

Supplementary information:

Supplementary Mandible Discussion

The mandible ATE9-1 preserves *in situ* the roots of LI2, LP3, RP3, and RP4, the root and crown of RI2, and the root and a part of the crown of the RC and LC. The RI2 and RC exhibit a marked buccal inclination due to a pathological process which has affected the alveolar bone. The dimensions, the similar high degree of occlusal and interproximal wear, as well as the appropriate fit between the preserved part of the alveolus and the root of the isolated LP4 suggest that this tooth belongs to ATE9-1. The crown of the LP4 lacks a portion of the enamel on the lingual side. The dental crowns exhibit heavy occlusal and interproximal wear.

The mandible ATE9-1 exhibits a well-developed anterior marginal tubercle placed at the C/P₃ level. This tubercle is absent in the genus *Australopithecus* and seems to appear as a new structure in the genus *Homo*^{S1}. In early *Homo* specimens, the tubercle is either absent (OH 13, KNM-ER 1483) or placed at the C/P₃ level, as in OH 37, D 211, D 2735, and D 2600. In African and Asian Lower Pleistocene hominins, the anterior marginal tubercle, when present, can be placed at the level of C/P 3 (Sangiran 9), P₃ (KNM-ER 730), P₃/P₄ (Sangiran 22), or P₄/M₁ (Sangiran 1). In African and Asian Middle Pleistocene hominins the tubercle is expressed at the P₄ level, whereas in European Middle Pleistocene specimens, the tubercle migrates to a more distal position: P₄/M₁ or M₁^{S2}. From this data, we conclude that ATE9-1 shows the primitive condition for the genus *Homo* regarding the presence and position of the anterior marginal tubercle.

Furthermore, the mandible ATE9-1 also exhibits a weakly expressed mentum osseum and a distinct mental trigone, a morphology that is also present in early *Homo* specimens. In fact, some authors consider that the mental trigone appeared early in the evolution of the genus *Homo*^{S3-4}. Tobias^{S4} concluded that the mandibles OH 7 and OH 13 exhibit both the mentum osseum and the mental trigone. Rosas and Bermúdez de Castro^{S2} observed that the Dmanisi D 211 mandible shows a mentum osseum (also recognized by Gabunia and Vekua^{S5} and Bräuer and Schultz^{S6}) and a "visible and prominent mental trigone" as well. The same applies for the big specimen D 2600, whereas in D 2735 only a clear mentum osseum can be described. Schrenk and colleagues^{S7} described the specimen UR 501 as having a distinct mental trigone and mental tubercles. Wood^{S8} includes "a more substantial basal component at the mandibular symphysis" among the derived traits that *H. ergaster* shares with *H. sapiens*. Thus, Day and Leakey^{S9} recognize a distinct mental trigone in KNM-ER 730. Kaifu and colleagues^{S10} also describe the mental trigone in Sangiran 9 and Sangiran 22. Concerning the Middle Pleistocene hominins, a mental trigone appears in Tighenif 1 and Tighenif 2, the specimens AT-300 and AT-605 from Atapuerca-Sima de los Huesos^{S11}, as well as in the Zhoukoudian mandibles^{S12}. However, a mentum osseum is generally absent in these hominins.

Given the state of preservation of ATE9-1, it is difficult to find the orientation plane of the specimen, as well as the estimation of the angle between the planum alveolare and the dental alveolar plane^{S4}. Still, it is remarkable that ATE9-1 lacks a marked planum alveolare and superior transverse torus. The planum alveolare is usually shelf-like in specimens like OH 13, OH 37, KNM-ER-1805, KNM-ER 1483, KNM-ER 3734, and D 2600. In other early *Homo*, a more or less inclined planum alveolare is combined with a thick symphyseal region, like KNM-ER 1802, D 211, and D 2735^{S6}. Thus, ATE9-1 exhibits a derived morphology for the posterior surface of the symphyseal region regarding the early *Homo* specimens. Moreover, the alveolar planum in ATE9-1 is more vertical than in specimens like those of Sangiran, Tighenif, KNM-ER 730, KGA10-1, OH 22, Mauer, Arago 13, Arago 2, Montmaurin, or those of Atapuerca-Sima de los Huesos, and resembles that of the Zhoukoudian specimens, which also lack a well developed superior transverse torus.

Supplementary Table 1: TE9 Faunal list^{S13-17} and this work

Macaca sp.
Sus sp.
 cf. *Bison* sp.
Dama nestii cf. *vallonnetensis*
Eucladoceros giulii / *Megaloceros* sp.
Rhinocerotidae indet.
Equus sp. (stenonian type).
Panthera cf. *gombaszoegensis*
Lynx cf. *issiodorensis*
Pannonictis cf. *nestii*
 cf. *Baranogale antiqua*
Mustela cf. *palerminea/praenivalis*
Canis cf. *mosbachensis/arnensis*
Vulpes cf. *alopocoides*
Ursus cf. *dolinensis*
Allophaiomys lavocati
A. burgondiae
A. nutiensis (= *Iberomys* aff. *I. huescarensis*)
Ungaromys nanus
Pliomys simplicior
Arvicolinae nov. (= *Mimomys* sp.)
Castillomys rivas
Apodemus sp.
Glis sp.
Castor sp.
Sciurus sp.
Asoriculus gibberodon
Beremendia fissidens
Sorex sp.
Crocidura aff. *kornfeldi*
Crocidura cf. *russula*
Talpa cf. *europaea*
Desmaninae indet.
Erinaceus cf. *europaeus*
Lepus sp.
Oryctolagus sp.

