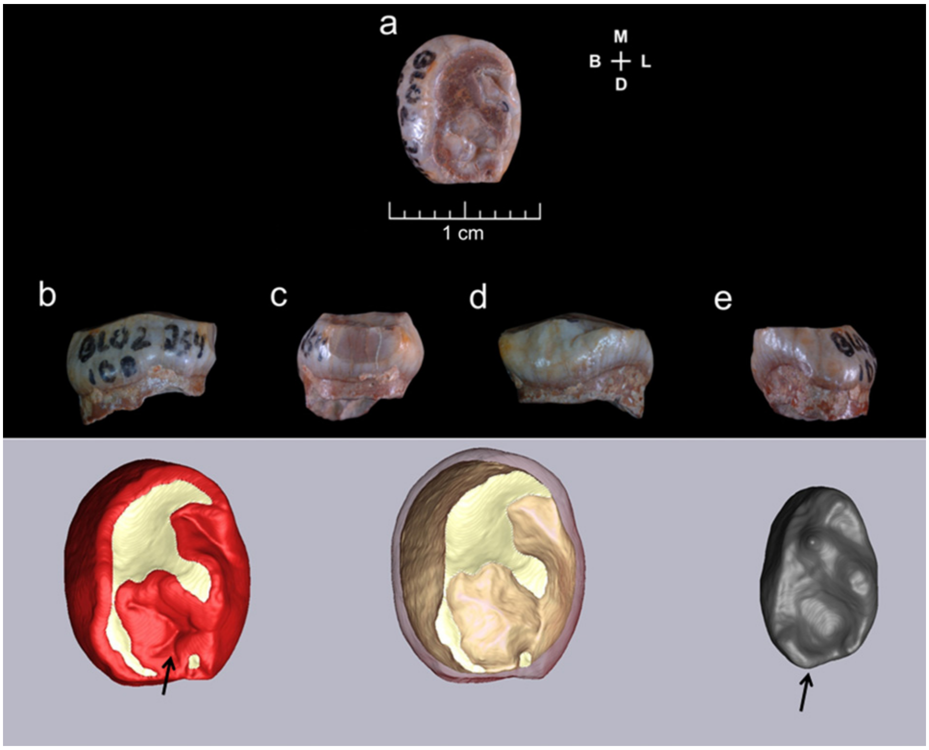

Figure 2. Upper: tooth specimen BL02-J54-100, left dm1 from Barranco León D. a: occlusal view; b: buccal view; c: distal view; d: lingual view; and e: mesial view. Lower: computed tomographic reconstruction of the enamel and dentine surfaces (left and center) and the pulp cavity (right) of the dm1. The arrow points to the presence of a small hypoconulid.

(Al) or titanium (Ti), that are created by the interaction of the natural radioactivity with the quartz sample (Ikeya, 1993). Similar to Optically Stimulated Luminescence (OSL) dating, ESR is an optical dating method that relies on the zeroing of any previously present ESR signal by sunlight exposure at the time of deposition (see details in Yokoyama et al., 1985). However, while OSL is usually limited to a late middle Pleistocene time range, ESR may potentially go further back in time and cover the whole Quaternary time range (e.g., Voinchet et al., 2010), given the long-term thermal stability of the ESR signal of the Al center (Toyoda and Ikeya, 1991) and its absence of saturation at high irradiation doses (Lin et al., 2006).

Five sediment samples for ESR dating (ESR BL-1 to ESR BL-5) were collected in situ in 2004, 2005 and 2006 from the sedimentary sequence of the excavated area at BL (Fig. 1). This study focused on the Al signal because no measurable Ti signal was detected in our samples. Experimental conditions and age calculations are derived from Duval (2008) and detailed in the SOM.

