

Ana Isabel Ortega, Alfonso Benito-Calvo, Alfredo Pérez-González,
Eudald Carbonell, José María Bermúdez de Castro, and Juan Luis Arsuaga

Abstract

The Sierra de Atapuerca caves are located in the southern flank of an anticline formed by Upper Cretaceous limestones and dolomites. These caves are mainly sub-horizontal passages or water table caves recording palaeodrainage from south to north, roughly parallel to the anticline axis. In the south, groundwater recharge is mainly associated with fractures at the contact between Mesozoic carbonates and the overlying Miocene marls, while the discharge area is located to the north, in the headwaters of the Pico River. The passages are arranged in three main levels interconnected by shafts and chambers. These cave levels are perched around +90, +70 and +60 m above the Arlanzón River, coinciding with the relative heights of fluvial terraces. Episodic fluvial downcutting led to the formation of successively lower karst levels and the entrenchment of the upper conduits under vadose conditions. Accessible dry caves were used by fauna and hominids, preserving an exceptional archaeo-palaeontological record spanning from ~1.2 Myr until the end of the Middle Pleistocene. The sites of Elefante, Gran Dolina, Galería and Sima de los Huesos have provided exceptional findings for understanding the first steps of human evolution in Europe. These sites relate to the occupation of the ancient cave entrances and areas inside the cave.

A. I. Ortega (✉) · A. Benito-Calvo · A. Pérez-González ·
J. M. Bermúdez de Castro
Centro Nacional de Investigación sobre la Evolución Humana
(CENIEH), Burgos, Spain
e-mail: anaisabel.ortega60@gmail.com

A. Benito-Calvo
e-mail: alfonso.benito@cenieh.es

A. Pérez-González
e-mail: alfredo.perez@cenieh.es

J. M. Bermúdez de Castro
e-mail: josemaria.bermudezdecastro@cenieh.es

A. I. Ortega
Grupo Espeleológico Edelweiss (GEE), Burgos, Spain

E. Carbonell
Institut Català de Palaeoecologia Humana i Evolució Social,
Tarragona, Spain
e-mail: eudald.carbonell@urv.cat

J. L. Arsuaga
Centro UCM-Carlos III de Evolución y Comportamiento
Humanos, Madrid, Spain
e-mail: jlarsuaga@isciii.es

Keywords

Karst • Multilevel caves • Fluvial incision • Archaeological site • Pleistocene

8.1 Introduction

The Sierra de Atapuerca, which constitutes the northernmost range of the Iberian Chain, is an inlier of Mesozoic formations located in the north-eastern sector of the Duero Basin, 15-km east of the city of Burgos (North Spain). This range covers 12 km² and reaches a maximum elevation of 1,085 m a.s.l. (San Vicente Hill). It contains a multilevel cave system, whose evolution has made possible the preservation of many prehistoric and palaeontological remains. The Pleistocene sites have been excavated systematically since 1978, when Emiliano Aguirre set in motion the Atapuerca Project (Aguirre 2007). Elefante, Gran Dolina, Galería and Sima de los Huesos sites provide crucial clues on the human history of Eurasia from ~1.2 Myr until the end of the Middle Pleistocene. The site was listed as Spanish Cultural Heritage in 1991 and an UNESCO World Heritage Site in 2000.

8.2 Geological and Geomorphological Framework

The Sierra de Atapuerca is located in the north-east sector of the Cenozoic Duero Basin, which is bounded to the north and south-east by the western Pyrenees (Cantabrian Mountains) and the Iberian Chain, respectively, while to the north-east it connects with the Ebro Cenozoic Basin through the Bureba Corridor (Fig. 8.1a). In this area, the Sierra de Atapuerca constitutes positive relief underlain by a NW–SE anticline composed of Mesozoic rocks, mainly Upper Cretaceous limestones and dolostones.

The long-term landscape evolution in this region is dominated by the development of planation surfaces related to erosion–sedimentation/uplift cycles during the Neogene (Benito-Calvo and Pérez-González 2007) and the predominance of the fluvial incision of the current valleys during the Quaternary (Benito-Calvo et al. 2008). In the Sierra de Atapuerca, four planation surfaces were recognised forming a high plateau in the summit of the Sierra (1,080 m). The youngest planation surface develops widely in Upper Miocene sediments of the Duero Basin near the Sierra de Atapuerca, forming the Lower Páramo Plateau. This surface is incised by fluvial valleys (Fig. 8.1b), whose main course, the Arlanzón valley, contains the most complete fluvial record, consisting of 14 fluvial terraces developed from +92 to 97 m above the active channel.

