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The first hominin of Europe

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The earliest hominin occupation of Europe is one of the most debated topics in palaeoanthropology. However, the purportedly oldest of the Early Pleistocene sites in Eurasia lack precise age control and contain stone tools rather than human fossil remains[1–5]. Here we report the discovery of a human mandible associated with an assemblage of Mode 1 lithic tools and faunal remains bearing traces of hominin processing, in stratigraphic level TE9 at the site of the Sima del Elefante, Atapuerca, Spain[6–8]. Level TE9 has been dated to the Early Pleistocene (approximately 1.2–1.1 Myr), based on a combination of palaeomagnetism, cosmogenic nuclides and biostratigraphy. The Sima del Elefante site thus emerges as the oldest, most accurately dated record of human occupation in Europe, to our knowledge. The study of the human mandible suggests that the first settlement of Western Europe could be related to an early demographic expansion out of Africa. The new evidence, with previous findings in other Atapuerca sites (level TD6 from Gran Dolina[9–13]), also suggests that a speciation event occurred in this extreme area of the Eurasian continent during the Early Pleistocene, initiating the hominin lineage represented by the TE9 and TD6 hominins.

The Sima del Elefante Site is located in the Sierra de Atapuerca, northern Spain, in the proximity of the well-known sites of Gran Dolina, Galería and Sima de los Huesos (Fig. 1a). All of them have yielded hominin fossils attributed to the species *Homo antecessor* (approximately 0.8 Myr[9–13]) in Gran Dolina and *Homo heidelbergensis* in Galería[14] and Sima de los Huesos[15–17].

The Sima del Elefante site is a cave 18 m deep and up to 15 m wide[6,7], infilled with clastic deposits. The sedimentary sequence is formed by 16 lithostratigraphic units (Fig. 1b) mostly made by debris flow deposits. Entrance clast-supported debris flows correspond to proximal facies, whereas deposits with higher content of brown and reddish-brown clays (HUE 7.5YR or 5YR) correspond to distal facies, derived from terra-rossa slope soils.

We report on the palaeoanthropological, archaeological and palaeontological record of level TE9, including geochronological and biostratigraphic data at Sima del Elefante, which together document the oldest-known site in Europe with hominin fossils and human activity.

A fragment of hominin mandible and an isolated lower LP_4 of the same individual were recovered from square I-31 of the TE9C level. The mandible (ATE9-1) consists of the symphyseal region, a portion of the right corpus from P_3 to the alveolus of M_1 with an irregular broken surface, and the basal part of the left corpus from P_3 to the level of M_1/M_2. Some teeth are preserved *in situ* (Fig. 2 and Supplementary Information).

The mental foramen is single on both sides and lies at the P_3/P_4 interalveolar septum. On the preserved part of the corpus, a well-differentiated torus marginalis is present. Anteriorly, this torus terminates as a well-developed anterior marginal tubercle below the C/P_3 (Fig. 2a). In lateral view (Fig. 2c), there is a slight anterior mandibular incurvatio of the bone between the alveolar border and the base. Thus a modest mentum osseum is expressed. The mental trigone is represented by a faint bone elevation along the midline of the symphysis and a visible mental protuberance. No signs of lateral mental tubercles or mental fossae are present. In anterior view, the lower margin of the symphysis is arched bilaterally, forming a conspicuous incisura submentalis. At the midline of the arch, a strong and pointed interdigastric spine projects downwards between the two disgastric impressions, which are shallow but well defined, and placed at the basal part of the symphysis. On the internal surface of the symphysis, the alveolar planum exhibits a minimum inclination, and the superior transverse torus is absent. However, on the right side a modest but clear alveolar prominence below P_3–P_4 is observed. In superior view, the alveolar portion of the corpus tends to diverge to form a parabolic arc, being more open than in early African *Homo* specimens such as OH 13, KNM-ER 1802 and UR 501, or in the Dmanisi mandibles. The thickness of the corpus of ATE9-1 at the M_1 level is similar to that of ATD6-96 from Gran Dolina[12] and falls at the lower limit of the range of the African Early and Middle Pleistocene *Homo* specimens[18]. The height of the corpus of ATE9-1 at the P_3/P_4 level is modest and far from the extreme values seen in many other Pleistocene specimens such as those from Tighenif, Sangiran and D 2600 from Dmanisi (Table 1). The C, P_3 and P_4 exhibit single roots of Tomes' root form (category 1R[19]), with a groove along the mesiolingual root surface. The crown of LP_4 presents an oval outline with a distolingual talonid, and the tip of the lingual cusp is mesial to the tip of the larger buccal cusp.