ESR age estimates are overall consistent with the stratigraphy, i.e., following a general increase with depth: they range from 1.02 ± 0.09 Ma to 1.88 ± 0.19 Ma and are all in agreement for attributing an early Pleistocene age to the deposits (Table S2). ESR BL-1 was sampled at the base of the sequence, about 1.5 m under the archaeological level D1, and yields a maximum age of 1.73 ± 0.17 Ma for the deposits. ESR BL-2 comes from D1 layer and provides an age of 1.46 ± 0.17 Ma. ESR BL-3 and ESR BL-4 samples were collected from level D2, which overlies D1. Their ESR ages are 1.88 ± 0.19 Ma and 1.23 ± 0.12 Ma, respectively. Sample ESR BL-5, originating from level E1 at the top of the local sequence, yields a minimum age of 1.02 ± 0.09 Ma for the deposits.

ESR age results obtained for layer D show some apparent scatter. More specifically, the age of ESR BL-3 looks somewhat overestimated in comparison with the other ages. This is probably due to the fitting of the dose response curve, which goes above the natural point and thus might induce an overestimation of the equivalent dose value (Fig. S3). Nevertheless, this age may not be discarded, regarding the small sample size ($n = 3$). Consequently, based on the three ESR samples, BL-2 to BL-4, a weighted mean ESR age of 1.43 ± 0.38 Ma may be calculated for the layer D that encloses the archaeological layer at Barranco León. The quite large final error may be interpreted as the consequence of the age scattering and the limited number of samples. This age is in quite good agreement with the ESR chronologies obtained for the nearby sites of Fuente Nueva-3 and Venta Micena, of 1.19 + 0.21 Ma and ~1.4 Ma, respectively (Duval et al., 2011, 2012). However, one should be cautious in their interpretation, since the quite large error range does not allow any chronological distinction between the three sites from the Orce area. These results show the potential of ESR dating of quartz grains from early Pleistocene fluvio-lacustrine deposits. Future work will definitely need to be focused on the improvement of the precision of this promising preliminary ESR chronological framework based on quartz grains extracted from sediment.

A new paleomagnetic study (Table S1), combined with previous results (Oms et al., 2000b), shows that the entire stratigraphic section of Barranco León has reverse polarity (Fig. 1). Consequently, the deposits may be correlated to the Matuyama chron (0.78–2.58 Ma; Gradstein et al., 2005), and more likely between Olduvai and Jaramillo subchrons as indicated by the ESR chronology and faunal evidence.

Both micro- and macrofauna support the ESR ages and the magnetostratigraphic interpretation. The combination of rodent species at the site, including *M. savini*, *A.* aff. *lavocati*, *Castillomys crusafonti* and *A.* aff. *mystacinus*, further constrains its age. An age younger than the Olduvai subchron (1.95–1.77 Ma) is inferred from the more derived morphology of *A.* aff. *lavocati* compared with

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Table 1
Metric data of the specimen BL02-J54-100 from Barranco León, compared with other hominin samples.