Supplementary Methods

Burial dating

Two samples were collected from the Sima del Elefante for burial dating with cosmogenic ^{26}Al and ^{10}Be in quartz. Each sample consisted of approximately 4 kg of sandy matrix from within a cave-fill breccia. After removal of carbonates and clays, 30–40 g of pure quartz was isolated using a combination of repeated leaching in weak HF/HNO_3 and heavy-liquid separations, following standard procedures.

Quartz was dissolved in HF/HNO_3 and spiked with $\sim 430 \mu\text{g}$ ^9Be in a carrier solution prepared from beryl. Stable aluminum concentrations were measured on an aliquot of the sample solution using the method of standard additions on ICP-OES; aluminum concentrations were $\sim 170 \mu\text{g/g}$ for both samples. Fluorides were removed from the samples by repeated fuming in H_2SO_4 . The remaining cake was dissolved in 9M HCl , iron was extracted as FeCl_6 on an anion exchange column, and the eluent was taken to pH 8 using NH_4OH to precipitate hydroxides. After rinsing twice in pure water to remove ammonia, the remaining hydroxide gel was dissolved and complexed in 0.4 M oxalic acid, and introduced onto a stacked series of cation and anion exchange columns. Beryllium adsorbed onto the cation exchange column, and was removed using 1 M HCl ; an aluminum complex adsorbed onto the anion exchange column, and was separated from titanium using a solution of 0.1 M $\text{HCl}/0.05 \text{ M}$ oxalic acid^{S18}. Oxalates remaining in the aluminum fraction were denatured by drying in the presence of small amounts of HClO_4 . Beryllium hydroxide was precipitated at pH 9 in the presence of EDTA, and aluminum hydroxide was precipitated at pH 8. Both hydroxides were oxidized in quartz vials at 1100°C . The oxides were wetted with pure acetone, then crushed and mixed with niobium (beryllium) and silver (aluminum) for analysis by accelerator mass spectrometry (AMS).

AMS measurements were performed at PRIME Lab (Purdue University). Beryllium standards were prepared by Nishiizumi^{S19}, and aluminum standards by Vogt^{S20}. Both standards were diluted from material of certified activity. For the age determination, we adjusted the beryllium standards for a ^{10}Be half-life of 1.34 Myr (see ^{S19}). Results are shown in table 2.

Supplementary Table 2: Cosmogenic nuclide data

Sample	$[^{26}\text{Al}]$ (10^6 at/g)	$[^{10}\text{Be}]$ (10^6 at/g)	Burial age (Myr)
C-TE9b	1.84 ± 0.13	0.485 ± 0.010	1.22 ± 0.14 (0.16)
C-TE7	1.76 ± 0.14	0.442 ± 0.009	1.13 ± 0.16 (0.18)

Ages were calculated following Granger and Muzikar^{S21,22}, assuming steady erosion prior to burial, and no postburial production by muons. Samples are buried sufficiently deeply (16 meters) that production by muons is inconsequential. We use a ^{10}Be half-life of 1.34 ± 0.07 Myr reported by NIST and confirmed by Nishiizumi and colleagues^{S19}, and a ^{26}Al half-life of 0.717 ± 0.017 Myr calculated from a weighted average of multiple half-life determinations^{S23}. Production rates at the surface prior to burial are taken as 69.8 and 10.2 at/g/yr for ^{26}Al and ^{10}Be , for a latitude of 42.3°N and an altitude of 1.0 km, following Stone^{S24} and corrected for the appropriate ^{10}Be half-life⁷. Uncertainties in the burial ages are reported two ways. The smaller uncertainty includes only analytical errors, and is appropriate for comparing multiple cosmogenic nuclide burial ages and calculating averages. The larger parenthetical uncertainty includes systematic errors in the half-lives, and is appropriate for comparing with other dating methods.

The Elefante sediments represent an episodic cave infill through a chimney open to the surface, with syndepositional or intradepositional collapse into a lower passage. Hillslopes above the cave have shallow soils, although there are at least 10 meters of valley fill found at a similar elevation at 40 meters north of the Elefante exposure. The sediment may have accumulated in the cave either through surface erosion and episodic storm runoff into the cave entrance, perhaps in response to climate cycles^{S25}, or alternatively through shallow-seated landslides that passed over the cave entrance but did not fill the cave completely. In either case, it is unlikely that sediments are derived from previously deeply buried sediments, so the cosmogenic burial ages should represent the true age of deposition.

