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Initial approach to the site formation and paleoecology of the “Sima del Elefante”: a
Pleistocene karst site at Atapuerca Hill.

In: E. Baquedano & S. Rubio Jara (eds)
Miscelánea en homenaje a Emiliano Aguirre. Volumen 1 Geología.
Museo Arqueológico Regional, Alcalá de Henares: 134-155.

Resumen

Este trabajo presenta una actualización de las investigaciones realizadas en el yacimiento de la Sima del Elefante, Sierra de Atapuerca (Burgos). Los datos aquí expuestos y los problemas derivados de su interpretación pretenden servir de base para el desarrollo de un modelo de estudio de la evolución ecológica durante el Pleistoceno. En particular, los aspectos relacionados con la formación del yacimiento son considerados básicos para la reconstrucción paleoecológica. La evolución del bioma mediterráneo es objeto de especial interés en las futuras líneas de investigación abiertas a raíz del estudio de este singular yacimiento.

El yacimiento de la Sima del Elefante (TE) se localiza en el extremo sur de la trinchera del ferrocarril de la Sierra de Atapuerca. La secuencia estratigráfica completa alcanza los 25 m de potencia y ha sido dividida en 21 unidades lito-estratigráficas delimitadas por discontinuidades mayores. La historia de la cavidad puede ordenarse en al menos tres fases. La fase inferior (niveles TE9 a TE14) data del tercio final del Pleistoceno Inferior, con una cronología entre 1.1 y 1.4 millones de años. Es rica en registro arqueo-paleontológico y presenta claras evidencias de actividad antrópica. Dada su cronología, los niveles inferiores de TE representan un importante referente para la comprensión de la primera colonización humana de Europa. La fase intermedia la constituyen las unidades TE15 a TE19. El tramo basal de esta segunda fase de relleno (TE15 a TE17) hasta la fecha no ha deparado contenido fósil. El tramo superior (TE18 y TE19), cuya cronología parece corresponder a la parte final del Pleistoceno Medio, es rica en restos de grandes mamíferos e industria lítica sobre sílex y cuarcita. La unidad TE19 se caracteriza por una sucesión de coladas detríticas ("debris-flow") (TE19A a TE19G), con matriz muy dura y carbonatada, rica en huesos de grandes mamíferos y ausencia de micromamíferos. El nivel TE19G contiene abundantes restos de carbón pendiente de verificar su posible carácter antrópico. Finalmente, la tercera y última fase de relleno (TE20 y TE21) corresponde al Pleistoceno superior y se define por la colmatación final de la cavidad y formación de un horizonte edáfico.

La fase inferior de TE tuvo lugar en un tiempo anterior a los niveles inferiores de Gran Dolina (TD4), mientras que el relleno de las unidades superiores de TE corresponde a un momento posterior a la sedimentación de GIII/GIV de Galería y TD10/TD11 de Gran Dolina.

Palabras clave: Pleistoceno Inferior, Pleistoceno Medio, Ocupación Humana, Ecosistemas mediterráneos, Paleoecología, Formación del yacimiento.

Abstract

This contribution updates the research currently underway on the Sima del Elefante (TE) site, at the Sierra de Atapuerca (Burgos, Spain). The data here presented and the problems derived from its interpretation aim to be an initial assessment of the grounds upon which a paleoecological systems approach to the study of the "Sima del Elefante" site can be developed. Site formation processes are considered as a fundamental step previous to paleoecological reconstructions. Furthermore, ecological evolution in the Mediterranean region is a major interest in the study of this site.

The "Sima del Elefante" (TE site) is a major cave infill with a stratigraphic succession 25 m thick and 15 m wide, wealthy in animal bones and evidences of human occupation at different Pleistocene ages. TE site is under systematic excavation since 1996, and the inferior and superior levels are being dug up independently. The exposed section has been divided into 21 lithostratigraphic units defined by major unconformities. Concerning the cave history, at least three main infill phases have been identified. The lower phase (TE9-TE14) is dated to Early Pleistocene (between 1.1 and 1.4 million years ago) on the basis of inverse paleomagnetism and belonging to the later Early Pleistocene on the basis of biochronology. The TE lower phase is providing a rich faunal assemblage, and shows evidence of human occupation. A set of stone tools of flint, and possibly, calcareous, is being found at these levels. Hence, the lower part of the TE section documents early presence of hominids in Europe and constituted an important element in the understanding of human dispersions out-of-Africa. The middle phase (TE15-TE19) dated to Middle Pleistocene and it is further subdivided into a basal part (TE15-TE17), still largely unexplored, but no vertebrate fossil record is present at these levels. Units TE18, and mainly TE19 unit, date to late Middle Pleistocene, and contain an abundant record of large mammals as well as stone tools included in calcareous breccias. The TE19 G level contains abundant pieces of charcoal, though verification of its anthropic character is pending. Finally, the third and last sedimentary phase (TE20 and TE21) date to Last Pleistocene and it defined the final infilling of the cavity and soil formation. The lower phase was deposited in a time previous to the lower levels from Gran Dolina site (TD4), whereas the TE upper levels possibly correspond to a moment later than the sedimentation of Galería GIII/GIV, and Gran Dolina TD10/TD11.

Key words: Early Pleistocene, Middle Pleistocene, Human occupation, Mediterranean ecosystem, Paleoecology, Site formation.

Initial approach to the site formation and Paleoeecology of the “Sima del Elefante”: a Pleistocene karst locality at Atapuerca Hill

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Introduction

This contribution updates the research currently ongoing on the TE karst site (Rosas *et alii*, 2001). The study of the Sima del Elefante site is approached from a trans-disciplinary perspective (systems paleoecology), with the final aim of building a formal model of Pleistocene ecological evolution in the Mediterranean region of Europe. Such an eventual model aims to serve as a template upon which hypotheses concerning life and development of Pleistocene human populations may be tested.

Pleistocene paleoecological context

The current paradigm of Cenozoic paleoecology is strongly influenced by the proposition that climate change acts as a major force triggering evolution of species and communities (Vrba *et alii*, 1995; Behrensmeyer *et alii*, 1997). Dramatic climate changes occurring cyclically during the Plio-Pleistocene make attractive the hypothesis that evolutionary change, extinction, and long-term displacement of faunas, including humans, may have been climatically induced

(Coppens, 1975; von Koenigswald and Werdelin, 1992; Stanley, 1992; Turner and Wood, 1993). In this line, questions concerning “Out-of-Africa” events are being approached from this viewpoint.

A number of chronological milestones have been identified in the Plio-Pleistocene fossil record, around which supposedly major evolutionary events may be related to climate changes. For instance, a major turnover of mammalian faunas has been proposed to have occurred in East Africa at ~2.7-2.5 Myr, originating, among other effects, speciation in the *Paranthropus* lineage, and the emergence of *Homo* (Turner and Wood, 1993; Vrba, 1995) (or more recently *Homo*-like australopithecines). Another relevant event is to be found at the Plio-Pleistocene boundary (deMenocal, 1995), with a new climatic deterioration, coincident with the earliest evidence of hominid migration out of Africa (Turner, 1999; Arribas and Palmqvist, 1999).

Likewise, at around 1.2 Myr B.P. periodicity and intensity of climatic changes begun to be altered, and ecological conditions experienced substantial changes. Around this time the 100 ky orbital exentricity cycle become dominant over the 42 kyr obliquity cycle, forcing global climate and minimum temperatures becoming lower (Clark *et alii*, 1999; Rutherford and D'Hondt, 2000; Lambeck *et alii*, 2002). Coinciding with this climatic transition, during the interval 1.2 to 0.9 Myr, there were successive dispersals of mammal species into Europe, most of them coming from North or Central Asia (van der Made, 2003), but others possibly coming from Africa. The last third of the Early Pleistocene was a time of ecological transformations during which first human settlements took place in the Mediterranean region.

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Early colonization of Europe seems to be restricted to the Southern part of the continent (Roebroeks, 2001), while a widespread distribution of hominids in Northern Europe did not occur apparently until 0.6-0.5 Myr; coincident with the occurrence of the Mode II toolkit in the archaeological record (e.g. Carbonell *et alii*, 1999a; Turner, 1999; Roebroeks, 2001). At present, published data supporting earliest human occurrence in Europe -between 1.2 and 1.0 million years ago- comes from Mode I stone tools found at Southern Spain sites, such as Fuente Nueva-3 (Martínez Navarro *et alii*, 1997) and Barranco León in the Guadix Basin (Granada) (Oms *et alii*, 2000). This evidence falls within the chronological interval during which deep environmental changes were taking place and arises a number of questions with regard to the timing and the ecological background of early human colonization of Europe. Specifically, did early Mediterranean ecosystems provide more suitable ecological conditions for hominids than other temperate climates?

The Sima del Elefante (TE site), at Atapuerca Hill (Burgos, Spain), is currently providing solid confirmation of human settlement in the Iberian Peninsula before 1 My ago. Such a circumstance, together with the rich faunal assemblage found at the same levels, makes of the TE site (TE9-TE14 units) a fundamental reference for the understanding of the physical, ecological and cultural factors that governed the initial dispersion of hominids into Europe (see Huguet, this volume). In addition, the upper litho-stratigraphic units of the Sima del Elefante (TE18 – TE19) offer abundant archaeo-paleontological evidences that date from the late Middle Pleistocene. Eventual comparisons of the lower and upper TE site archaeo-paleontological record may contribute to the understanding of the taphonomy and the ecological evolution of the Mediterranean bioma in a restricted geographical area.

Context and background of the Sima del Elefante

The Atapuerca Hill contains a large number of cave sites, with a rich Pleistocene geo-arqueo-paleontological record (see Aguirre *et alii*, 1990; Carbonell *et alii*, 1998; Pérez-González *et alii*, 2001). Among these sites, the "Sima del Elefante" (TE site) is a major cave infill with a stratigraphic succession 25 m thick and 15m wide, wealthy in animal bones and evidences of human occupation at different Pleistocene ages (Fig. 1). The site is catalogued as cavity IV-A-8, plan 6 (Martín-Merino *et alii*, 1981), and it is under systematic excavation since 1996. A large part of the cave infill outcropped after the construction of the railway cutting¹. The remaining 6 m are below the present Trinchera ground level. At present, three main sedimentary phases (early, middle and late) have been distinguished.

Field operations

The investigation of the TE site started with a sampling of the sedimentary succession, and the description of the spatial

heterogeneity of the infilling. Regular digging at the lower levels began in 1996, taking advance of a projection of the outcrop (~9m²). Excavation and processing of the archaeo-paleontological record is conducted following the methods described by Carbonell *et alii* (1999b).

A large scaffold was erected in 2001 in order to give access and physical support for the long-term excavation at the upper levels. At the moment, upper TE levels have been only excavated at restricted areas, those projecting outside the section. These levels contain hard carbonated breccias that make the extraction of fossils difficult. Surface excavation is being planned, and new techniques might be implemented for bone extraction (e.g. electric drills).

Arqueo-paleontological levels are firstly identified on the ground of litho-stratigraphic units, denoted by numbers (e.g. TE19), and defined by major unconformities. Further subdivision of levels are denoted by letters (e.g. TE19C), and are based on matrix texture, composition as well as fossil content.

A systematic topography program is carry out since 1997 in the Atapuerca sites (Pérez Martínez, 2002). Maps and site sections refers to UTM coordinates, and include both the absolute height over the sea level and the archaeological 3D local coordinate reference system. Figure 2 shows a scale drawing of the TE site section.