Specimens	*n*	MD		BL		BL * MD (computed crown area)		BL/MD * 100 (crown shape index)		Data source
		X	s.d.	X	s.d.	X	s.d.	X	s.d.	
Paranthropus robustus										
DNH 44, DNH 47, DNH 60, Kromdraai, SK61 (right), SK3978, SK3979	7	10.28	0.66	8.38	0.63	86.55	11.70	81.53	3.15	Robinson, 1956; Day, 1986; Keyser et al., 2000
Paranthropus boisei										
KNM-ER 1477, L704-2	2	11.65	–	9.30	–	108.41	–	80.03	–	Howell and Coppens, 1973; Wood, 1991
Australopithecus africanus										
Stw104, Stw151, Stw296, Sts24, Taung	5	8.77	0.32	7.50	0.45	65.90	5.82	85.53	3.98	Robinson, 1956; Moggi-Cecchi et al., 2006
Australopithecus afarensis										
AL333-43 (left), AL333-30, LH3, LH2	4	9.77	1.48	8.35	0.77	82.41	20.44	86.030	6.41	White, 1980; Johanson et al., 1982
early *Homo*										
DNH 35	1	9.10	–	7.50	–	68.25	–	82.42	–	Keyser et al., 2000
Homo erectus										
African *Homo erectus*: KNM-ER 820 (right), KNM-ER 1507	2	8.95	–	7.30	–	65.41	–	81.49	–	Leakey and Wood, 1973, 1974
Asian *Homo erectus:* Sinanthropus 123, 125	2	8.75	–	6.80	–	59.71	–	78.57	–	Weidenreich, 1937
Homo antecessor										
Gran Dolina-TD6 (ATD6-94)[a]	1	9.00	–	8.80	–	79.20	–	97.78	–	
Homo heidelbergensis										
Arago 34, 55, 66[a]	3	9.43	0.66	8.03	0.40	75.96	9.30	85.23	1.71	
Homo neanderthalensis										
Archi, Gibraltar II, Kulna III, Pech de l'Azé[a], Shanidar III, Shanidar VII, Chateauneuf I, Chateauneuf II, Krapina 67, Krapina A, Arcy 18, Arcy 25, Arcy 33, Roc de Marsal, Dederiyeh, Kebara, Teshik-Tash, Combe-Grenal, Taubach, La Chaise H13, La Chaise H14, La Chaise Bourgeois Delauney, Engis, La Ferrassie 8[a]	24	8.83	0.44	7.56	0.47	66.86	6.23	85.68	5.46	Tillier, 1979; Wolpoff, 1979; Madre-Dupouy, 1985; Bailey and Hublin, 2006
Homo sapiens										
Middle Paleolithic: Skhül I, Skhül X, Qafzeh 4	3	9.43	0.60	7.50	0.30	70.63	1.76	79.86	8.35	Tillier, 1979
Upper Paleolithic: Miesslingtal, Isturitz 72, Badger's Hole, Bruniquel 537,Bruniquel 540, Isturitz 4, Isturitz 9, Laugerie Basse 905, Laugerie Basse 909, La Madeleine 4, Le Figuier[a]	11	8.13	0.75	7.23	0.76	59.14	10.11	89.22	8.35	Frayer, 1978
Contemporary: Musée de l'Homme collections (various geographical origins)[a]	21	8.31	0.36	6.96	0.26	57.99	3.95	83.88	3.79	
BL02-J54-100	**1**	**10.05**	–	**8.48**	–	**85.22**	–	**84.4**	–	

[a] Measurement taken by authors.

