

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

by

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Abstract

The Orce region, which is known in the literature as the *Spanish Olduvai*, has 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 by a combination of Electron Spin Resonance (ESR), paleomagnetic and biochronologic methods. This is, at the moment, the oldest human remain from Western Europe.

Keywords

Human tooth, Early Pleistocene, Orce, 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 (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) (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, 2008). The excavated layers of the BL section show sediments associated to 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 composed by *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., *Erinaceinae* 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 (Wood, 1991; Weidenreich, 1937), 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 dm₁ dimensions (Table 1 and Fig. S2). The 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 BL diameter is also close to the mean of *Paranthropus robustus* and *Australopithecus 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 *Paranthropus robustus*, *Australopithecus afarensis* and *Homo 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 around 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 technique (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 percutors 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 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 Poggio (Sussman, 1987; Keely and Toth, 1981; 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 evidences of anthropic activity, including true spiral or helical fractures, impact points, flake scars and bone flakes (Binford, 1981; Blumenshine and Selvaggio, 1988; Johnson, 1985; Shipman, 1981a, b) (Figs 3d-i).

Chronology

Electron spin resonance (ESR) dating was applied to optically bleached quartz grains extracted from sediments. This method is based on the detection of paramagnetic centres, e.g. Aluminium (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 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 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 supplementary online information.

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., 2004), and more likely between Olduvai and Jaramillo subchrons as indicated by the ESR chronology and faunal evidence.

Microfauna supports the ESR ages and the magnetostratigraphic interpretation. The combination of rodent species at the site, including *Mimomys savini*, *Allophaiomys* aff. *lavocati*, *Castillomys crusafonti* and *Apodemus* 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 *Allophaiomys* aff. *lavocati* compared with *A. 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). Moreover, a recent dating of the site of Sima del Elefante (Atapuerca, Spain), with *Allophaiomys* aff. *nutiensis* (Cuenca-Bescós et al., 2001), a more evolved form than *A. aff. lavocati*, has provided an age of 1.22 ± 0.16 Ma based on cosmogenic nuclids for this Atapuerca site (Carbonell et al., 2008). Therefore, the age of the level BL D is constrained between 1.77 Ma (top of Olduvai subchron) and ~1.2 Ma (age of Sima del Elefante). This constrain is in agreement with previous biozonations

developed in the early Pleistocene sequences of the Guadix-Baza Basin (Agustí et al., 2010) and the Atapuerca karstic complex (Cuenca-Bescós et al., 2010).

Interpolation of metric parameters measured on the lower first molar of diverse well-dated Early-Middle Pleistocene microtine species allow 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 *Allophaiomys* 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.

Conclusions

The specimen BL02-J54-100 found at Barranco León site, 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, ratifies that Western Europe was colonized soon after the first expansion out of Africa, currently documented at the Dmanisi site.

Acknowledgements: We thank all the members of the Orce research project involved in the excavations and the study of the Barranco León paleoanthropological site. We thank Prof. P. Rivas for his support and encouragement. Also we thank Prof. H. de Lumley and his team for their help. M. T. Alberdi, M. R. Palombo, L. Abbazzi, F. Lacombat, S. Bailón, H. A. Blain, J. Madurell, and M. Furió helped in the determination of the vertebrate fauna. C.F. and M.D. thank P. Voinchet and J. Despriée for their help during the ESR sampling. R. Grün and J.-J. Bahain provided helpful comments on the ESR

dating. Photographs and microscan of the hominin molar were carried at CENIEH of Burgos, Spain. We thank L. Martín-Francés and M. Martínez de Pinillos for their help with the micro-CT analysis. ESR data were obtained at the Prehistory Department of MNHN (Paris, France). Paleomagnetic measurements were carried out at the SCT of the Barcelona University. Scanning photographs of the lithic artefacts were carried out at the CERP of Tautavel (France) by Mme. B. Deniaux. We thank Ms Sheila Wglie for reviewing the English version of this paper. E. Delson, E. Carbonell, T. D. White, D. Lordkipanidze, S. C. Anton, M. M. Lahr, M. Tappen, L. Rook, R. Ferring, the Associate Editor and three anonymous reviewers revised a first draft of the manuscript. This study has been sponsored by the Dirección General de Bienes Culturales (Consejería de Cultura, Junta de Andalucía, Spain), and it has been supported by projects CGL2010-15326, CGL2010-16821, CGL2009-7896, and CGL2008-04896 of the Spanish Ministry of Science and Innovation.

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Figure legends

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

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.

Figure 3: Archaeological evidences from level D of Barranco León. a) refitted pieces; b) retouched piece; c) striation and 1 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.

Table legend

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