Stratigraphical settings

The Sima del Elefante infill shows a high degree of tri-dimensional heterogeneity, with rapid lateral changes in lithology and normal faults, and our understanding of the complex succession of the TE site is still incomplete. In spite of it a remarkable regularity is also present at some particular areas of the succession; a fact common in other sites from the Atapuerca railway. Attending to this particular areas, the TE section has been divided into 21 litho-stratigraphic units. A detailed description of the exposed stratigraphic succession, and unit's sediment composition can be found in Rosas *et alii* (2001) (Fig. 2).

The 21 stratigraphic units are further grouped into three sedimentary phases. The lower phase (lower TE) ranges from the bottom of the sequence until the unit TE14. The middle phase is composed by TE15 to TE19 units. And, finally, the upper phase comprises the TE20 and TE21 litho-stratigraphic units.

The TE site: Phase I

In the exposed section, the lower phase comprises a series of strata embracing from the lowermost outcropped unit (TE-9) to TE-14. Sediments composing these units are, all of them, of an allocthonous origin, and they display marked inclination of the

1. At the end of the 19th century a railway trench was opened by a British Mining Company in the south-western slope of the Atapuerca Hill. Along the nowadays abandoned railway trench some cave infillings are exposed, and they are systematically explored, sampled and excavated since 1978.

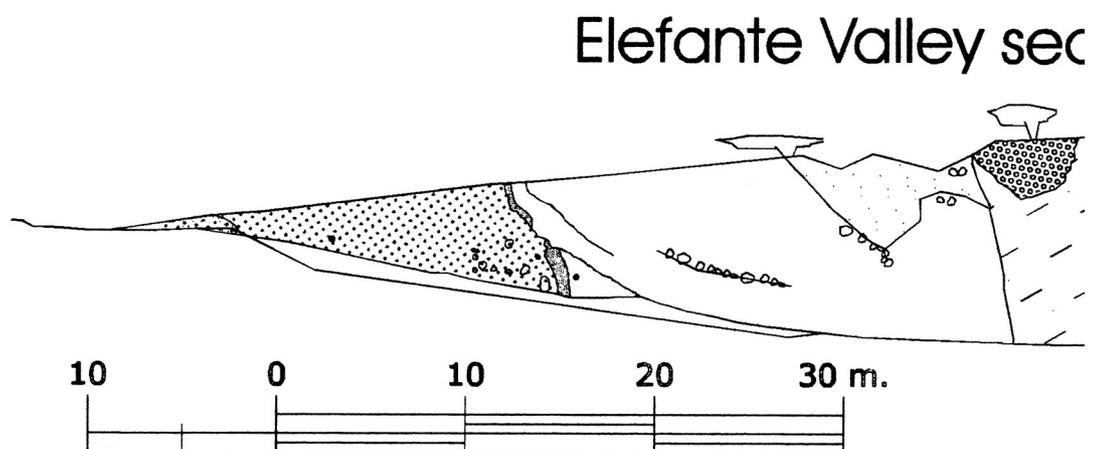


Fig. 1. General view of the Sima del Elefante site (Atapuerca Hill).

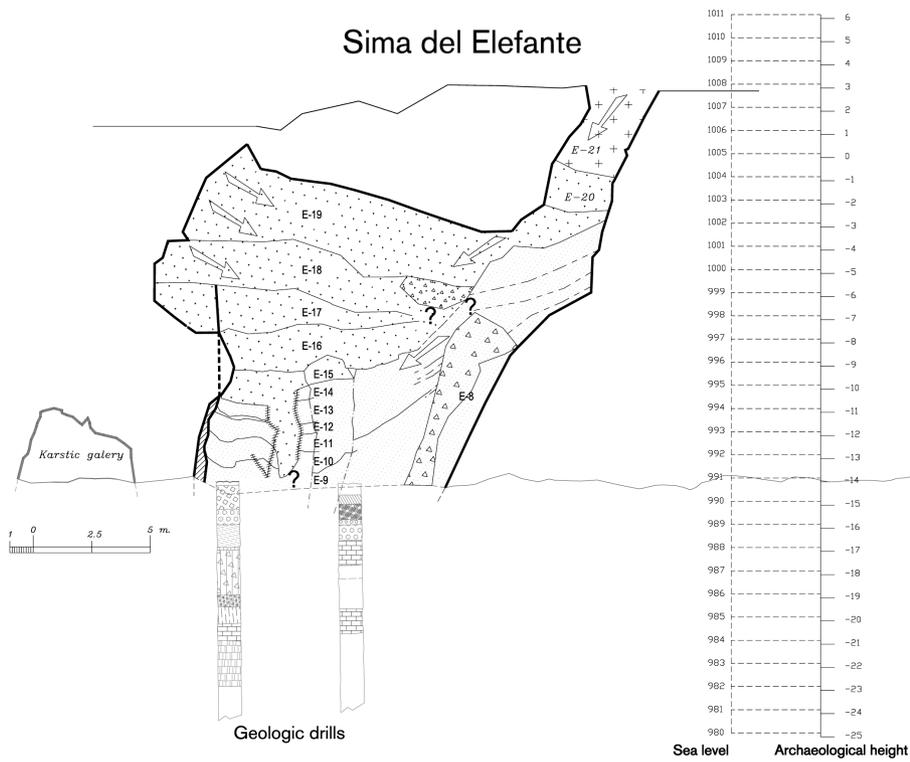


Fig. 2. The topographic profile of the Sima del Elefante site (Atapuerca). Cave section at the level of railway-trench limestone cut. Main contact lines and stratigraphic units are indicated. At the bottom, below the present ground level, stratigraphic succession of non-exposed sediments coming from core samples. Scale indicates the heights on the sea level and the archaeological reference from the zero level chose for the excavation of the site.

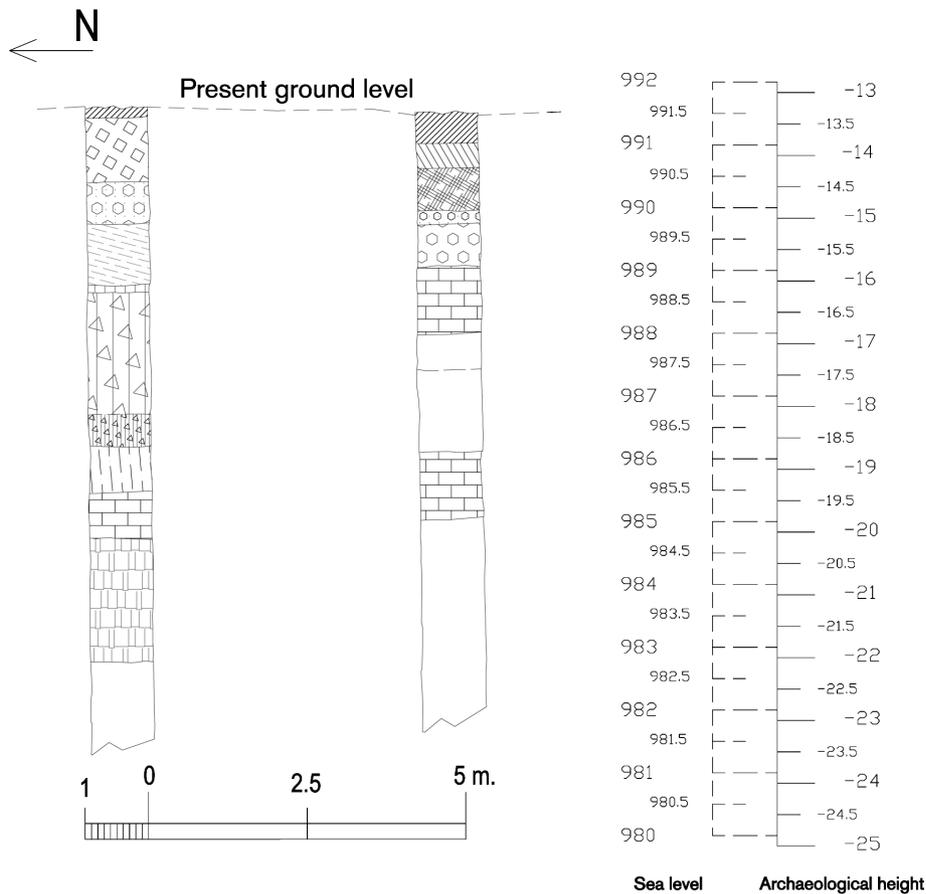


Fig. 3. Stratigraphic columns resulting from the geologic drills performed at the Sima del Elefante base. The north drill shows that below the current Trinchera ground level there are 6 m of sedimentary succession. At this depth, cave's floor was identified by the presence of a 40 cm thick limestone layer, underneath of which lower karst level sediments were also found (see text).

strata, more specially at TE9 and TE10. In fact, a clear angular unconformity is appreciated within this Early Pleistocene phase. The subset TE11-TE14 relay on a much slower bedding angle on the subset TE9-TE10. Patterns of sedimentation includes mud flows at the bottom of the succession, and hydraulic activation layers at the top of the succession, alternating with gravitational sediments (debris flows). The lower units show transport directions towards the NW in the central part of the locality and towards the south in the northern part of the locality, suggesting entries in the SE and N, respectively. In the exposed section, lateral continuity of the succession is partially broken up by a sort of cut-and-fill structure coupled to a set of local faults.

Two hypotheses were advanced in order to account for the structure and present inclination of the strata from the lower phase. One of them maintains the idea that the inclination of the whole series took place as a result of collapse of lower karst galleries. The other hypothesis holds that present inclination is sedimentary in origin. Several facts seem to support the latter.

Firstly, the inclination of the lower series decreases along the sequence from bottom to top. This feature is, moreover, coupled to a noticeable lateral change of facies. Proximal facies, located at the south end, are coarser than distal end, whose sediments increase in fine silt, and in cases laminated. This fact, in addition to the fossil preservation, allows to hypothesise that the original entrance of the cavity during Early Pleistocene was mostly of a fissure configuration better than a large cave entrance. Preserved sediments seems to entry the cavity by a talus cone.

The recent discovery of Early Pleistocene levels at the south and north end of the infill, acting as perched terraces with sharp lateral erosive contacts, support the hypothesis of a major erosive process, washing away part of the Early Pleistocene sediments, and partially emptying the cavity. Therefore, the original Early Pleistocene sedimentary succession at the TE site was longer than it is today preserved as it was cut by a noticeable erosive episode, well delimited by an erosive unconformity.

The lower limit of the Early Pleistocene sequence remained undefined as this part of the sequence does not outcrop. In order to know the length and composition of the sedimentary succession below the present ground level, two geologic drills were carried out during the 2001 field season, 5 m off the outcrop. Figure 3 shows the stratigraphic columns of the two drillings. A rough description of the north sequence drill, the longest of the two, is provided next.

Five different strata have been identified in the 6 m long sedimentary infill below the present ground level. At this depth, a limestone layer 60 cm thick was detected and interpreted as the floor of the cavity. From young to old these are composed as follow.

- 1) brown silts with rock fragments,
- 2) rock fragments with brown silts (7,5YR4/6),
- 3) dark brown silts (7,5YR4/6),

4) brown silt with rock fragments (2-4/10 cm) with fewer rock fragments at the base of this stratum,

5) A dark layer with brown silt and guano (7,5YR3,4/2 and 7,5YR5,6/8).