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The morphology of the anterior surface of the symphysis and the position of the anterior marginal tubercle suggest similarities between ATE9-1 and early *Homo* specimens like OH 7, OH13, KNM ER 730 and UR 501, and especially with those of Dmanisi. However, the morphology of the posterior surface of the symphysis and the shape of the alveolar part of the corpus are clearly derived in these hominins (see Supplementary Information, Mandible Discussion). Although the symphysis is not represented in the current TD6 hominin hypodigm, so we cannot make the pertinent comparisons, we assign ATE9-1 provisionally to *Homo antecessor*[10].

The lithic assemblage includes 32 artefacts: four simple flakes, five waste flakes (*debris*) and 23 indeterminate items made of Neogene and Cretaceous chert, both raw materials available within 2 km of the archaeological site. There are many indeterminate pieces, owing to the chemical weathering particularly suffered by the Neogene chert.

Hominins probably knapped inside the cave, as deduced from the presence of small waste flakes and two medium-sized Cretaceous chert flakes that seem to belong to the same core. The reduction sequence was devoted to producing simple flakes ranging between 30 mm and 75 mm long. Artefacts were detached by direct hard-hammer percussion on hand-held, medium-sized cores. Knapping strategies were simple, and they tended to remove the irregularities and shape the blank to obtain a single striking platform. Flakes show plane rather than cortical butts, and dorsal scars are parallel to the flake extraction axis, which indicates unidirectional knapping (Fig. 3a–c).

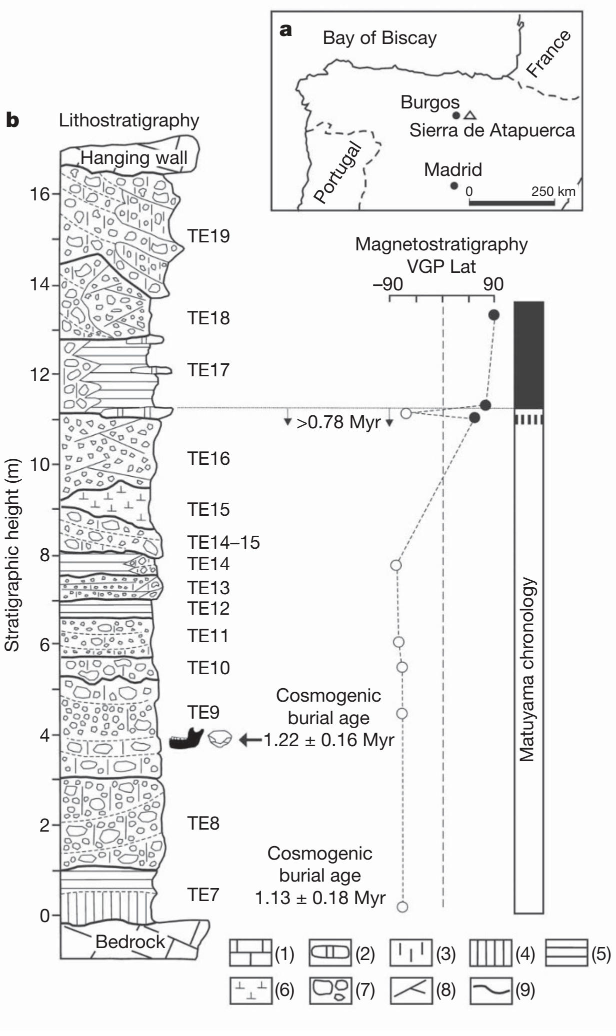

Figure 1 | Geographic setting and geological context. a, Geographic setting of the Atapuerca archaeological sites. **b**, Summary of the lithostratigraphy and chronology of the Sima del Elefante locality. The synthetic column on the left shows the different stratigraphic units visible at the central–north section, labelled TE. Symbols: 1, Mesozoic limestone; 2, speleothem; 3, lutite/clay; 4, bat guano; 5, clay and laminated sandy silts; 6, marls; 7, gravels and boulders; 8, cross-lamination; 9, main stratigraphic discontinuity. VGP Lat, latitude of the virtual geomagnetic pole. Cosmogenic burial ages are also shown, with the standard error given at the 68% confidence interval.