8.3 The Atapuerca Cave System

The caves in the Sierra de Atapuerca have mainly developed in a 40–70-m-thick sequence of Upper Cretaceous limestones and dolomites, next to the contact with Neogene sediments of the Duero Basin. The known caves are located in San Vicente Hill (1,085 m a.s.l.), forming a sequence of sub-horizontal inactive passages perched above the modern course of the Arlanzón River (Ortega et al. 2013). The cave system has 4.7 km of explored passages, including the Cueva Mayor-Cueva del Silo system and the Elefante, Dolina and Galería cave entrances, completely filled by sediments (Figs. 8.2, 8.3). These entrances and their detrital fill were discovered at the beginning of the twentieth century, when a deep trench was excavated in the limestones on the SW flank of the Sierra de Atapuerca for the construction of a railway.

8.3.1 Upper Level

The 1,000-m-long upper level is the largest one (Figs. 8.2, 8.3a) and has an average cross section 10 m wide and 15 m high. This passage in Cueva Mayor exhibits subcircular-shaped roofs at 1,015–1,020 m a.s.l., while some dissolution chimneys can reach 1,025–1,030 m a.s.l. Vadose entrenchment has produced keyhole cross sections, whose base reaches the intermediate level at the end of the conduit.

The Salón del Coro displays evidence of major breakdown processes in the walls and the roofs. This chamber is the largest volume in the system (about 53,000 m³) and is related to the collapse of the current entrance of Cueva Mayor. The enlargement of this chamber also affects the intermediate and lower levels. Speleothems reach large sizes and a strongly eroded flowstone formed at 1,014–1,010 m a.s.l. marks the position of the former floor in this passage before vadose entrenchment (Fig. 8.4a).

8.3.2 Intermediate Level

The intermediate level consists of a sub-horizontal passage situated at 1,000–1,005 m a.s.l. In Cueva Mayor, this level is 700 m long, 6–10 m wide and 2–4 m high, and is shifted towards the west (Figs. 8.2, 8.3). This passage begins in the south associated with a fracture-controlled conduit at the