Underneath of this series of sediments, just bellow the limestone layer, a distinct set of sediments was found, which was interpreted to represent the infill of a cavity from a lower karst floor. Two strata have been distinguished. The uppermost is composed by clay with small clasts (1-2 cm), and manganese oxide. Bellow this, appears a stratum with rounded quartzite pebbles, which is interpreted as part of a terrace left by the Arlanzón river into the cave.

The TE site: Phase II

Middle sedimentary phase is dated to Middle Pleistocene age on the grounds of local correlations within the Atapuerca karst system stratigraphic succession. The middle phase is a long sequence comprising from TE15 to TE19 units. Two distinct further sub-arrangement may be differentiated in the TE Middle Pleistocene phase. The basal part of this sequence is characterized by a non-local sedimentary regime (TE15, TE16 and TE17). Bedding is mostly of hydrodynamic origin, and there is a recurrent pattern of speleothem formation along the sequence; specially in the TE17 unit where, at least, two solid stalagmite floors (of 20-30 cm thick) outcrop in the section. The sediments have light colours and are allocthonous, with few or no elements of the immediate surroundings. Until present, no vertebrate fossil record has been recovered from TE15, TE16, and TE17 units, which seems to be sterile in macrofossils. We think that there was no nearby entry to the cave when these sediments were formed. These preliminary observations suggest that the nearby valley affected the sedimentation of the lower and middle units of TE (now on called Trench Valley). This is evidenced by reworked Miocene and/or Cretaceous marls in the cave sediments, as well as by the similarity in texture and color of the sediments present in this nearby valley and those infilling the cavity (Fig. 4).

The uppermost units within the middle phase (TE18 and TE19 units) are characteristic of allocthonous sedimentary input. Four different sectors have been distinguished, informally named: north tower (squares D-E-F-G), central sector (squares J-K-L), south sector (squares M-N-O) and south tower (squares P-Q-R-S). The latter sector is almost unexplored up present (see Fig. 5 for the emplacement of the archaeological grid at the site).

TE18 unit is still largely unexplored. As a whole, it represents a stratified scree with marked lateral changes, and several erosive channels. A massive travertine concretion is located in the south end of the section, with evidences of later erosion and transport of travertine blocks and tuffs. A spring hole may be a reasonable interpretation of this structure.

TE19 is a large stratigraphic unit that presents a complex organization (Fig. 6). A succession of at least 5 debris flows

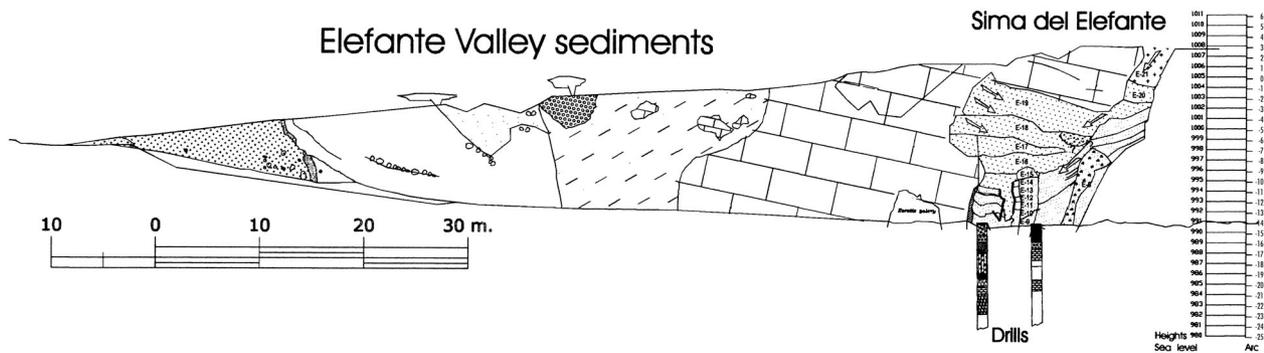


Fig. 4. Profile of the south end railway-trench with a general outline of the sediments belonging to a nearby valley in-between the two areas of the Atapuerca Trench, and the topographic profile of the Sima del Elefante site.

(named by letters A to F) are located at the north tower and central sector of the section. These layers interfinger laterally with laminated silts, which define the south sector. The south tower sector records coarse sediments.

According to this information, two distinct sedimentary regimes have been identified to occur in the TE19 unit. First, gravitational debris flows coming from the south and principally north cave entrances, and, second, sedimentation in a pond located at the south sector where the sediments are more finely bedded (Fig. 6). Possibly debris flows and pond sedimentation alternates in time.

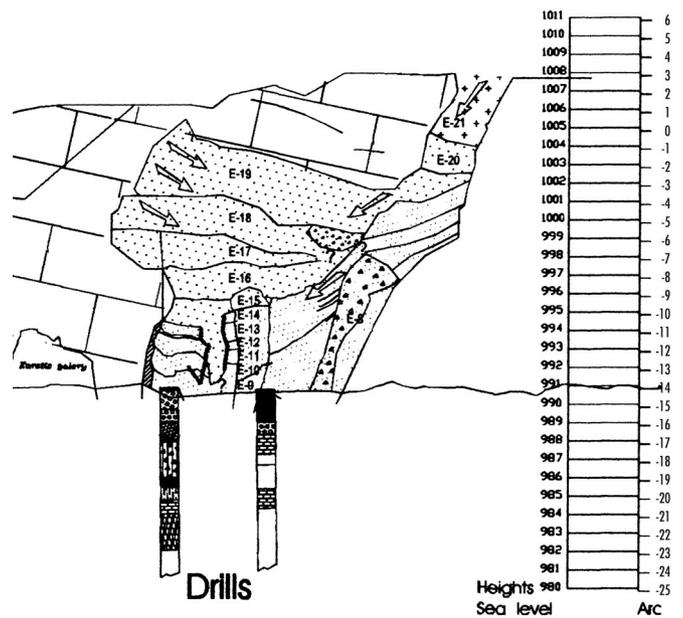
The TE site: Phase III

This is the shortest part of the sequence and is restricted to uppermost part of the section in the south. It is composed by pit fall debris (TE20), and Terra Rossa (TE21). Due to access difficulties, no excavation or sampling have been performed yet.

Chronological settings

The precise chronological allocation of the TE site is of major importance. Both the understanding of the evolution of the Mediterranean biome in a time of deep climate alterations, as well as the timing of early human presence in Europe, partially depends on it. Unfortunately, no chronostratigraphic data are available at present, and an accurate temporal definition of the site is still pending. Nevertheless, some information may be offered.

The stratigraphic section of Sima del Elefante site has been sampled for dating by palaeomagnetism, U-series, and ESR. Preliminary paleomagnetic analysis at TE8 and TE12 units (lower phase) showed an inverse polarity with a high congruence in the orientations, as previously reported by Rosas *et alii* (2001). This fact allowed to locate the lower part of the TE succession within the cron Matuyama, that is Early Pleistocene. Additionally, biostratigraphic data fully corroborate this assignation. The association of small and large mammals from the lower units is characteristic from the last third of the Iberian Early Pleistocene (see later).



The TE lower phase is biostratigraphically lower than the lower levels of Gran Dolina site (TD4) and it is, therefore, the oldest record of the Sierra de Atapuerca. There is, however, an uncertainty on the precise timescale of the lower levels of TE. Further research is extremely needed.

A similar situation is found in the TE19 unit. No radiometric dating is presently available. In spite of the several attempts, the low uranium content in the sediments of the TE site has precluded any dating with this technique (Bishoff, pers. com.). New assays with new samples are, however, underway. Likewise, ESR analyses on enamel teeth are in progress by C. Falgueres. On the other side, the scarce record of small mammals makes a biochronologic assignation difficult. The large mammal assemblage is typical for the final third of the Middle Pleistocene (0.35-0.15 Myr), but a more accurate estimation is at present difficult. Additionally, advanced technical features of the stone tools from this unit may fit a final Middle Pleistocene age for the TE19 unit. The ongoing dating program on the site may eventually refine this approximation.

Cave history of the Sima del Elefante site

A major concern in the investigation of the TE site is to elucidate the evolution of the cave, as a framework where the genesis of the geo-arqueo-paleontological record can be comprehended. A reasonable control on the cave history helps with the interpretation of the sedimentary successions at different temporal scales. Therefore, special attention is drawn to those data that may contribute to unravel the development of the cave. Such a set of evidences ranges in a multifactorial spectrum which includes tectonic predisposition to karst development, regional geomorphology, stratigraphic and sedimentological processes, as well as the wide set of aspects covered by arqueo-paleontological disciplines. A preliminary sequential definition of cave development episodes and three-dimensional geometry of the cave system is next provided.

Three-dimensional geometry of the Sima del Elefante site. Background

Available information on the geological background of the Sierra de Atapuerca may be found in Aguirre *et alii* (1990); Carbonell *et alii* (1998); Parés and Pérez-González (1999); Pérez-González *et alii* (2001); Benito and Pérez-González (2002). Likewise, Atapuerca caves topography and speleologic field research is provided by Grupo Espeleológico Edelweiss (GEE) (see Martín-Merino *et alii*, 1981; Martín-Merino and Ortega, 2003; Martín-Merino, 2002).

As a summary, the Atapuerca karst is of phreatic origin, which evolved throughout the formation of the three floors: upper, middle, and lower floors respectively (Martín-Merino and Ortega, 2003). The cave pattern is geographically organised in two independent systems. The larger of them is formed by the Cueva Mayor-Cueva del Silo galleries network, further subdivided into Cueva Mayor and Cueva del Silo subsystems with two distinct current openings (see Martín-Merino *et alii* (1981); Fig. 7). The other set of cavities is located at the western end of the Atapuerca railway cutting, and it outcrops in series of independent caves and fissures sections (e.g. Gran Dolina (TD) site and Galería/Covacha (TG/TZ) site, among several others). As far as free galleries allow to explore, these latter cavities present a much more local extension, without connections among them. Yet, according to Eraso *et alii* (1998a), the Gran Dolina site is a large karstic conduit fully filled.

Both cave systems are geographically separated by a small valley (Fig. 7; see also Fig. 4). The geomorphological evolution of this nowadays dry valley seems to have had a significantly influenced the infilling of the Sima del Elefante. A large amount of sediments from the TE cave, and more especially those corresponding to the phase II, may have have a fluvial origin closely related to this valley.