The faunal assemblage[6,7,20,21] (see Supplementary Table 1) provides valuable chronological information. The mustelid *Pannonictis* is a typical Plio-Pleistocene taxon, and the species *P. nestii* is a likely candidate as a last survivor of the genus, which might reach the late Early Pleistocene. In size and in cranial and dental morphology, the specimens from TE level 9 resemble *P. nestii* from the site of Pietrafitta (Italy), dated to around 1.4 Myr[22], suggesting the fossils in TE9 are closer in age to the Italian site than to the last occurrence of this species[23]. The murid *Castillomys*, found in TE levels 8–14[20], has its latest appearance in localities such as Barranco León, with a Matuyama age[1]. The rodents and insectivores of levels TE9–TE13 are primitive compared with those present in Cromerian localities (around 1.0–0.6 Myr); that is, they include advanced forms of *Mimomys savini* as well as *Microtus* species that are absent in levels TE8–TE13[21,24]. Also, the *A*/*L* index (the relative length of the anteroconid complex in relation to the anteroposterior length of the tooth) of the *Allophaiomys* first lower molar found at Sima del Elefante resembles that of *Allophaiomys* measured at Fuente Nueva 3, Pietrafitta, Pirro Nord and Monte Peglia. The small mammals found at the Sima del Elefante site are notably more primitive than the oldest small mammal assemblages that appear in Gran Dolina[20,21,24], especially the absence of *Microtus* and *Allocricetus bursae*, and the presence of *Asoriculus gibberodon*, *Castillomys* and the *Allophaiomys* species. In addition, the evolution of the insectivore associations at levels TE9–TE13 suggests a general warm and humid palaeoenvironment with warmer–cooler shifts. This could tentatively correlate with the Waalian[20], an Early Pleistocene warm stage also with warmer–cooler shifts, dated to 1.5–1.3 Myr[25].

Large mammals of TE9 are mainly represented by long bones, whereas Leporidae and birds preserve whole anatomical segments, mainly limbs. Some bones of large mammals show clear evidence of hominin processing, such as percussion marks on long bones (Fig. 3d) and on a bovid mandible, pointing to fresh fracture made to access the marrow cavity and other food resources. The mandible and a vertebra of bovid, and some indeterminate macromammal long bones, also show defleshing cut marks[26] (Fig. 3e, f).

Previous work on the chronology of the sedimentary infill at Sima del Elefante has been based on palaeomagnetism[8] and faunal evidence[20]. The initial palaeomagnetic study revealed that stratigraphic layers TE16 and older recorded reverse magnetization directions only, consistent with a Matuyama age of the sediments (1.78–0.78 Myr) and with the mammal assemblage. Layer TE17, on the other hand, showed normal polarity directions. New palaeomagnetic results of a flowstone capping unit TE16 and the overlying poorly consolidated silty sandstones reveal normal polarity directions, constraining the stratigraphic position of the reverse to normal polarity change within the section around a stratigraphic height of 11 m.

The age of level TE9 is further constrained by burial dating based on the radioactive decay of cosmogenic ^{26}Al (half-life, $t_{1/2} = 0.717 \pm 0.017$ Myr) and ^{10}Be ($t_{1/2} = 1.34 \pm 0.07$ Myr) in quartz collected from the sediments. These two radionuclides are produced at a fixed ratio by secondary cosmic rays interacting with quartz near the ground surface. When quartz containing inherited ^{26}Al and ^{10}Be is carried into a cave, the mineral grain is shielded from cosmic rays and the concentrations of these two nuclides decay over time, serving as a chronometer of deposition[27,28]. The burial dating method assumes that quartz was first exposed near the surface in a steadily eroding