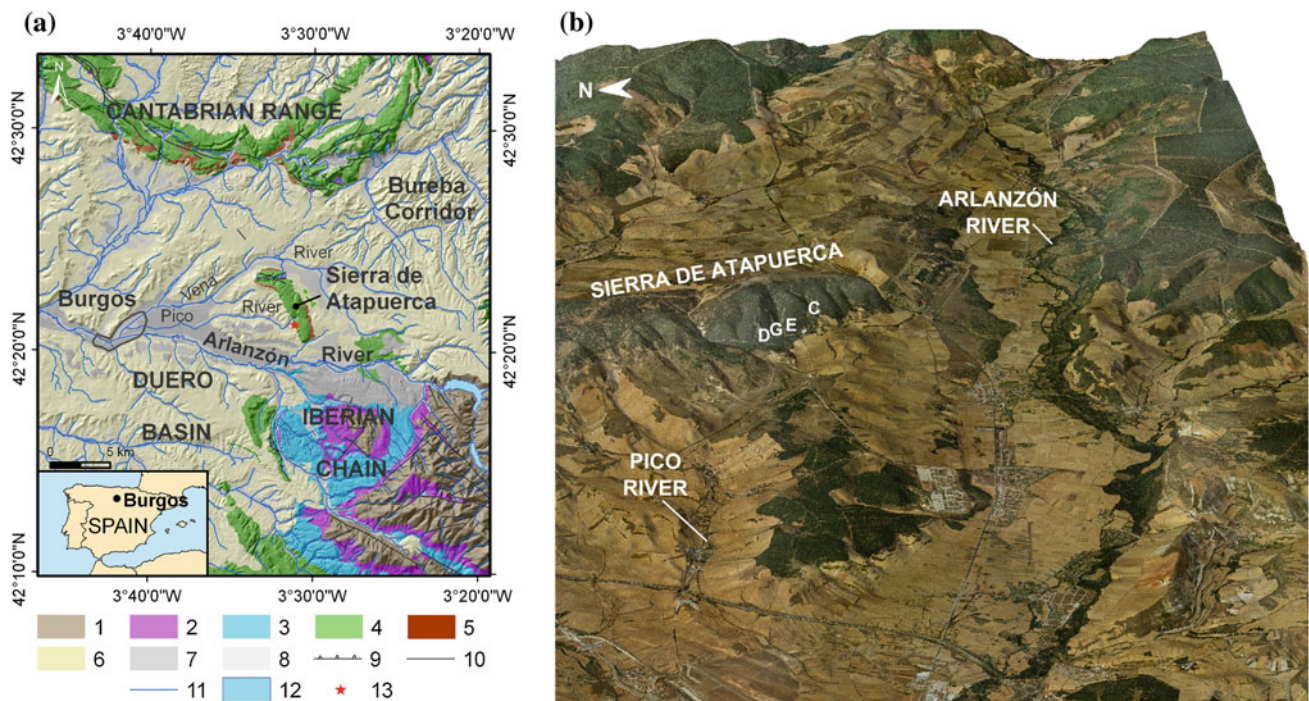


Fig. 8.1 **a** Geographical and geological framework. *Legend 1* Palaeozoic; 2 Triassic; 3 Jurassic; 4 Cretaceous; 5 Palaeogene; 6 Neogene; 7 Pleistocene; 8 Holocene; 9 Thrust; 10 Fault; 11 Drainage network; 12 Reservoir; 13 Sierra de Atapuerca cave system. **b** 3D perspective of

the Sierra de Atapuerca and de Arlanzón Valley, showing the location of the archaeo-palaeoanthropological sites. *Legend D* Dolina; *G* Galería; *E* Elefante; *C* Cueva Mayor

contact between Cretaceous carbonates and Miocene marls. The passage continues to the confluence of the Propiedad and Valhondo valleys, where it intersects the ground surface (Elefante Cave). As in the upper level, vadose entrenchment developed at the downstream end of the passage (Fig. 8.4b).

The Trinchera caves belonging to this level are Dolina-Penal, Galería Complex and Elefante (Figs. 8.3b, 8.5a–d), which contain important Early and Middle Pleistocene deposits. Dolina-Penal and Galería Complex are located on the northern slope of Propiedad valley and constitute the entrance sectors of the caves, which were completely filled by sediments. These clastic deposits currently block the entry to the passages, which continue eastward. Dolina-Penal is the entrance sector of a WNW-ESE-oriented passage, with a keyhole section and a subcircular roof at 1,000–1,001 m. The Galería complex corresponds to a large elongated chamber with a phreatic roof above 995 m a.s.l. Roof collapses facilitated the accumulation of allochthonous sediments and the access of humans and animals.

8.3.3 Lower Level

This is the smallest level, and its location also displays a westward shift (Figs. 8.2, 8.3a), near the contact with the

Miocene sediments. At the southern and northern ends of this level, there are two mazes: Cueva del Silo and Cueva del Compresor, respectively. Between them, the passage in Cueva Peluda formed at the same level as the principal conduit in Cueva del Silo. The Sima de los Huesos in Cueva Mayor, a 15-m-deep shaft with scallops indicating upward flow, completes this level (Fig. 8.5e). The lower level developed at 985–990 m a.s.l. and is perched at +58–51 m above the Arlanzón River. The lower level includes numerous dissolution chimneys with evidence of rising flow that reached 1,000–1,005 m a.s.l. and 990–995 m a.s.l. in the Silo and Compresor caves (Fig. 8.4c), respectively. Thick fluvial fill consisting of gravels of metamorphic rocks as well as sand and silt facies (Figs. 8.3a, 8.4e), situated at +40–53 m above the Arlanzón River, is preserved inside Cueva del Silo, Cueva Peluda and Sima de los Huesos.