Topography and fieldwork investigations carried out by the Grupo Espeleológico Edelweiss (GEE) (see Martín-Merino *et alii*, 1981; Martín-Merino and Ortega, 2003) led to propose the hypothesis that TE site represents an old entrance to a

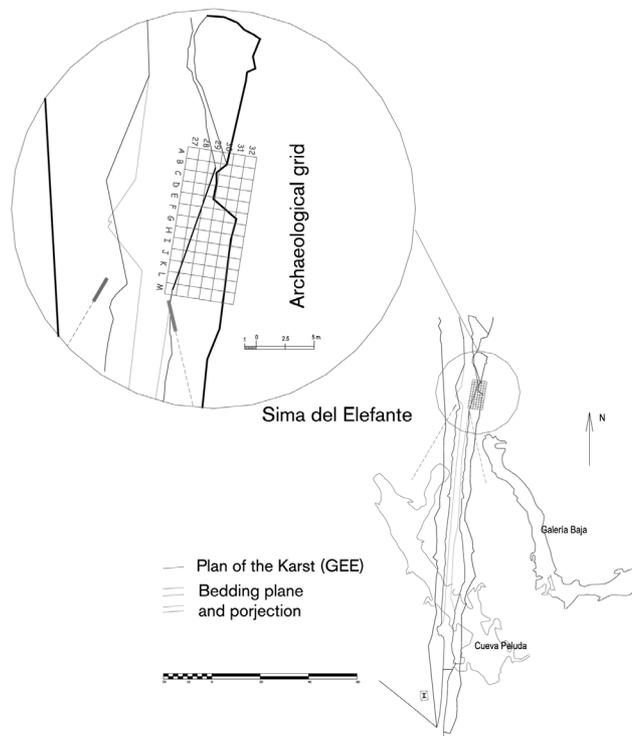


Fig. 5. Plan of the railway trench and the TE site with the archaeological square grid. Superimposed on the surface site plan is of the longitudinal profile of Cueva Peluda (BU-IV-A-5 and Galería Baja galleries at its distal end (speleo-topography after GEE; see Martín-Merino *et alii*, 1981). Dashed lines are calculated planes after measuring the limestone wall at the site, and its respective prolongation on the plan. Note the coincidence between limestone planes and axis of galleries.

branch of the Cueva Mayor karst subsystem. Superposition of surface and cave topography locates the TE site at a short distance of the end of the longitudinal axis of the Galería Baja. Thus, on the grounds of the GEE's field studies, Arsuaga *et alii* (1997) claim that “the Sima del Elefante site belongs to the Cueva Mayor karst subsystem, representing an ancient opening, now completely filled by sediment”.

In order to test this proposal, three limestone planes were measured on the TE site cave walls (Fig. 5). Projection of these planes on the Atapuerca karst map allows to corroborate how the direction of the south wall of the TE site perfectly fit the major axis of the Galería Baja, fully supporting the GEE's hypothesis.

Similarly, Cueva Peluda develops in a parallel direction to the Galería Baja axis, but at the lowest level of the karst system, at a similar deepness as that of Cueva del Silo. Figure 8 shows a profile of the south end railway-trench on which it has been projected the longitudinal sections of the Cueva Peluda karst gallery (BU-IV-A-5; see Martín-Merino, 1981). It is highly likely that a lateral branch of Cueva Peluda cave reach the bottom of the Sima del Elefante site. The aforementioned geologic drills performed at the base of the TE site detect both an empty cavity as well as fluvial terrace sediments also present in Peluda and Silo caves (GEE: Martín-Merino, 1981).

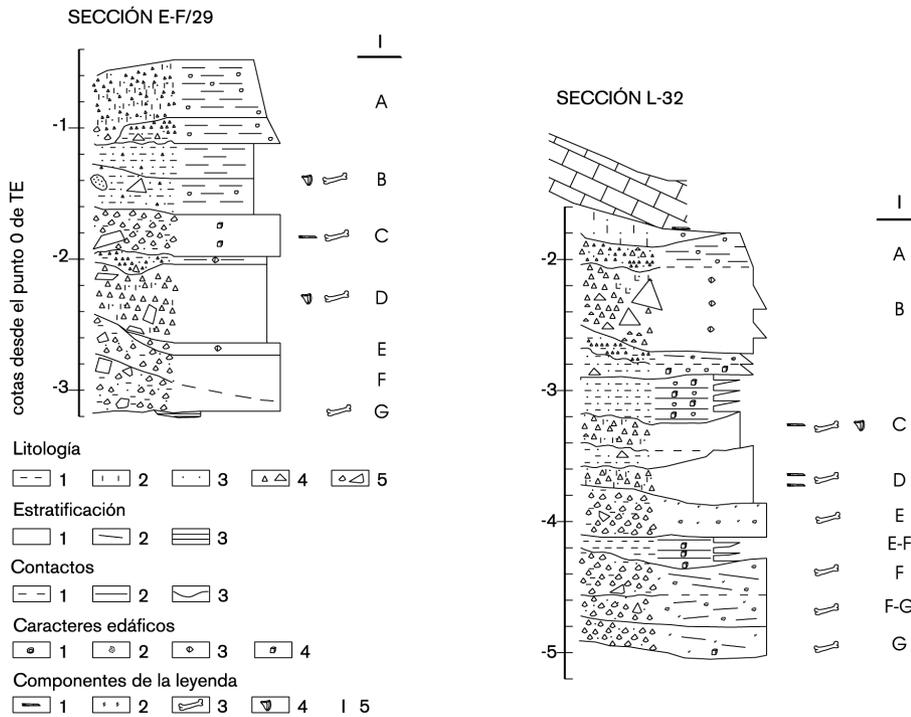


Fig. 6. Stratigraphic columns of the Sima del Elefante TE19 unit.

Leyenda
 Perfiles sintéticos del nivel 19 de Trinchera Elefante. Litología: 1, arcillas; 2, limos; 3, arenas; 4, gravas angulares; 5, gravas subangulares. Estratificación interna: 1, masiva; 2, discontinua; 3, laminar. Contactos: 1, gradual; 2, recto claro; 3, ondulado claro. Caracteres edáficos: 1, nódulos carbonatados; 2, microagregado (grumo); 3, agregado poliédrico; 4, agregado prismático. Componentes de la leyenda: 1, espeleotema; 2, microcarbones; 3, restos óseos; 4, industria lítica; 5, niveles arqueopaleontológicos de la unidad estratigráfica 19.

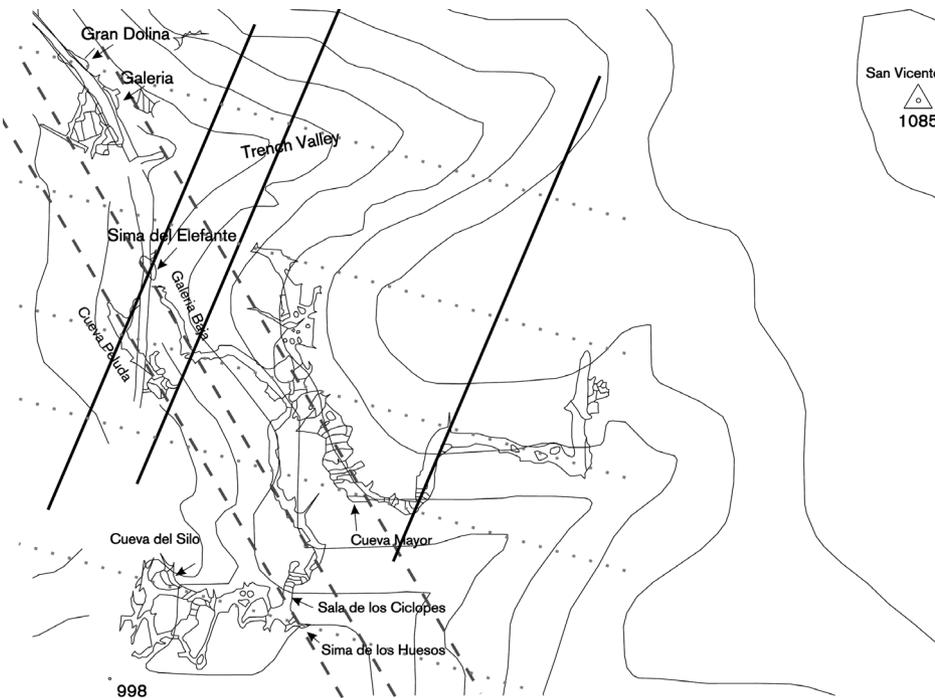


Fig. 7. Plan of the Atapuerca karst system after G.E. Edelweiss (Martin Merino *et alii*, 1981). Superimposed on it, lines defining the planes measured on the Sima del Elefante limestone walls has been drawn. Also, several parallel lines to those planes has been recorded on the plan. Also, an extra set of parallel lines following the axis main galleries has been put on the plan. Structural features of the Sima del Elefante and its development may be initially understood in the context of the major structural features of the Atapuerca cave network. Note, for instance, that cave entrances are located at joint points of major structural planes; the TE site being an example of this pattern.

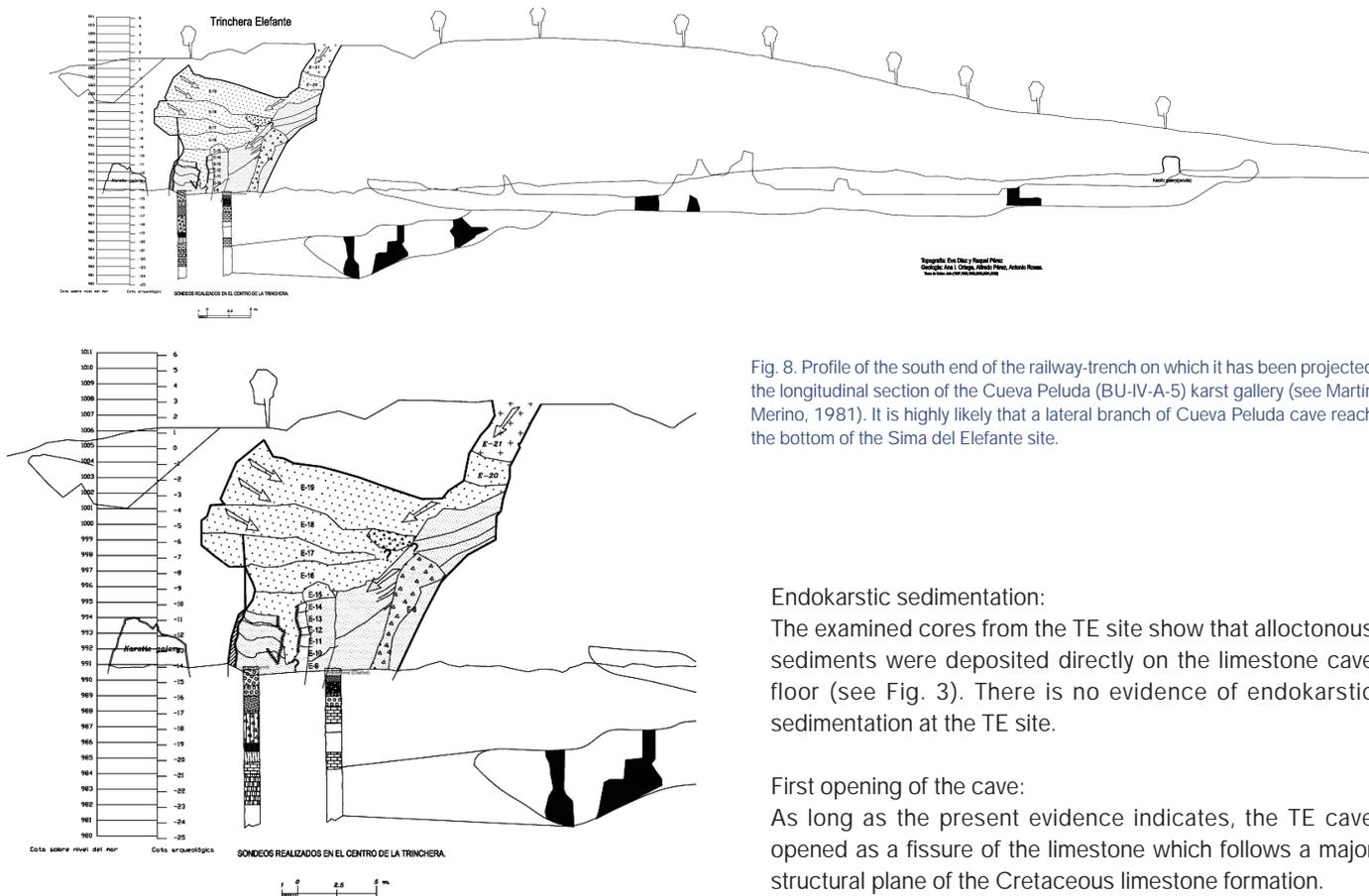


Fig. 8. Profile of the south end of the railway-trench on which it has been projected the longitudinal section of the Cueva Peluda (BU-IV-A-5) karst gallery (see Martín Merino, 1981). It is highly likely that a lateral branch of Cueva Peluda cave reach the bottom of the Sima del Elefante site.