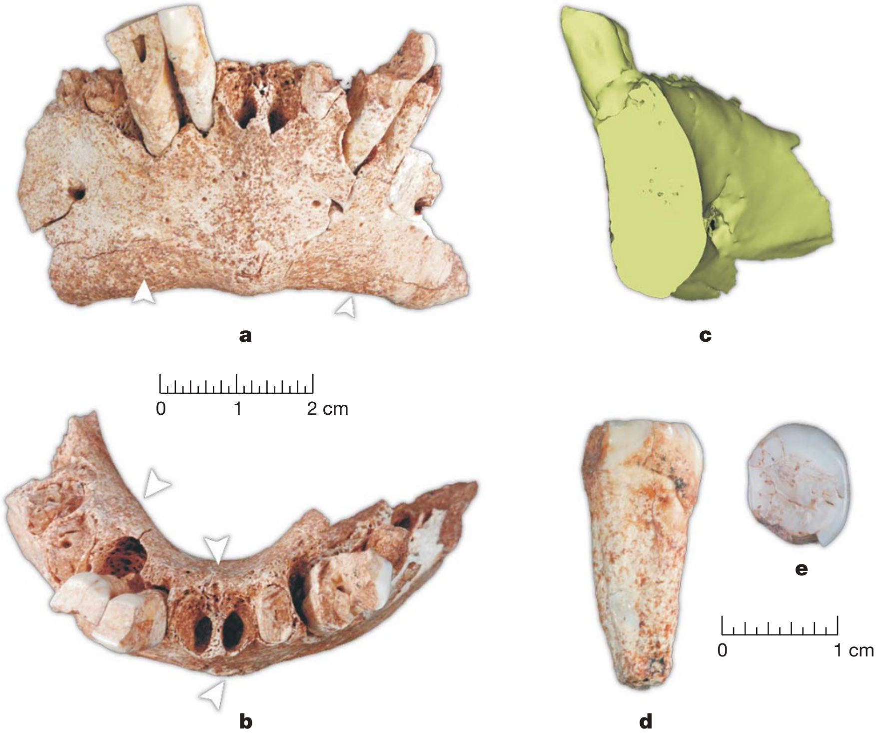

Figure 2 | Mandible ATE9-1. a, Frontal view. Arrowheads point to the position of the anterior marginal tubercle, and the arch of the marked incisura submentalis. **b**, Superior view. Arrowheads point to the mental protuberance, the subvertical alveolar planum and the slight alveolar prominence. Note also the parabolic arc formed by the alveolar part of the corpus. **c**, Median sagittal cross-section of the symphysis based on a three-dimensional computed tomography reconstruction. Fossils are housed at the Centro Nacional de Investigación sobre la Evolución Humana. **d**, Distal view of the LP4 of ATE9-1. **e**, Occlusal view of the LP4; mesiodistal dimension: 8.9 mm; buccolingual dimension: 11.4 mm (estimated).

environment, and was then buried deeply enough in the cave to ensure adequate shielding. We collected two samples from the study area, each shielded by approximately 16 m of bedrock and sediment (see Supplementary Tables 2 and 3).

The first sample was collected from layer 9b, in the central part of unit TE9. This sample was collected about 40 cm above the artefacts and the hominin fossils in layer 9c, and has a burial age of 1.22 ± 0.16 Myr. A second sample was collected from unit TE7, which contains a similar microfaunal assemblage to unit TE9. This second sample has a burial age of 1.13 ± 0.18 Myr, indistinguishable from that of layer TE9b.

Table 1 | Measurements of ATE9-1 compared with some *Homo* specimens

	Thickness (mm)		Height (mm)	
	M_1	Symphysis*	P_3–P_4	Symphysis
ATE9-1	17.0	15.3	30.0	33.5
ATD6-96	16.6		28.5	
D 211	18.1	16.5	26.0	31.0
D 2735	19.3	16.0	24.6	32.0
D 2600	21.6	21.0	42.4	49.0
Sangiran 9†	21.2	18.0	38.2	42.0
Sangiran 22†	17.3	16.1	31.1	36.0
Sangiran 6	27.0		48.0	
Sangiran 1B	16.3		35.7	
KNM-ER 1802‡	23.0	21.3	35.8	36.2
UR 501‡	21.3	16.8	34.1	34.0
OH 13‡	18.0		26.0	
OH 22‡	19.4	18.9	29.0	30.7
KNM ER 730‡	19.0	17.6	31.3	31.0
KNM ER 992‡	20.2		31.0	
Tighenif 1	19.0	18.8	36.2	36.0
Tighenif 2	16.9	18.0	33.4	33.3
Tighenif 3	19.0	19.2	38.4	37.5

The preservation of ATE9-1, D 211 and D 2600 prevents measurement of the height of the corpus at the M1 level. *Taken approximately at a right angle to the axis of the symphyseal inclination. †From Kaifu *et al.*[29] ‡From Schrenk *et al.*[30]. All other measurements were taken on originals or high-quality casts.