8.4 Archaeo-Palaeoanthropological Sites

The Pleistocene sites in Sierra de Atapuerca record the occupation of ancient cave entrances associated with the intermediate karst level (Elefante, Dolina and Galería Complex) and areas inside the cave, such as the Sima de los

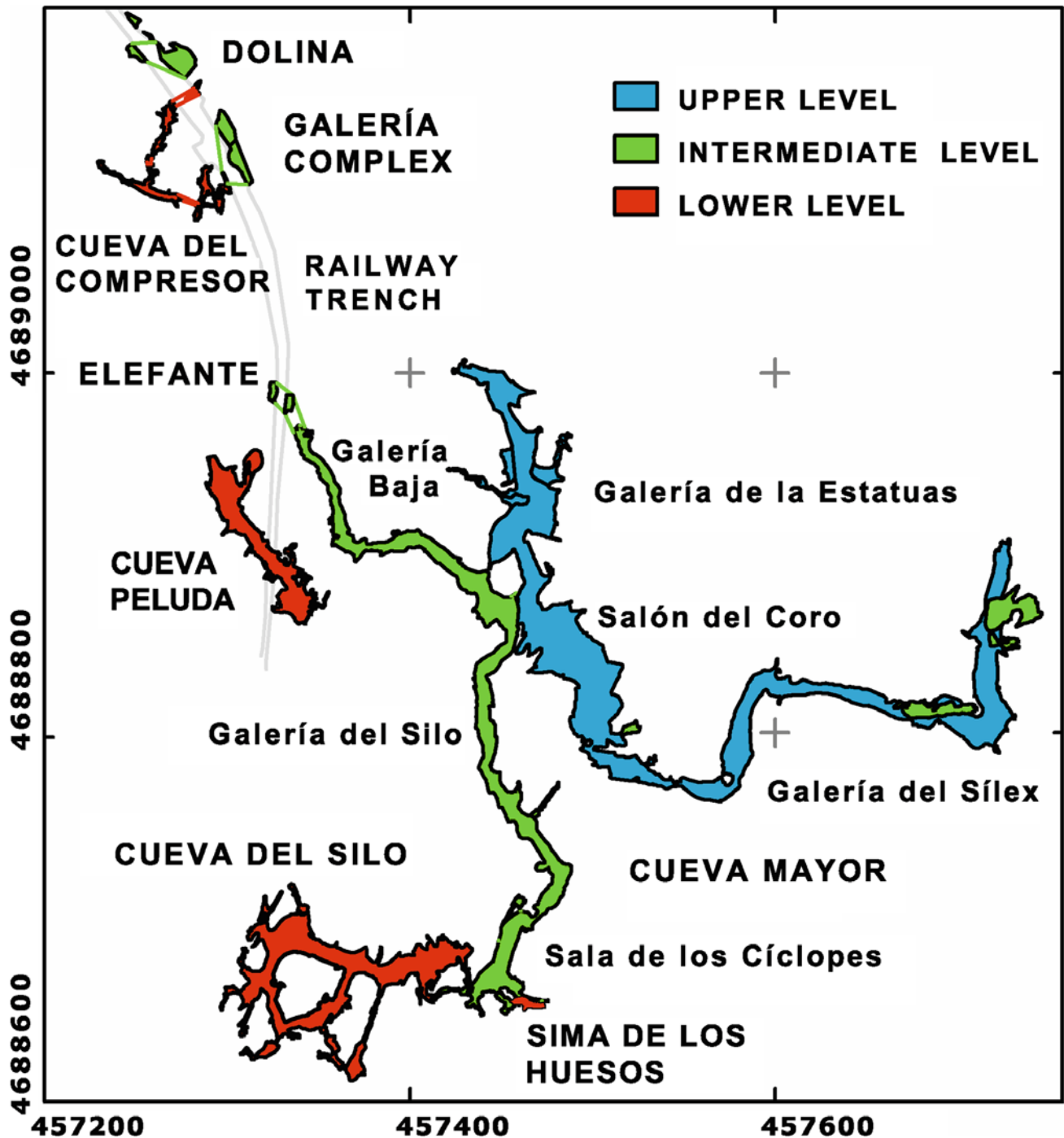


Fig. 8.2 Map of the Atapuerca multilevel cave system (Modified from Ortega et al. 2013)

Huesos. These sites host a very continuous Early and Middle Pleistocene archaeo-palaeoanthropological record, offering the possibility of analysing environmental, faunal, human and technological evolution throughout the last one million years.