Endokarstic sedimentation:

The examined cores from the TE site show that alloctonous sediments were deposited directly on the limestone cave floor (see Fig. 3). There is no evidence of endokarstic sedimentation at the TE site.

First opening of the cave:

As long as the present evidence indicates, the TE cave was opened as a fissure of the limestone which follows a major structural plane of the Cretaceous limestone formation.

In spite of the highly unpredictable behaviour of dissolution, the composition of the limestone and the tectonic history of the formation prefigure a pattern of probability for the directions of gallery development (Eraso *et alii*, 1998b; Kaufmann, 2003). The question whether the Atapuerca karst developed throughout fractures, extensional planes or bedding partings is important at the time of interpreting the cave entrance and the origin of the allogenic infill. According to Eraso *et alii*, (1998b) four primary directions prefigure the Atapuerca karst. These authors found a strong statistical association between main directions of galleries development and the extensional planes of the Atapuerca Cretaceous outcrop. That is, most caves follow the patterns of joints in the rock. This circumstance permits, to certain degree, to forecast major structural features of the sites, and eventually the possibility of testing some of these predictions. In this direction, White and White (2001), Palmer (2003) and Ford (2003) propose that plan pattern of caves may be understood attending to: a) type of recharge, and b) dominant type of porosity. The Atapuerca karst seems to fit a rectilinear branching network. This circumstance allows to assay a search for structural regularities.

Figure 7 shows the Atapuerca karst system and, superimposed on it, lines defining structural planes along with

Therefore, the 3D configuration of the Sima del Elefante seems to be structurally linked to the evolution of the Cueva Mayor/Cueva del Silo cave system, and its functioning as an old entrance to the Galería Baja.

Tempo-structural evolution of the Sima del Elefante site

The following episodes, from old to young, can be identified. Due to its preliminary character, no sequential nomenclature is here adopted; other stages or further subdivision may be identified in future research.

Phase 0 episodes

Formation of the Sima del Elefante cave:

Timing of Atapuerca karst development has been related to Late Miocene erosion of the Duero Basin, synchronous to the sedimentation of the Aragonian or Middle Vallesian limestones (Zazo *et alii*, 1983). The Atapuerca karst developed in a time when Miocene sediments were level near the top of the limestone relief, and covering most of the present hill. Underground water came to circulate across the rock and developed a karstic aquifer, which began to dissolve the limestone giving rise to the cavities. At the present time there is no available information on the specific age of galleries formation.

galleries and singular spots can be located. In the light of this, a possible approach to the understanding of the Atapuerca karst is by the superimposition of two grids both sharing a common series of parallel planes. These major planes are all of NW direction, nearly parallel to the anticlinal axis.

In order to this representation, the formation of the Sima del Elefante cave seems to have been controlled by a combination of joint and bedding planes. A working hypothesis would establish that the original entrance to TE cave may have been a narrow and elongated fissure opened in the direction of a major extensional plane in the rock. Through this fissure, exokarstic sediments may have entered the cavity mainly by gravity process. No atrium cave or interface space is supposed to exist at the beginning of the TE site formation. This may have important consequences for the potential use of the cavity by organisms as well as for the interpretation of accumulation patterns.

Phase 1 episodes

Early Pleistocene exokarstic sedimentation:

Even though in the light of small mammals homogeneity a relatively short period of time seems to span the infilling of this phase, several sedimentary processes occurred. There is a sedimentary body still without a clear position on the succession (e.g. the so called TE8 unit). Over it, there is a series of steeply layered mud flows grouped under TE9. These are decreasing the slope and above it is a thin layer of silt at the distal end, which accumulates a large number of big rock fragments. A talus cone structure is the most plausible explanation for the TE9 and TE10 units. Possibly, the cave was functioning as a fissure through which sediments roll down.

Erosion of Cretaceous or Miocene (still to be determined) marls is present in the form of mud ball.

In angular unconformity, sediments of a layered bedding appear, indicating that a hydraulic regime becomes installed in the cavity. This bedding is intercalated with mud flows as represented by levels TE12, TE14C and TE14A.

Erosive phase of the Early Pleistocene infill:

As previously stated, the end of the phase 1 of infill is demarcated by an extensive process of erosion affecting the whole gallery. A large scale erosive process has also been identified in the Cueva Mayor system. Thus, Arsuaga *et alii* (1997) wrote "the southern half of the Sala de los Ciclopes was completely filled by sediments that were later largely washed out in an erosive phase of the karst history". Whether these two erosive episodes correspond to the same event is open to question. A late Early Pleistocene age may be advanced as a hypothesis to be tested. Whatever the answer, at least two large-scale phases of infilling may be recognised in the history of the Atapuerca karst system.

On the other side, there is evidence of cave breakdown (fall of rock from roof or wall of a cave) at the end of TE14 unit. Collapse of lower galleries at this time may fit the set of faults observed between TE14 and TE15 units. In summary, a profound transformation of the karst topology seems to have occurred at some time between the late Early Pleistocene and the beginning of the Middle Pleistocene.

Phase 2 episodes

Closure of the nearby entrances to the Sima del Elefante cavity:

This situation is not directly observed in the exposed section of TE, but inferred from the outstanding change in the sedimentary regime appreciated after the TE14 unit. A new source of sediments occurs and there is no trace of gravity flows as observed in the phase I.

Second generation Cave infilling:

A preponderant hydric activation regime is recognised, and sediments are disposed in graded beds in TE15 and TE16 units. Quite possible, water was flooding from inside the karst towards outside the cave. On the other hand, texture, colour and composition of the sediments from this part of the sequence are not found in TD and TG sites. Better, they are more similar to those outcropped in the nearby valley. Hydric activated sediments of a different origin and composition install within the cavity.

TE17 unit presents speleothem formation across the gallery with lacunar and varved sediments. There is also an erosive phase in which speleothem formations are broken away and transported. It is proposed the hypothesis that Sima del Elefante site functioned as a spring cave at its upper levels. That is, a permanent natural flow of water from inside the cave.

Opening of new entrances:

Opening of new entrances are evidenced by the presence of sediments of different nature, and differences in infill directions as compared to previous strata in the sequence. TE19 levels belong to this episode that is dated to Middle Pleistocene.

Third generation Cave infilling:

It is dominated by breccias of a red matrix together with accumulation of large mammals remains. The sequence ends with several layers of "paella" sediments.

Phase 3 episodes

Soil formation:

The soil present petrocalcic paleosol features, what may indicate warm conditions. Local correlations may indicate this kind of soils potentially correspond to an age of isotopic stage 5.

Arqueo-paleontological record of the Sima del Elefante

In general terms, fossil documentation coming from the lower and the upper levels present a different profile. Up to the 2002 field season, TE lower levels have delivered ~3450 bone remains larger than 2 cm, thousands of small vertebrate remains, ~25 flint stone tools, ~50 pieces of charcoal, among other items. The mentioned record has been recovered along 7 years of systematic excavation (~20m³). The TE19 unit has delivered during 2 years of restricted area excavation (~4m³), ~1250 bones, 20 stone tools on quartzite, sandstone and flint, dozens of snail shells, and abundant pieces of charcoal. A synopsis of the arqueo-paleontological record of the TE site is given in Table 1.

Taphonomic profile

The archaeo-paleontological record of caves is usually preserved as discrete fertile layers containing a variable amount of informative items. In some cases, several levels present a similar fossil content whereas, in others, distinct levels preserve a clearly distinct content. Quite often paleoecological analyses are limited by reduced samples size (and/or fragmentary preservation). An essential question is whether samples coming from different levels and/or sites may be pooled in a large combined sample. In other words, do successive fertile layers represent sampling from different "biotas"? Or, on the contrary, do they correspond to different taphonomic biases from the same biota? This problem may be defined as "paleoecological representativity".

The problem was here handled from two different perspectives. The lower units were qualitatively compared while a quantitative approach was essayed in TE sup.

Regarding TE inf., the homogeneity in small mammal species, with slight changes in species abundance, seems to indicate that the lower units were laid down in a "relatively" short time-interval. Other taphonomic features may also reinforce this conclusion. The arqueo-paleontological record of the successive units of the TE lower phase present the following characteristics:

- 1) Occurrence of abundant small mammals remains, as well as lagomorphs and *Corvidae* and *Columbidae* remains. That gives a certain taphonomic homogeneity to the distinct sedimentological beds.
- 2) A certain individualization of the levels when attending to the presence of specific taxa or frequency of them (e.g. turtle, fishing eagle, fragment of antlers, among other, taxa, moles, rabbits).
- 3) Regular presence of fossils in anatomical connection. These are frequent in bird's wings, legs of rabbits and distal legs of large mammals. Additionally, a nearly complete skeleton of a beaver and a fishing eagle were found at TE10.
- 4) Herbivore and carnivore species present a different pattern of representation. It is relatively frequent to find complete skulls of carnivores (Fig. 9), including the lower jaws. Herbivores, by contrast, appear heavily fragmented.

- 5) Large mammal remains rarely appear complete, fragments of bones are the most usual way of appearance.

Richness and diversity of the fossil record varies among the different sublevels of the TE19 unit, with TE19C preserving the most abundant and diverse record.

The following features can be identified in TE19.

- 1) Among the species, there is a significant size biased representation. Small animals are very rarely found, whereas large mammal remains are quite abundant.
- 2) Within the vertebrate community, almost only mammals are preserved, with very few avian remains. Among the mammals, the horse is the best represented species, with the 50% of the total sample. Bears are also well represented.
- 3) There is a differential representation of skeletal elements by species. Most of the species are represented by teeth and distal leg elements (phalanges, carpal and tarsal bones). By contrast, most of the skeletal parts are preserved in the case of the horse.
- 4) Frequency of appearance is quite different between herbivore and carnivore guilds. While herbivore guild is well documented, presence of carnivores is sporadic, evidenced by isolated remains.

Cluster analysis –calculated with Euclidean distances and complete agglomeration– were employed for the analyses. Statistical procedures were performed with Statistica Software (1996). As far the reduced recovered sample allows to say, there is no reason to suppose significant differences in taphonomic sampling or ecological differences acting on the TE19 fossil assemblage formation. Homogeneous environmental conditions seem to have prevailed during the deposition of the TE19 unit.