The lithic assemblage found at level TE9 shows similar primary technical features to those from the other Early Pleistocene European sites: a Mode 1 simple technology without handaxes and cleavers, which are the most characteristic tools of Mode 2 or Acheulean. Furthermore, the oldest European assemblages show scarcity or even absence of retouched tools[2–5,9,11], as is the case at TE9. These simple industries usually appear in archaeological contexts related to basic human activities devoted to processing and consuming meat and marrow.

Current archaeological data unequivocally indicate human presence in southern Europe (south of 46° N) quite early in the Early Pleistocene[1–5,13] (see Supplementary Table 4). The recently discovered hominin and lithic industry in level TE9 reported here, and the dating based on palaeomagnetism, biostratigraphy and cosmogenic nuclides, provide the oldest direct evidence, to our knowledge, for a human presence in Europe at 1.2–1.1 Myr. The most parsimonious interpretation of this new finding in the Sierra de Atapuerca is that western Europe was settled during the Early Pleistocene by a hominin population coming from the east. This population may be related to an 'early' expansion of hominins out of Africa. Considering that the TE9 hominin could be also assigned to *H. antecessor*[10], the Sima del Elefante and Gran Dolina TD6 populations would represent a speciation that occurred in this extreme part of Eurasia during the Early Pleistocene.

Overall, the Sima del Elefante site, with other Early Pleistocene, Mediterranean sites (for example Pirro Nord, Barranco León and so on)[1–5,13], strengthens the evidence that peopling of Europe occurred much faster and in a more continuous manner than previously thought.