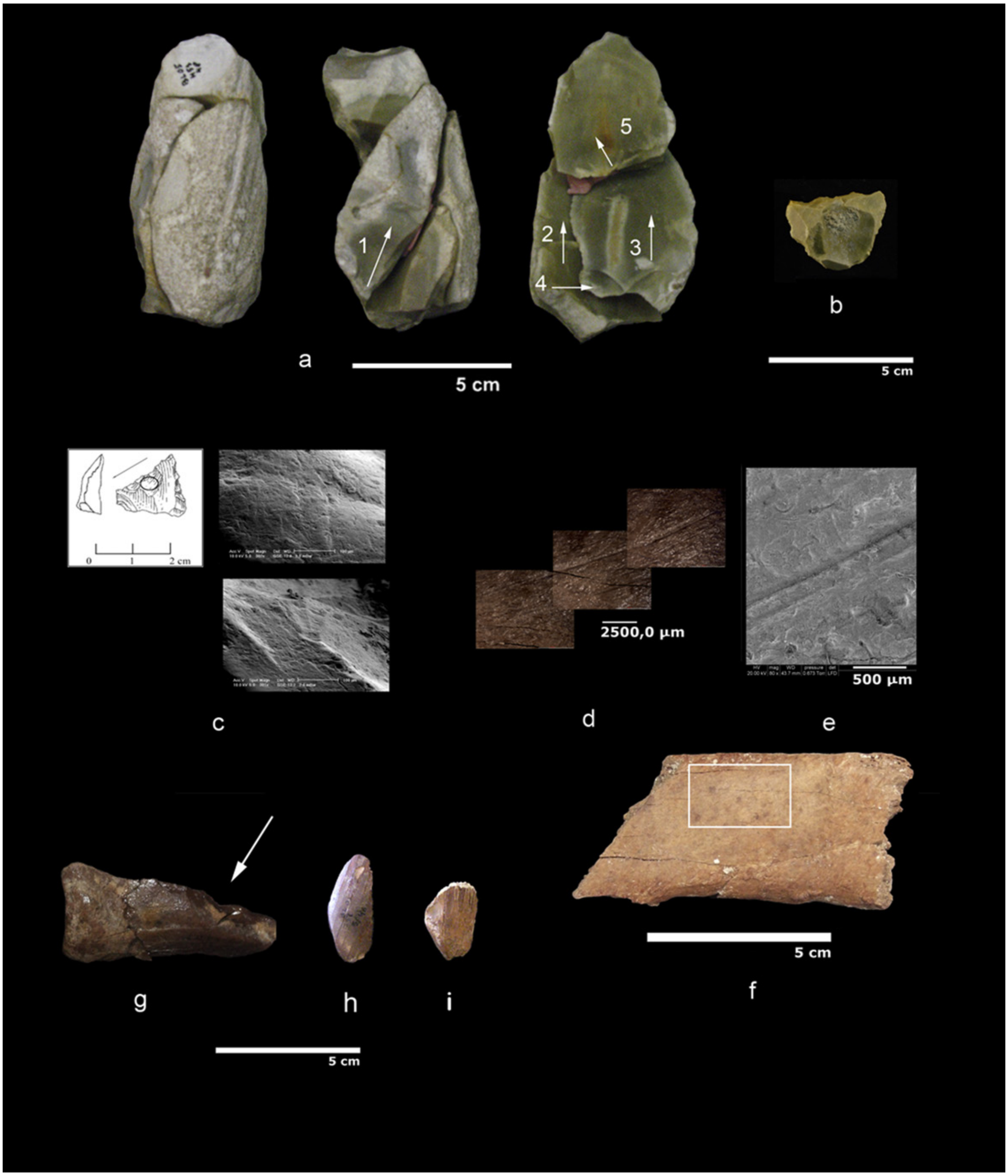

Figure 3. Archaeological evidence from level D of Barranco León. a: refitted pieces; b: retouched piece; c: striation and polished marks; d–f: bone cut marks, BL03-L62-2, rib fragment of megaherbivore (cf. *Hippopotamus antiquus*), it shows a long and curved cut mark oblique to the major edge of the rib in the central area of the bone, which is related to the evisceration process; g: bone impact point; h, i: bone flakes.

Allophaiomys cf. *deucalion* from the site of Kryzhanovka (Tesakov, 1998), which is associated with the Olduvai subchron (Pevzner et al., 1998). *Allophaiomys* aff. *lavocati* is, in turn, more archaic than the microtine species present at Vallonet (France) and Untermassfeld (Germany), two localities dated to the Jaramillo subchron (0.99–1.07 Ma; Yokoyama et al., 1988; Wiegank, 1997). Therefore, Barranco León is placed within the reverse interval between the Jaramillo (0.99–1.07 Ma) and Olduvai (1.95–1.77 Ma) subchrons.

In the Guadix-Baza Basin, a biozonation based on rodents includes four biozones within this interval: *M. oswaldoreigi* Zone, *Allophaiomys ruffoi* Zone, *A.* aff. *lavocati* Zone and *Iberomys huescarensis* Zone (Agustí et al., 2010; Oms et al., 2011). The average duration of each biozone is 200 thousand years. The *M. oswaldoreigi* Zone includes the sites of Barranco Conejos, Orce 2 and Orce D. The *A. ruffoi* Zone includes the famous site of Venta Micena and other levels such as Cañada de Murcia 1, Fuente Nueva 2, Orce 4 and Orce 7 (Agustí et al., 2010). The *A.* aff. *lavocati* Zone includes the sites of Barranco León D and Fuente Nueva-3. The *I. huescarensis* Zone includes the sites of Huéscar 1, Puerto Lobo and Loma Quemada (Mazo et al., 1985; Agustí et al., 2010). The last occurrence (LO) of *A.* aff. *lavocati* can be established below the base of the *I. huescarensis* Zone, dated to the Jaramillo subchron at 1.07 Ma. The first occurrence (FO) of *A.* aff. *lavocati* is more difficult to establish, since there is no section in the basin where the boundary between the *A. ruffoi*

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Zone and the *A.* aff. *lavocati* Zone has been recognized. However, a recent dating of the level TE9 from Sima del Elefante, in the Atapuerca karstic complex (Cuenca-Bescós et al., 2001), contains a more evolved *Allophaiomys* than *A.* aff. *lavocati* from Barranco León D. The age of this level has been established at 1.22 ± 0.16 Ma, based on cosmogenic nuclids (Carbonell et al., 2008). Therefore, the age of the level BL-D can be constrained between 1.77 Ma (top of Olduvai subchron) and ~1.2 Ma (age of Sima del Elefante).