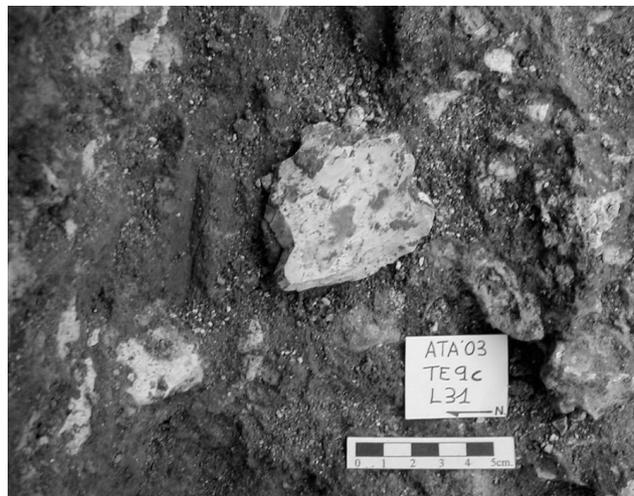
Lower TE is mainly characterised by the presence of cave dwelling animals and their rests of food. In this line, even though taphonomy of small mammals has not been studied yet, owls and other bird-prey pellet dropping is a reasonable explanation for this assemblage; some complete pellets have been also recovered. Besides, birds nesting or living at the cave threshold and limestone walls, such as crows and pigeons, are systematically found in the site. In the case of rabbits, their abundance, state of preservation and bone-traceology indicate a possible double accumulation origin: natural death at dwelling and predation. A wide range of predators on rabbits may be preliminary proposed.

Upper TE may have functioned as a spring-hole, and animals went there, either for water or fresh grass. They died around a "water-hole trap". Bear presence may be easily assign to hibernation or cave bearing activities. The high number of horses is still unexplained. Two gross hypothesis may be considered: 1) horses were the most abundant large mammal species in the original paleoecosystem; 2) humans or any other predator is the selective action responsible of such a number. Also, the absence of birds and small mammal remains unexplained.



Fig. 9. Complete skull of a large mustelid (cf *Pannonictis* sp.) coming from the TE9 unit (Early Pleistocene).

Fig. 10. Flake of Cretaceous flint found in situ at the lower levels of the Sima del Elefante site (Atapuerca) during the 2003 field season.



Evidence of human presence

At present, no human remains have been found at the Sima del Elefante. However, several other evidences testified the presence of humans at different Pleistocene ages in the site (Table 1).

Stone tools

Three different technological complexes are represented at the different levels of the TE site (Table 1). Stone tools of Mode I, II and III have been recovered at TE inf. (TE9-14), TE18, and TE19, respectively. Raw materials include Cretaceous flint, sandstone, and quartzite. Industry from TE inf. is mostly made on flint (Fig. 10), but knapping on calcareous rocks is also possible. Several flakes on micrite limestone have been recovered at these levels. Distinction between natural fractures and anthropic activity is difficult, but a technical and functional analysis is underway.

Zoo-archaeology

Even though carnivore/hominid interaction processes are still under analysis (Huguet, in prep.), it may be advanced that these processes are a plausible agent responsible for part of the fossil assemblage. Attending to traces on bone surfaces and bone fracture patterns, carnivore activities co-occur with human presence. On the one hand, biting marks and fresh fracture occur. On the other, a number of cut marks have been recognised. The specific pattern of interaction still has to be resolved.

The study of the biostratigraphic agents is of large difficulty in TE19. Most of the bone surfaces are lost because they remain attached to the sediment matrix. No information is currently available on this aspect.

Biological assemblages

Table 1 shows the taxa identified along the Sima del Elefante succession. Additionally, Table 2 gives taxa and number of

skeletal elements recovered at the TE19 unit. On the whole, sediments from the TE inf. levels contain a diverse though scarce assemblage of large mammals, but is very rich in small mammals, lagomorphs, and avian remains. By contrast, TE19 provides an abundant fossil record of large herbivores, few carnivores and very scarce small mammals documentation.

Apart from the conspicuous presence of small mammals (see Laplana and Cuenca-Bescós, 2000), birds are the best represented animals in the lower levels. *Corvus antecorax*, and in lesser degree, pigeons (*Columba livia/oenas*) are present in almost every sublevel. The presence of *Haliaeetus albicilla* is a significant finding. Lagomorphs (*Lepus* sp. and *Oryctolagus* sp.) are also quite abundant at the TE inf. levels. Among the large mammals species, the most abundant taxa are the *Cervidae*, and more specifically the fallow deer (genus *Dama*). Other large herbivores cover a wide range of animals including rhinos, hippos, large Bovids, Equids, and omnivores like *Sus* sp. Also, the presence of *Macaca* may be attributed to this latter category. Along with the carnivores, specimens attributed to the genus *Canis* (e.g. *Canis arnensis mosbachensis*) are the carnivores more frequently found at these levels. The small size felid *Lynx* is also reasonably well preserved. In this line, and with the exception of the jaguar-size felid, the absence of large carnivores stands out (large felids and hyenas), usually present at other South European sites of a roughly similar age (Le Vallonnet, Fuente Nueva-3, Barranco León). By contrast, the presence of at least three species of mustelids (small, intermediate, and large) at these levels is notable.

A foremost characteristic of TE inf. is the relative abundance of vertebrate species linked to inland water biotopes e.g. hippopotamus, beaver, fishing eagle, otter-like mustelid (this latter, however, pending of further studies), and others.

Concerning the TE19 unit, very few small mammals and bird remains have been recovered. Among the large mammals, the Equidae (genus *Equus*) is the most represented taxa. Likewise,

TABLE 2. Complete set of identified taxa derived from the TE19 unit (Sima del Elefante site), and distribution of identified anatomical parts. See text for definition of stratigraphy and definition of levels. TE19X designs all records without concrete sublevel attribution (mostly recovered during cleaning sections).

| Taxon/Level | TE19X* | TE19A | TE19B | TE19C | TE19C/D | TE19D | TE19E | TE19E/F | TE19F | TE19G | Total |
|-----------------------|--------|-------|-------|-------|---------|-------|-------|---------|-------|-------|-------|
| Artiodactyla indet. | | 1 | | 2 | | | | | | | 3 |
| Arvicolidae indet. | | | | | | 1 | | | | | 1 |
| Aves | | | 3 | | | | | | | | 3 |
| Bison sp. | | | | 3 | | | | | | 1 | 4 |
| Bobinii indet. | 1 | 1 | | 32 | 1 | 9 | 7 | | | | 51 |
| Bos sp. | | | | 1 | | | | | | | 1 |
| Cervidae indet. | 4 | 1 | 4 | 31 | 1 | 15 | 5 | | 2 | | 63 |
| Cervus elaphus | 2 | 1 | | 1 | | | | | | | 4 |
| Dama sp. | | | | 1 | | 1 | | | | | 2 |
| Equus caballus | 8 | 21 | 4 | 100 | 6 | 15 | 13 | 2 | 3 | | 172 |
| Equus cf. hydruntinus | | | | 7 | | | | | | | 7 |
| Erinaceus sp. | | | 1 | 1 | | 5 | | | | | 7 |
| Gasteropoda indet. | 1 | | | 5 | | | | | | | 6 |
| Lagomorpha indet. | 3 | 1 | 8 | 42 | | 5 | 6 | 1 | 23 | | 89 |
| Lepus sp. | | | | | | | 1 | | | | 1 |
| Megacerini indet. | | | | 4 | | | | | | | 4 |
| Panthera sp. | 1 | | | | | | | | | | 1 |
| Rana sp. | | | | 1 | | | | | | | 1 |
| Rodentia indet. | | | 1 | | | | | | | | 1 |
| Stephanorhinus sp. | 1 | | | 21 | | | | | | | 22 |
| Ursus deningeri | 1 | | | 12 | | 17 | 1 | | | | 31 |
| Vulpes sp. | | | | 1 | | | | | | | 1 |
| Suidae indet. | | | | 2 | | | | | | | 2 |
| Proboscidea indet. | | | | 1 | | | | | | | 1 |
| Crocota crocuta | | | | 1 | | | | | | | 1 |
| Canidae indet. | | | | | | 1 | | | | | 1 |
| Total identified | 22 | 26 | 21 | 269 | 8 | 70 | 33 | 3 | 28 | 1 | 481 |
| Total recovered | 46 | 73 | 39 | 668 | 39 | 157 | 163 | 15 | 37 | 14 | 1251 |
| % identified | 48% | 36% | 54% | 40% | 21% | 45% | 20% | 20% | 76% | 7% | 38.45 |

the diversity of bovinii seems to be higher than at lower levels. The presence of these species together with elephant, rhinos, and deer testified a high large herbivore diversity. By contrast, *Ursus sp.* is the most frequently found carnivore species, combined with sporadic finding of felids, hyenas and canid specimens.

Snail shells are uncommon in the Atapuerca cave sites. As an exception, gasteropods are occasionally found at TE19, most of the cases concentrated in particular areas of the site.

Charcoal evidence

Small bits of charcoal appear at several levels in the succession (table 1). Charcoal recovery was made manually, as any other archaeological record. However, a flotation procedure was attempted in the 2003 field season with good results for the fine fraction (sieve 0.5 mm). Fig. 11 shows the distribution of identified charcoal in the richest units. Either the small size and bad preservation permit the identification of a few number of species. Among the tree species *Acer sp.* and deciduous *Quercus sp.* de are present in TE9, which may indicate a certain degree of environmental humidity. By contrast, *Pinus silvestris/nigra* is the most abundant taxon in TE19 from which cold climatic conditions may be inferred at this unit.

With regards to the origin of charcoal at the site two different possible explanations are given. Natural fires are fairly common in Pleistocene sites (Scarascia-Mugnozza *et alii*, 2000), and

this is accepted as the most reasonable explanation for the charcoal remains found at the TE lower phase. A regular presence of charcoal in the TE inf. units, if evidence of natural fires, may suggest a dry season or periods of drought during the time of TE inf. accumulation.

Level TE19G contains abundant pieces of charcoal disposed in a well defined archaeological horizon in close association to possibly burned bones. An anthropic origin of this evidences is a feasible hypothesis, but human use of fire cannot be confirmed at the moment. The charcoal has been identified as belonging to the *Pinus silvestris/P. nigra* group species.

Paleoecology settings

Mammals community structure

Previous studies on mammals paleoecology at Atapuerca sites reached a surprising conclusion: the large-scale stability in mammals community structure along the Pleistocene (van der Made, 2001; Rodríguez, in press). According to this interpretation of fossil samples, climatic changes do not produce noteworthy alteration of the ecological structure (at least in mammals). This conclusion clearly contrast with the alternation of cold/warm faunas in Northern Europe. In this theoretical framework, an initial study of the location of TE samples in the taxon-free eco-space defined by Rodríguez (1997, 2001) has been attempted. Community structure is

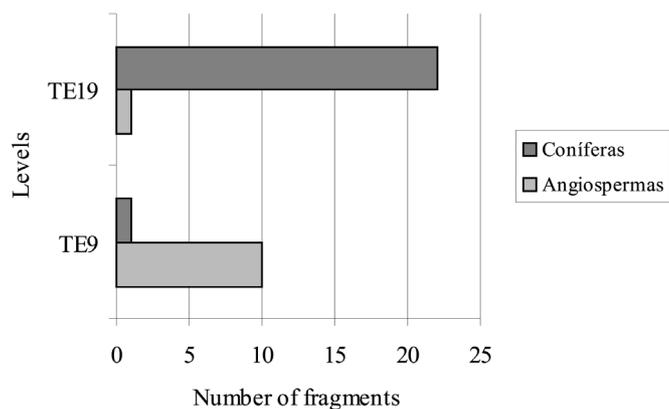


Fig. 11. Charcoal evidence from the Sima del Elefante (Atapuerca): unit TE9 (Early Pleistocene) and unit TE19 (late Middle Pleistocene). Ratio of coniferous/angiosperm remains (identified pieces).

defined by means of three ecological variables: size, locomotion, and diet of the species (Andrews, 1996). Once is characterised in this way, community structure may be compared without species specific reference. Further detail on the methodology can be found in Rodríguez (2001). Principal Component Analyses (PCA), and cluster analysis were employed for the analyses. Statistical procedures were performed with Statistica Software (1996).