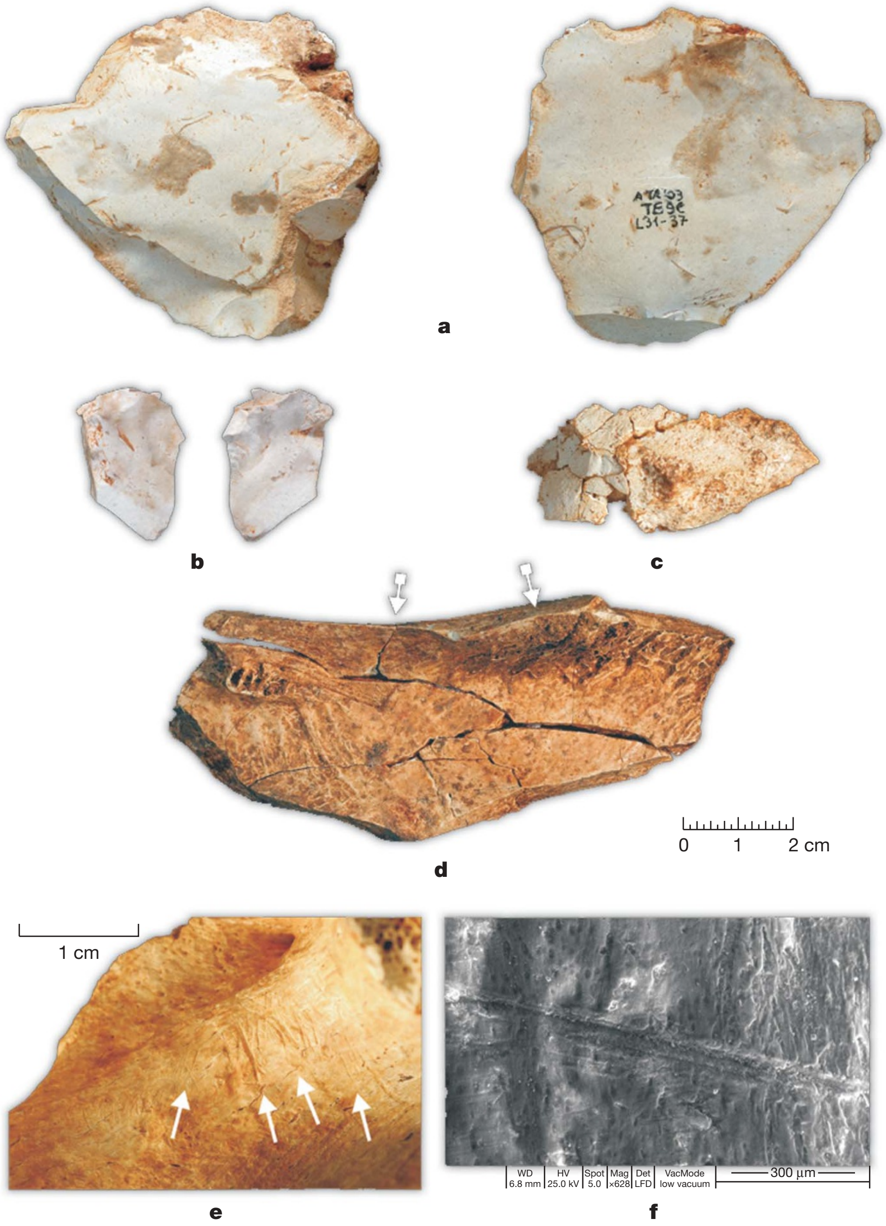

Figure 3 | TE9 lithic tools and faunal remains with cut marks and hominin breakage. a–c, Chert artefacts from TE9; 3a and 3b are flakes of Cretaceous chert probably belonging to the same core; 3c is the lower surface of a flake of Neogene chert. **d**, Large mammal bone with fresh fracture to access the marrow; arrows point the percussion marks. **e**, Cut-marked bovid vertebra; arrows point the main group of cut marks. **f**, Detail under environmental scanning electron microscope of one of the recorded cut marks on a bovid mandible.

METHODS SUMMARY

Sierra de Atapuerca (Burgos, Spain) contains several well-known Early and Middle Pleistocene sites: Gran Dolina[11], Galería[14], Sima de los Huesos[16] and Sima del Elefante[7], among others. All these sites have been excavated and studied by an interdisciplinary team formed in the late 1970s comprising archaeologists, palaeontologists, taphonomists, zooarchaeologists, geologists, palaeoanthropologists and biologists.

The interdisciplinary approach began with fieldwork, the basis for the archaeological and palaeoanthropological studies. All the Sierra de Atapuerca sites have been studied following systematic excavation; all items recovered were registered in a three-dimensional coordinate system and placed in stratigraphic context. Such thorough background work is required for understanding the context of human evolution, opposite to the interpretations made with isolated discoveries.

Identification, measurement and interpretation of the Sima del Elefante and all the Sierra de Atapuerca specimens follow conventional procedures of comparative anatomy for palaeoanthropology, lithic technology for stone tool production, and zooarchaeology and taphonomy for subsistence strategies. Also, microscopic analyses and archaeological experimentation are common procedures. Results and interpretations were situated in time and in palaeoenvironmental context using geochronological and biochronological analyses.

Full Methods and any associated references are available in the online version of the paper at www.nature.com/nature.

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Supplementary Information is linked to the online version of the paper at www.nature.com/nature.

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Author Contributions E.C., J.M.B. de C. and J.L.A. directed the excavations and the research project. Authors contributed in the following areas: A.P-G., J.V. and A.B., geology, sedimentology and micromorphology; J.M.P., D.E.G. and G.M.S., geochronology; G.C.-B., J. van der M. and N.G., palaeontology of micro- and macromammals; E.C., A.O., M.M., R.S., X.P.R., J.M.V. and M.N., stone tool technology; R.H., I.C., C.D., A.M. and J. Ros., zooarchaeology; J.M.B. de C., A.R., M.M.-T., M.L. and J.L.A., palaeoanthropology; A.C., archaeostratigraphy; E.A., F.B. and J. Rod., palaeoecology. Unless indicated, J.M.B. de C. took the measurements of hominin fossils for Table 1. A.O. and M.M. edited and coordinated the manuscript.

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METHODS

Research at the Sierra de Atapuerca sites (Burgos, Spain) has followed an interdisciplinary methodological model for more than 30 years, since the inception of a research team in 1977. Such long-term systematic excavation at the Atapuerca karst[14,31,32] and other major sites offers a rare perspective on human evolution and its context.