8.4.1 Elefante Site

In Elefante site, the cave has a typical keyhole section and displays a stratigraphic sequence 18 m thick comprising 16 lithostratigraphic units (Fig. 8.6a). Facies consist mostly of

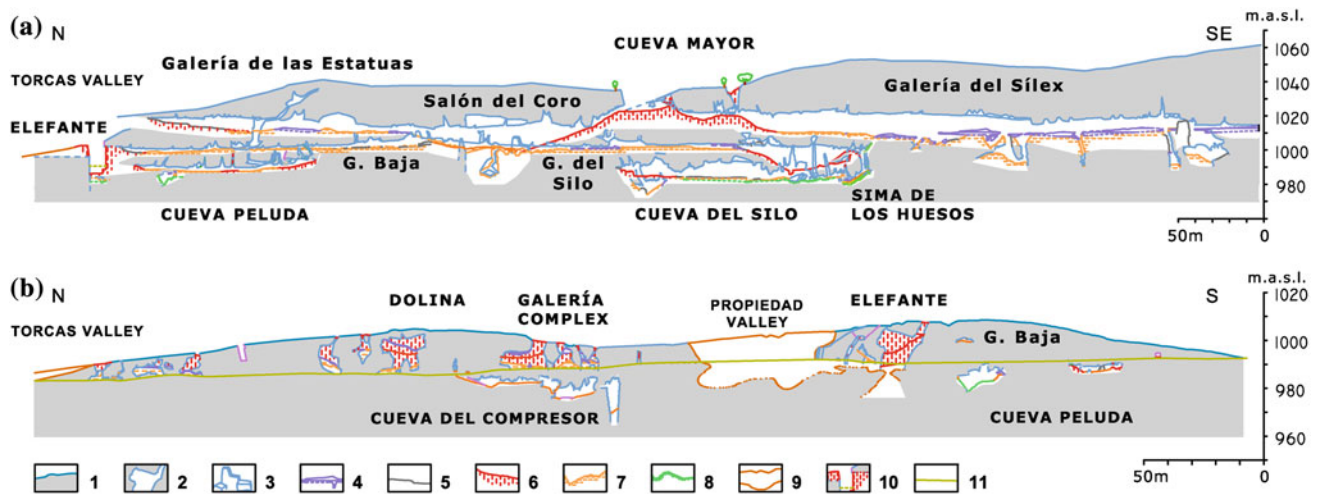


Fig. 8.3 Longitudinal profiles of the caves of the Sierra de Atapuerca. **a** Cueva Mayor—Cueva del Silo System and Cueva Peluda. **b** Caves and passages exposed in the railway trench. *Legend* 1 Land

surface; 2 Caves; 3 Blocks; 4 Eroded speleothem; 5 Speleothem; 6 Allochthonous facies; 7 Autochthonous facies; 8 Fluvial gravels; 9 Valley; 10 Railway trench; 11 Base of railway trench

debris flow deposits and to a lesser degree of sands, gravels and laminated clays. Lateral facies changes are common, and the lower units are affected by normal faults due to the collapse of the sediments (Rosas et al. 2006). The sequence can be divided into three sedimentary packages. The lower package (TE7–TE16), Early Pleistocene in age according to the cosmogenic burial dating of TE7 (1.13 ± 0.18 Ma) and TE9 (1.22 ± 0.16 Ma), has yielded the oldest European hominid fossils and evidence of the earliest human culture, together with a rich faunal assemblage earlier than the Jaramillo Subchron (Carbonell et al. 2008; Bermúdez de Castro et al. 2011). The intermediate package (TE17–TE19), dated to the Middle Pleistocene, has yielded an abundant assemblage of large mammals and stone tools included in the calcareous breccias of TE18 and TE19 (Cuenca-Bescós et al. 2010; Rodríguez et al. 2011). Finally, the youngest package (TE20 and TE21) records the final fill of the cavity and soil formation processes, possibly in the Upper Pleistocene.

8.4.2 Gran Dolina Site

Dolina Cave formed in the northern side of Propiedad valley and displays a keyhole section filled by a sedimentary sequence 16 m thick, in which interior and exterior facies can be divided into 11 units (Fig. 8.6b). TD1 and TD2 consist of reverse polarity interior facies (silty clays, breakdown facies and eroded speleothems) that display features indicative of a closed cave (Pérez-González et al. 2001). The overlying allochthonous sequence represents an open cave with the input of external sediments, including Pleistocene animal and human remains. This sequence is