TE19 fossil assemblage has been quantitatively compared with five living communities and three fossil Pleistocene assemblages from Atapuerca (Gran Dolina TD10, and Galería GII and GIII). Results from the Principal Component Analyses (PCA) are graphically summarised in figure 12. TE19 mammal assemblage is closely grouped together with other Atapuerca samples, and far from living communities. This conclusion perfectly fits the previous results achieved with the Atapuerca samples (Rodríguez, 2001).

Because of several reasons, no such a sort of analyses has been applied to TE inf. However, in spite of the apparent differences, a first comparison between large and intermediate size mammal assemblage of TE inf. and TE19 seems to indicate a broad coincidence in the represented genera. A gap of nearly a million years certainly allows changes at the species level, but the kind of animal and their respective size are equivalent. It is pending, nonetheless, to establish whether species level changes may correspond to local evolution or immigration. The major differences between TE inf. and TE19 refer to, on the one hand, the representation of carnivore species and, on the other, to the biotope specific influence on the fossil assemblages. So, mustelidae are well represented in TE inf., and they are absent in TE19; a deficit in the representation of this family has been already noted in other cave sites from Atapuerca (Rodríguez, 1997). In addition, the otter-like species present at TE inf. support a specific biotope influence. Hyena remains are rare in

the Atapuerca sites, and it is represented in TE19 just for a mandible (Table 2). The presence of a number of immature carnivores may indicate a particular use of the cavity by carnivores (e.g. hibernation, den, refuge), and, therefore, a different pattern of preservation probability. In line with the results before exposed, topological conditions of the cave at that time may give support for such an interpretation.

Inland water biotope influence on TE inf. levels is evidenced by several signals. The presence of beavers, hippos, and the mentioned large mustelids, among the mammals, may explain some of the major differences found between TE inf. and TE19. No structural ecological change might be invoked for such a difference. Nevertheless, the biostratigraphic distribution of the genus *Hippopotamus* and its paleoecological implications should be considered. Consequently, the null hypothesis of a large-scale stability in the mammals community structure is provisionally hold, but this important topic needs further comprehensive studies. Furthermore, frequency and relative abundance of species or any other higher taxa are potentially useful ecological indicators.

Climatic and environment reconstruction

The fact that ecological structure was maintained stable during the Pleistocene climate changes is a challenger hypothesis.

Several indicators point to clear differences in the environmental conditions prevailing at the time of TE inf. and TE19 sedimentation, respectively. Also, soil formation recorded at TE21 grants certain climatic information. Different signals seem to indicate that both humidity and temperature have varied along the succession.

Humid environmental conditions are detected in TE inf. by the relative abundance of vertebrate species linked to inland water biotopes e.g. hippo, fishing eagle, beaver. This strongly suggests the existence of permanent and extensive water layers at a short distance from the site (the hippos need permanent water with a minimum depth of 1.5 m). Evidence from small mammals, specifically from the insectivore assemblage, also support wetter condition (Cuenca and , in prep.). Arboreal species such as *Acer sp.*, and deciduous *Quercus sp.* reinforce this proposal. Also, Sánchez-Marco (1999) stated that more open country and wetter conditions prevailed during the early Pleistocene than previously inferred.

Temperature indicators come mostly from field observation of sedimentary matrices, which indicates a warm environment. Besides, the existence of possible systemic natural fires also point to such a set of physical environmental conditions. This pattern coincides with those found in other sites of similar age; Sierra de Quibas (Murcia) dated between 1.3 and 1.0 (Montoya *et alii*, 2001), and Fuente Nueva-3 and Barranco León (Granada) Casablanca 3 also indicate warm, and also, wetter conditions as compared with the present time. Therefore, the interval between 1.3 and 1.0 myr ago was a warm and humid period. According to this, TE inf. would correspond to a period prevailing wetter and

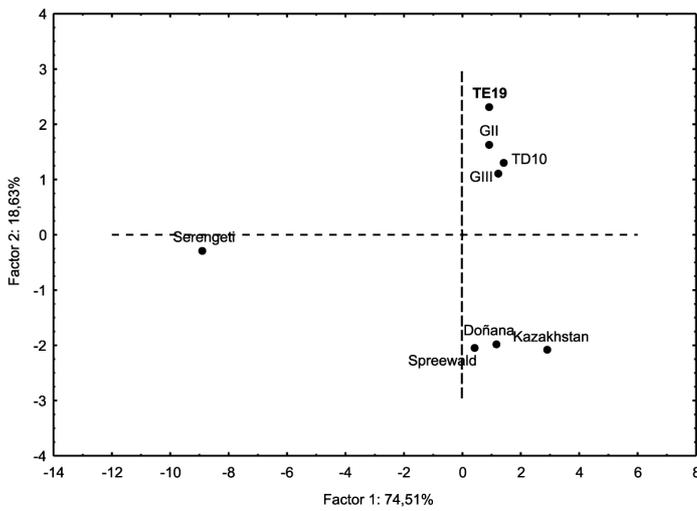


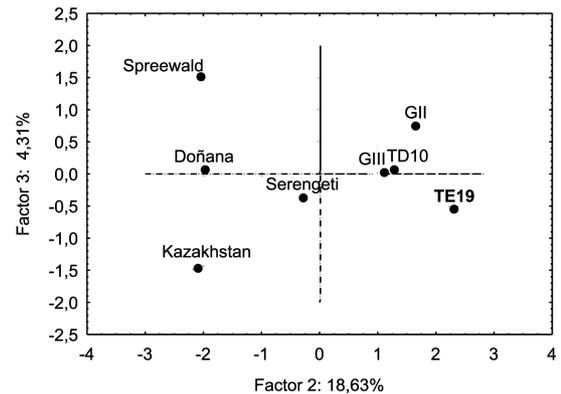
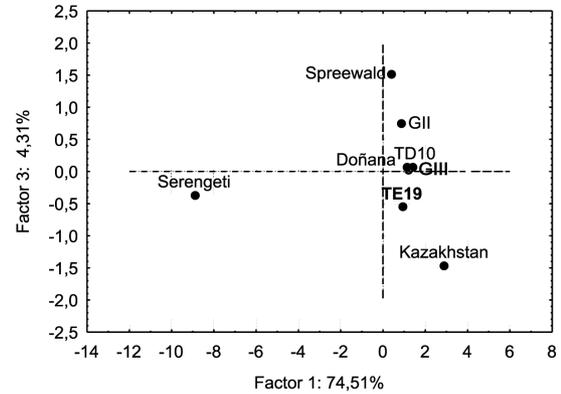
Fig. 12. Comparison by means of PCA of the mammal assemblage from the Sima del Elefante (TE19 unit) with other Atapuerca sites and living communities. Note the strong similarity of TE19 with other Pleistocene fossil samples from Atapuerca.

warmer conditions than present, before the cooling recorded at the Jaramillo sub chron, as evidenced in Untermassfeld, and Le Vallonnet, both date to around 1.0 myr, and corresponding to OIS 30 (de Lumley *et alii*, 1988).

A distinct situation is found in TE18 and TE19. Both units seem to indicate cold conditions. TE18 presents stratified slope deposits (scree) which may be associated with glacial conditions. On the other side, TE19 unit displays conditions of elevated carbonate precipitation. Besides, the appearance at these levels of *Pinus silvestris/nigra* is also an indicator of colder conditions. Also, the relative frequency of *Equidae* vs *Cervidae* is also a potential indicator for environmental conditions. Among the large mammals the more represented species at the lower units is *Dama dama vallonnetensis*. Conversely, the genus *Equus* is poorly represented. By contrast, the upper phase present a high representation of *Equus caballus*. A preponderance of horses may indicate more open landscapes, and hence dry/cold climate conditions. An example of this situation was also detected in Atapuerca-Galería site, in the transition from GII to GIII units (Rosas *et alii*, 1999).

Discussion and conclusions. Future research Chronology

A program of chronometric analyses is still pending on the Sima del Elefante site. Unfortunately, essays on U-series already have failed to provide valid datings (Bishoff, pers.



comun.). Chronological information available comes from preliminary sampling in paleomagnetism, and biostratigraphy are currently the most convincing evidence.

From a chronological viewpoint, the small rodents association is characteristic from the later part of the Early Pleistocene, and age close to that of the French site Les Vallerots (~1.1. myr) was proposed by Lapana & Cuenca-Bescós (2000; in Rosas *et alii*, 2001). However, López-Martínez (pers. comun.) found a larger similarity of the lagomphs with the Italian site of Monte Peglia (Maul *et alii*, 1998), dated to 1.3-1.1 myr. New data on small mammals biostratigraphy are currently under study (Cuenca-Bescós *et alii*, i.p.).

Large mammals, on the other side, provide the following information. The remains of the ungulates from the lower part of the TE section tend to be scarce and fragmented, which limits their value for biostratigraphy.

Some bovine remains are larger than their homologues in *Leptobos*, but are in the ranges for *Bison*. *Leptobos* was the only west European Bovine at the beginning of the Pleistocene, but was replaced by two lineages of *Bison* at the end of the Early Pleistocene: the *Bison deguiullii* - *B. s. lagenocornis* - *B. s. schoetensacki* lineage (first in Pirro Nord, about 1.2 Ma) and the *B. menneri* - *B. voigtstedtensis* group or lineage (first in Untermassfeld, about 1.07-0.99 Ma) (Masini, 1989; Sher, 1997; Van der Made, 1999, 2001). The material from the lower part of TE seems to belong to *Bison*, and though it is too poor to be assigned to species, seems to suggest an age younger than 1.2 Ma.

Some remains belong to *Dama*. *Dama*-like deer arrived in western Europe during the latest Pliocene. Recent studies suggest that those deer should be placed in a single genus (Pfeiffer, 1999) and can be seen as a single lineage with gradual changes in morphology and size (Van der Made, 1998, 1999, 2001). From about 1.4 Ma the size increased till about 0.4 Ma ago, after which size decreased. A P_2 from TE14 is interesting in that it is larger than those of *Dama nestii vallonnetensis* from Untermassfeld and Vallonnet, while another specimen from TE10 is in the upper ranges of those samples. These samples are very large and date from the Jaramillo. This would suggest that TE10-14 is younger than the Jaramillo event. The other ungulates are even less indicative.

The carnivores are represented by much better material and offer a more accurate information. Interesting is a large mustelid, which seems to represent the genus *Pannonictis*. The latest presence of *Pannonictis nestii* correspond to the Italian site of Pietrafitta from the Late Villafranchian (Rook, 1995), with an age around 1.3-1.4 myr (Ambrosetti *et alii*, 1989). Likewise, cf. *Baranogale antiqua*, *Mustela* cf. *palerminae/praeivalis*, *Vulpes* cf. *alopeoides* and cf. *Lynx issodorensis* are typical from the Middle-Late Villafranchian (MNQ16 a,b, 17, 18). Therefore, in a preliminary study of the carnivorous association from the TE inferior levels (TE9-TE14), a minimum age of 1.3-1.4 myr can be proposed.