Palaeomagnetism

Natural Remanent Magnetization (NRM) and its progressive demagnetization of the samples were measured with a three-axis 2G SQUID magnetometer housed in a field-free room. The noise level of the magnetometer is $\sim 7 \mu\text{A/m}$, well below the magnetization intensity of the measured samples. Specimens were stepwise demagnetized in a ASC Thermal Demagnetizer. Demagnetization behavior is described in Parés and colleagues^{S26}. Characteristic Remanent Magnetization (ChRM) component directions were calculated for all specimens using Principal Component Analysis^{S27}, guided by visual inspection of orthogonal demagnetization

plots^{S28}. Mean directions and associated statistical parameters were estimated using Fisher's method^{S29}. All measurements were made at the Paleomagnetism Laboratory at the University of Michigan.

In addition to the major reversal occurring at height of 11 meters, we notice the presence of an interval at the very bottom of stratigraphic unit TE17 that has normal polarity, within the Matuyama reverse polarity chron. Such an interval corresponds to a flowstone that separates TE16 (bottom) from TE17 (top). The flowstone does not have much lateral continuity, although it seems to appear again towards the south in the sedimentary infilling. Whereas the palaeomagnetic direction unambiguously shows normal polarity, the meaning of this change remains unclear. One possibility is that it corresponds to a present day field overprint, confined within a stratigraphic layer in the section. Nevertheless, considering the general palaeomagnetic behavior of the bulk of the samples, such a flip could instead correspond to a geomagnetic reversal. If that is the case, we could be facing the Jaramillo Subchron (0.990 – 1.070 Myr) or the Cobb Mountain event (1.201 – 1.211 Myr). Alternatively, and given its proximity to the major reversal occurring just a few centimeters above, the normal-reverse duplet could be a precursor to the Matuyama-Brunhes reversal. Ongoing rockmagnetic and palaeomagnetic studies will help determine the meaning of the reversal at 11 m.

Supplementary Table 3: Palaeomagnetic data. Unit- Stratigraphic Units sampled (see Figure 1b); Stratigraphic height is expressed in meters above bedrock; VGP Lat- Latitude of the Virtual Geomagnetic Pole.

Unit	Stratigraphic Height	Samples	VGP Lat
TE18	13.40	EL5	87.0
TE17	11.50	AT6-5,6;EL7-10	75.5
TE17	11.10	AT6-1,2,3,4;EL7-01 to 09	-61.2
TE17	11.05	EL7N	55.3
TE14	7.90	EL4,AT1-1,2	-83.6
TE11	6.20	E1N-4,5,6	-78.8
TE10	5.60	E1N-1,2,3	-77.6
TE9	4.50	AT2-3,4	-72.7
TE7	0.30	EMU1,2,3,4	-70.5

Supplementary Table 4: Western Europe Early Pleistocene archaeological sites. Dating methods: PM= Palaeomagnetism, BS= Biostratigraphy, ESR= Electron Spin Resonance, U= Uranium Series, K(Ar)/Ar= Potassium (Argon)/Argon, CN= Cosmogenic nuclides.

Archaeol. Site	Local.	Geolog. setting	Age in Myr (Post quem – Ante quem) [Direct dating]	Method	Lithic Ind.	Fauna	Hom. Fossils
Pirro Nord ^{S30}	Italy	Karst infilling	<i>L. Pleistocene</i> (1.7 – 1.3)	BS	Mode 1	Y	N
Sima del Elefante TE9 ^{S26} and this work	Spain	Karst infilling	[1.2]	PM,CN,BS	Mode 1	Y	Y
Barranco León ^{S31,32}	Spain	Fluvio-lacustrine	<i>L. Pleistocene – Matuyama</i> (1.3-1.2)	PM BS	Mode 1	Y	N
Fuente Nueva 3 ^{S31,32}	Spain	Fluvio-lacustrine	<i>L. Pleistocene – Matuyama</i> (1.2)	PM BS	Mode 1	Y	N
Pont-de-Lavaud ^{S33}	France	Alluvial	[1.1]	ESR	Mode 1	N	N
Le Vallonnet ^{S34}	France	Karst infilling	(1.07 – 0.98)	ESR,PM,BS	Mode 1	Y	N
Soleilhac ^{S35}	France	Maar	(1.07 – 0.6)	Ar/Ar,PM,BS	Mode 1	Y	N
Sima del Elefante TE16-10 ^{S26}	Spain	Karst infilling	(1.2 – 1.07)	PM,BS	Mode 1	Y	N
Monte Poggiolo ^{S36}	Italy	Alluvial	[0.9]	PM,ESR	Mode 1	N	N
Gran Dolina TD4 ^{S37,38}	Spain	Karst infilling	>0.8	U/ESR,PM,BS	Mode 1	Y	N
Ceprano ^{S39}	Italy	Marsh	(1.0 – 0.7)	K/Ar,PM	No	N	Y
Gran Dolina TD6 ^{S37,38}	Spain	Karst infilling	[0.8]	U/ESR,PM,BS	Mode 1	Y	Y

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