formed by Units TD3–4 to TD11 and comprises mainly debris gravity flows (mud and clasts), tractive facies, laminated silts and some layers of speleothems. This sequence is important for the hominid fossils found in Unit TD6, which have been proposed as a new species, *Homo antecessor* (ca. 800–900 ka), associated with primitive Mode 1 stone tools, and rich fauna characteristic of the end of the Early Pleistocene (Bermúdez de Castro et al. 1997; Carbonell et al. 1999a; Berger et al. 2008). This record may be attributed to an intensive occupation of the cave with complex behaviours, including the oldest evidence of cannibalism. Palaeomagnetic data indicate that the Matuyama-Brunhes boundary is situated at the top of TD7 (Parés and Pérez-González 1995). Unit TD8 represents the last Early Pleistocene fauna and TD8–9 and TD10 record the occurrence of Middle Pleistocene fauna (Cuenca-Bescós and García 2007). TD10 provides evidence of intense human activity in a new cultural phase of Mode 2 to Mode 3 technology (Ollé et al. 2013), dated from about 430 to 250 ka (Falgüeres et al. 2001; Berger et al. 2008).

8.4.3 Galería Site

The Galería complex is about 50 m south of Gran Dolina. Its sedimentary fill is formed by five lithostratigraphic units (GI to GV) and a soil developed on Unit GV (Fig. 8.6c). The oldest unit GI consists mainly of interior facies (laminated silts, limestone breccias, as well as reworked and in situ speleothems) with bioturbation and some external influence at the top (Pérez-González et al. 2001), where the Matuyama-Brunhes boundary was detected. The GII to GIV units are allochthonous and are composed of calcareous



Fig. 8.4 Examples of morphological features and sediments of the Atapuerca caves. **a** Incision in the Galería de Sílex (*upper level*) has eroded the deposits accumulated in its floor, leaving a perched flowstone (*left*). **b** The Sala de los Cíclopes (*intermediate level*) shows a typical keyhole section with significant erosion. **c** The solution

chimneys of Cueva del Compressor, with scallops indicating upward flow (*lower level*). **d** Partially eroded sediments in the wall of the Sala de los Cíclopes. **e** Lower gallery of the Cueva Peluda fluvial deposits (Photo M. A. Martín, Edelweiss Speleological Group)

fluvial gravels and debris flow facies grading towards the north into laminated sandy clay-loam. Human presence has been confirmed in Units GII and GIII, between about 500 and 250 ka years ago (Berger et al. 2008; Falguères et al. 2013). A rich assemblage of Mode 2 lithic artefacts is associated with two fossil human remains and an abundant Middle Pleistocene palaeontological record (Carbonell et al. 1999b; Ollé et al. 2013).

8.4.4 Sima de los Huesos Site

The Sima de los Huesos site is located in a shaft inside Cueva Mayor. Its stratigraphic sequence has not been exposed to the outside environment and displays three sedimentary

episodes, interrupted by at least one erosional phase (Bischoff et al. 1997, 2007). At the bottom, there are reworked marls overlain by sand and clay units with reverse polarity (Parés et al. 2000). At the top, two Middle Pleistocene fossiliferous units develop in clay breccias, capped by flowstone and a guano layer (Fig. 8.6d). The fossiliferous units contain the skeletal remains of hundreds of bears (*Ursus deningeri*), some carnivores, and the most representative sample of fossil hominids for the Middle Pleistocene worldwide, with remains of at least 28 *Homo heidelbergensis* individuals (Arsuaga et al. 1997; García 2003; Martínón-Torres et al. 2012). In addition, a single Mode 2 hand-axe is proposed to be evidence of symbolic rituals (Carbonell and Mosquera 2006), distant from the site of human occupation.