In sort, the large mammals suggests an Early Pleistocene age for TE9-14. Palaeomagnetism with its normal polarity indicates that the lower part of the TE sequence is Matuyama, and within that chron either above or below the Jaramillo. However, the herbivorous fauna is not conclusive in whether these units are just below, or above the Jaramillo, but suggests that, in any case, they are close to the Jaramillo. In a sharp contrast, carnivorous seem solidly indicate an older age for TE inf., well into the Early Pleistocene.

Upper units of the TE site are much younger, and, as far as local correlation and large mammal assemblage indicate, date to late Middle Pleistocene. In addition, there is a speleogenesis phase formation at TE17, which may be tentatively correlated with those found at TD8 unit (Gran Dolina site), and GIA unit (Galería site). In both cases, dating of this layers gives an age of ~0.4 myr, corresponding to a warm stage. Such a correlation would establish a post-Cromer date for the TE upper levels, with a tentative assignation to the Saalian period (9/8/7 OSI curves). In addition, TE18 and TE19 units record cold conditions, what fits the proposed hypothesis.

From the large mammals information the following can be said. Many of the specimens of TE19 that were studied are not very indicative (carpals, sesamoids etc.), and are often broken or not yet prepared. This limits the reliability of the results. The more indicative taxa are briefly discussed here. Correlations to the oxygen isotope stages (OIS) as by Van der Made (2001) and Van der Made *et alii* (i.p.).

There is a small *Cervus elaphus*. *Cervus elaphus* is present in western Europe since some 0.9-0.8 Ma or the end of the Early Pleistocene and various chronosubspecies can be recognised on the basis of morphology and size (Van der Made, 2001; Van der Made *et alii*, i.p.). Small subspecies are *Cervus elaphus priscus* (first in Mauer, OIS13, 500 ka and last in Grotte des Cèdres, OIS 8, 250 ka) and the form of OIS 3-4 and the recent red deer *Cervus elaphus elaphus* (OIS1). The small sized material from TE19 seems to belong to one of these taxa, and to one of these periods.

There is some material of *Dama* that is large compared to recent *Dama dama dama* from Spain, well within the ranges for *Dama dama geisalana* from Neumark Nord, and in the lower range of *Dama* from Atapuerca TG (Van der Made, 1999). The *Dama*-like deer were common in Europe from the latest Pliocene onwards. Recent studies assign them all to a single genus *Dama* (Pfeiffer, 1999) and the west European samples can be arranged according to age and morphology from old with simple antlers to recent with more complex palmate antlers, showing size increase during most of the Pleistocene till some 400 ka (Bilzingsleben and Petralona), after which size decreased (Van der Made, 1999, 2001). The remains from TE19 would fit any subspecies of *Dama* that lived in western Europe between some 300 ka and the Late Pleistocene.

Some large cervid remains might either belong to a not very large form of *Megaloceros giganteus* or to *Megaloceros solilhacus*. The smaller and earlier *M. g. antecedens* is known from about OIS9-7, its direct ancestor is still older and *M. solilhacus* still occurs in OIS 10-11 (Van der Made, 2001, in press; Van der Made *et alii*, i.p.).

The remains attributable to *Stephanorhinus hemitoechus* are not particularly large, nor robust. *Stephanorhinus hemitoechus* appeared in western Europe in OIS12, initially it had slender limb bones (as in Bilzingsleben, OIS 11), but later (as in Neumark Nord, OIS7) it had more robust metapodials (Van der Made, 1999).

At the first sight, the large mammals suggest a correlation of TE19 to OIS 8-9. This suggests that TE19 is younger than TG10-11 and TD10-11. But it should be stressed that this is based on the study of too few specimens to be very reliable.

Taphonomy and Paleocological inferences

A number of reasons reveal the particular interest of the cave infills in Quaternary Sciences. Their relative abundance and richness in the fossil record make of karst sites a major source of vertebrates remains (Simms, 1994). Archaeo-paleontological record is frequently found in cave sediments because probability of preservation is increased under cavern physical conditions (as compared with other sedimentary environments, e.g. lacustrine, fluvial, deltaic, etc). Both biotic and abiotic agents favour the accumulation of animal remains, and signatures of human activities at cave sites (Brain, 1993; Andrews, 1990; Behrensmeier, 1991; Simms, 1994). In our

case, a broad range of factors influence the accumulation of vertebrates remains in the Sima del Elefante.

The study of cave sites, nevertheless, is frequently plagued with uncertainties. Unclear assessment of the fao-stratigraphic relationships of fossils as well as dating deficiencies are common problems found in cave site research. These nuisances are but consequences of the fact that cave systems develop through a wide variety of chemical, physical and biological processes, shaping the "site formation" as a complex multifaceted phenomenon (Goldberg *et alii*, 2001). Consequently, to unravel the sequence of geological episodes, the chrono-stratigraphic correspondence of such events, and the delimitation of its co-temporalities with biotic processes becomes an exercise of special significance.

Fossil assemblages generally constitute a diachronic sampling of populations. As we have already mentioned, both TE inf. and TE19 seem to have been formed in a relatively short period of time. Nevertheless, no direct estimation has been performed to account for time-averaging at this site. This is an important aspect if we are to define the hierarchical influence of the physical and ecological factors shaping fossil assemblages. In this direction, no measure of the fidelity of the fossil assemblage with respect to the original community has been essayed yet. In this line, previous studies dealing with paleoecological aspects of Atapuerca Pleistocene sites have been approached from a taxon-free perspective (Rodríguez, 2001) or biotopes profile (Sánchez Marco, 1999). Potential taphonomic biases in vertebrate ecological representability have been mostly overlooked. Is that the reason of the apparent large-scale mammal community structure stability? As an example, there is no sabre-tooth or hyenas species represented in TE inf., while they are common in another faunal assemblages of similar age (Sierra de Quibas, Le Vallonet, Fuente Nueva-3, Barranco León). Possible straightforward explanations of such a circumstance would range from the particular physical conditions of the cavity, the taphonomic effects of biotopes on the fossil assemblage, etc. In this latter case, how to distinguish the possible taphonomic influence of the different biotopes? In this network of questions, the factual problem is: How to evaluate whether absences in the fossil assemblage are due to taphonomic biases or because they were really absent in the original paleoecosystem.

Conscious of the matter difficulty, however, a possible way to solve this kind of problems is through the inference of environmental conditions by means of the direct study of the biases in the representation. For instance, what kind of taphonomic biases are produced under Mediterranean climate conditions? The influence of summer drought on the record profile has not been evaluated yet. Signals of such a possible effect might be looked for in future research. This may be considered a positive view towards the taphonomic constraints. In other words, absence of information is potentially information. In order to decode

such information an ecological model should organise the analyses.

Climatic conditions are a major factor determining the structure of vegetal communities. However, two radically distinct concepts are being considered in synecology. One of them, just mentioned, admits that vertebrate communities developed in a structured mode (Valverde, 1984). The other consider the community as a simple assemblage of species, without strong links among them (see McIntosh, 1995 for a review).

Preliminary conclusions assert that community structure was stable, but, simultaneously, environmental conditions were changing. Four levels of exploration may be considered. Firstly, the composition and the evolutionary changes of the bioma as a whole (in the current case approached through the mammal community structure). And more specifically the Mediterranean bioma structure and its potential evolution (changes in primary productivity and effects on non-linear feed-back mechanisms) (Rosas, 1999). The second point regards the variables defining the specific climate regime in a region, considered in a broad sense as may be temperate climate vs tropical climate. The third level of analysis to be considered concern the influence of the variants within a particular climate regime e.g. the bioclimatic spectrum from termo-mediterranean to crio-mediterranean variation, which, in turn, produce conspicuous variation in the landscape. The fourth level of analysis is the local influence of biotopes, fairly dependent on local water supply, soil composition, winds regime and insolation, etc. Finally, we may add the specific use and functioning of the site by human and animals, also essential at the time of understanding the composition of the fossil assemblage.

The statement of warm/cool/cold conditions, or wet/dry conditions derived from a particular fossil assemblage seems to be not enough in a rigorous and ambitious approach to Pleistocene paleoecology. We might try to consider and decode the potential effects of the above mentioned levels of interface. Local, regional and global effects produce particular consequences on the taphosystem in the broadest sense of the word. As an example, TE inf shows a faunal composition proper of a Palearctic bioma, and its stability along the sequence (and other Atapuerca sites) may be indicative of more stable conditions as compared to the cold/warm faunas fluctuations of Northern Europe. However, internal regulation of the system and regional and/or altitudinal influences on the site are not well distinguished from global climate fluctuations. Even though a global climate effect seem to be recorded at the site due to the coincidence of climate inferences with other chronologically close sites, a direct biotope influence of a riverine/palustric environment is the most outstanding signal emerging from these levels. Would we be able to enlarge our competence for a broader understanding of the past ecosystem and the particular role of humans?

Human presence

The Sima del Elefante is providing essential information on human presence at the Sierra de Atapuerca. TE inf. units are providing information of early colonization of Europe, and a warm period seem to have been the background for those early occupations. Besides, TE site upper levels match the time when classic Neandertals were living. At present, no human remains have been found at the Sima del Elefante.

Human remains recovered at European late Early Pleistocene sites are currently ascribed to *Homo antecessor* (Bermúdez de Castro *et alii*, 1996), represented by Atapuerca-TD6 sample, dated to 0.8 myr (Carbonell *et alii*, 1995), and Ceprano (Italy) calotte, dated to 0.9 myr (Manzi *et alii*, 2001). These two samples, in principle, illustrate the anatomy of the first incomers. As long as the available evidence can be considered, the first human species arriving to the west end of the Palaeolithic realm was *Homo antecessor*. According to the proposed scenario, *H. antecessor* were the inhabitants of Europe during the Early Pleistocene, and time of speciation of this species was predicted to have happened in Africa at ~1 myr B.P. But, if hominid come to Europe at 1.3 myr ago, who were they? Were they *H. antecessor*? To hold the model the speciation time should be sent back at least 0.3 million years. There is another possibility, however. A different wave of incomers of a different species (*H. erectus*?) were inhabiting Europe before *H. antecessor* came into place. Future findings from this period, being TE site a potential candidate, will or will not support this statement.

European hominids after ~0.5 myr are generally named *Homo heidelbergensis*; a species which evolved into the classic Neandertals (see Rosas, 2001). As mentioned, TE site upper levels match the time when classic Neandertals were living. In principle, eventual findings of human remains will correspond to *H. neanderthalensis*; a species still not found in any of the Atapuerca sites. The potential finding of human remains at these levels will enrich the sequence of human evolution in a single region, and eventually will greatly help to solve some of the biological questions set down on the evolutionary processes acting on the European hominid lineages. As an example, the pattern of features evolution (e.g. mosaic or integrated) could be eventually approached (Rosas, 2001). With luck, we might ask and answer these and other questions in a near future.

Acknowledgements

We would like to thank Enrique Baquedano his invitation to contribute to the present volume; thanks are also given to Susana Rubio. We are in debt with all the people from the Atapuerca Research Project, who, in one way or another, have contributed to the field work and the study of the Sima del Elefante site. We are grateful Manuel Salesa for his valuable help with anatomical identification. Special thanks are given to "Jimmy" for his continuous assistance. In the field. This research has been funded by the MCYT Project B052003-08938-C03-02, and the CSIC Unidades Asociadas program. Field work was funded by the government of Junta de Castilla y León. Thanks are also given to the Fundación Atapuerca for his financial support to several authors of this contribution.

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