The methodology includes surface excavations that follow the stratigraphy, allowing recovery of all the archaeological items, as well as building a context in which to place the discoveries in relation to the occupational strategies followed by the primitive hominins, their palaeoenvironment, the chronology, the taphonomy of the items and the sites, the palaeontology and so on[33]. This systematic research allows comparison of findings at a global scale. In this sense, the observations at Sierra de Atapuerca are not isolated, but can be placed in a highly reliable context that allows strong evolutionary interpretations[34–37].

The particular methodology used to study the lithic industry includes: petrologic techniques for characterization of raw materials by optical light microscopy, X-ray diffraction and scanning electron microscopy (SEM) linked with energy-dispersive X-ray analysis; analysis of the technological processes for lithic production focused on the reduction sequences for a global view of the whole industrial assemblage, and avoiding typological conceptions; and microwear analyses based essentially on SEM examination[38–40]. The approach to interpreting subsistence strategies of the early hominids related to their use of animal resources is made through zooarchaeological studies. This involves analyses of skeletal representations, anatomical elements and species identification. Also, microscopic analysis (optical light microscopy as well as SEM) is used for human-induced damage on fossil remains, carnivore tooth marks and post-depositional features of taphonomic interest[41–45]. The SEM image in Fig. 3c was obtained in a FEI QUANTA 600 Environmental SEM from the Scientific and Technical Resource Service of Rovira i Virgili University. Technological and zooarchaeological studies systematically resort to experimental procedures to obtain reference patterns, as well as to check hypotheses deduced from the archaeological analysis.

For palaeoanthropology, the comparative anatomy of ATE9-1 was made following conventional procedures, recording the mandibular traits usually used in this type of study (see Supplementary Information). For the comparative analysis, the following original specimens were studied: Atapuerca-SH from the Sima de los Huesos site, Atapuerca-TD6 from the Gran Dolina site, Arago, Dmanisi, Montmaurin and Tighennif. High-quality casts from the Olduvai (OH 7, OH 13, OH 22, OH 37) and Koobi Fora specimens (KNM ER 730, KNM ER 1802, KNM ER 1805, KNM ER 1483), as well as Mauer and UR 501, were also analysed. Some data were obtained from the literature: specimens Sangiran 1, 9 and 22 (ref. 29), KGA 10-1 (ref. 30) and Zhoukoudian[46,47]. Other articles were also consulted to compare our own observations[48–52]. ATE9-1 was scanned in lateral view using an YXLON MU 2000-CT scanner at the University of Burgos, with the following parameters: scanner energy 160 kV, and 4 mA. Slice thickness was collimated to 0.5 mm, and the inter-slice spacing was 0.5 mm. The sections were used to create a three-dimensional computer model of the specimens using Mimics 8.1 (Materialise N.V.) software.

Finally, dating of the sedimentary infill is based on a combination of faunal analysis, cosmogenic ^{26}Al/^{10}Be burial dating and magnetic reversal stratigraphy. For the collection of fossil micromammal remains, all the sediment was systematically water-screened using 10 mm, 5 mm and 0.5 mm superimposed screens, then bagged by square, layer and excavation level. Subsequently, the microfossils were processed, sorted and classed. The faunal assemblage is available in Supplementary Table 1. Burial ages of two samples were calculated following previously published equations for deeply buried sediments, assuming steady erosion before burial, and ignoring post-burial production by muons (see Supplementary Information). ^{26}Al and ^{10}Be were measured by accelerator mass spectrometry at the Purdue Rare Isotope Measurement Laboratory, Purdue University. ^{10}Be measurements were normalized after measurement to standard SRM 4325, and we used a ^{10}Be half-life of 1.34 ± 0.07 Myr. Results are available in Supplementary Table 2. The magnetic reversal stratigraphy was based on primary remanent magnetization directions determined using both stepwise thermal and alternating field demagnetization and a three-axis 2G SQUID magnetometer at the University of Michigan. The virtual geomagnetic pole position was computed for each sample, with its latitude indicating the sign of the ancient geomagnetic field. Results are available in Supplementary Table 3. The palaeomagnetic polarity record was then compared with the well-dated magnetic reversal sequence.

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