However, interpolation of metric parameters measured on the lower first molar of diverse well-dated early middle Pleistocene microtine species provides a way to further constrain the age of the findings. The relative length of the anteroconid complex in microtines (the *A*/*L* parameter) (Meulen, 1973) has proven to be a useful tool for dating Plio-Pleistocene sites (Maul et al., 1998). The *A*/*L* values of *A.* aff. *lavocati* from level BL-D also suggest an age older than Sima del Elefante and close to 1.4 Ma (Table S3), which is in agreement with the ESR dates.

The large mammals assemblage also points to an older chronology for BL-D than level TE9 from Sima del Elefante. In addition, although it is commonly accepted that due to taphonomic reasons the lack of evidence of a taxon in an assemblage is not an evidence of its absence from the original community, the nonappearance of suids in any of the Late Villafranchian Orce sites is a strong argument that should not be ignored as a reliable biochronological marker. Suids are found in Europe before and during the Olduvai subchron, including at the Fonelas P-1 site in the Guadix-Baza Basin, dated to 2.0 Ma, where the suid remains have been ascribed to *Potamochoerus magnus* (Arribas et al., 2009), as well as in many other localities with the presence of *Sus strozzii* (see Rook and Martínez-Navarro, 2010). However, there are no pigs in the chronological range between the post Tasso Faunal Unit, in the base of the Late Villafranchian (~1.8 Ma), and their arrival in Western Europe at level TE9 from Sima del Elefante (~1.2 Ma), where pigs are recorded as *Sus* sp. (Carbonell et al., 2008), and at the site of Untermassfeld (Germany), dated 1.0–1.1 Ma, and described as *Sus scrofa priscus* (Guerin and Faure, 1997). At sites such as Dmanisi (Georgia), as well as at Pirro Nord (Italy), Apollonia-1 (Greece), Sainzelles (France) and, of course, at the Orce sites, no record of pigs has ever been documented. After 30 years of excavation of 350 m^2 at Venta Micena, 140 m^2 at Barranco Léon, and 106 m^2 at Fuente Nueva-3, and continuous research in the triangle formed by the region of Orce-Fuente Nueva-Venta Micena, pig remains have never been found among the more than twenty-five thousand large mammal fossils unearthed from these sites, and this is probably the best record of the early Pleistocene fauna in Europe. When pigs are present in an ecosystem, they tend to be abundant in the large mammal community given their opportunistic feeding behavior and reproductive success. For this reason, they are usually well represented in the fossil assemblages. Suids are well recorded in the African and Asian archaeological and paleontological sites, including those from the Levantine Corridor such as 'Ubeidiya (Geraads et al., 1986) or Evron Quarry (Tchernov et al., 1994), but they are not definitively present in Orce or in any other sites on the European continent during the period between 1.7 and 1.2 Ma. Later, the genus *Sus* is recorded everywhere in Europe. For this reason, the absence of suids from level BL-D constrains the upper limit of the chronological range estimated for this site to >1.2 Ma, in agreement with the age of 1.4 Ma estimated from the ESR dates and the small mammal assemblage.

Conclusions

The specimen BL02-J54-100 found at Barranco León, a human tooth with an estimated age of ca. 1.4 Ma, represents the oldest anatomical evidence of human presence in Western Europe. This finding, combined with the important lithic tool assemblage from the level D of Barranco León, confirms that Western Europe was colonized less than 0.5 Ma after the first expansion of *Homo* out of Africa, currently documented at the Dmanisi site.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jhevol.2013.01.012.

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