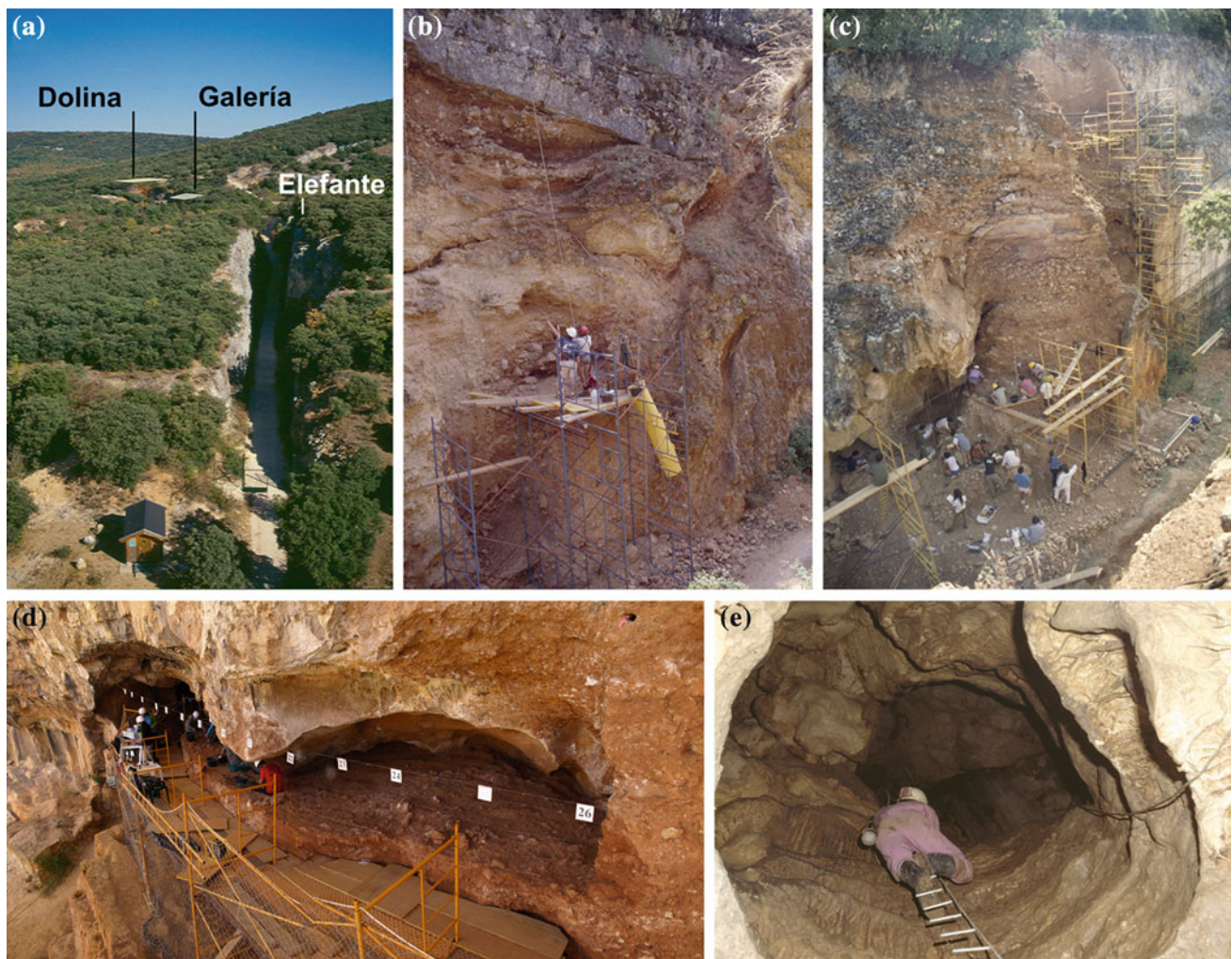


Fig. 8.5 Sediment-filled passages of the intermediate level exposed in the railway trench. **a** Aerial view of the railway trench. **b** Elefante site. **c** Gran Dolina site. **d** Galería site. **e** Shaft-chimney of Sima de los

Huesos, with scallops indicating rising flows (Photo M. A. Martín, Edelweiss Speleological Group)

8.5 Speleogenesis and Human Occupation

The Atapuerca cave system exhibits three sub-horizontal levels of inactive passages. These conduits record prolonged periods of base-level stability. In addition, the palaeocurrents inferred from the scallops indicate a flow from the south towards the north in the three levels. In the south, fracture-controlled chimneys with scallops are indicative of rising flows, along which maze cave systems formed. These features suggest rising groundwater inputs in the southern sector, near the Arlanzón valley, especially for the lower and intermediate levels. The main portion of the passages was formed by groundwater flowing towards the north, and their sub-horizontal attitude was controlled by the water table. These underground channels intersect the ground surface at the headwaters of the Pico valley, where

resurgences or springs were active during the formation of each cave level (Fig. 8.1b).

The upper level is situated at +80–90 m above the present-day base level, coinciding with the Lower Páramo Plateau (1,020–1,025 m a.s.l) and terrace T2 of the Arlanzón River (+80–88 m). This indicates long-sustained base-level stability of the water table over a long time span, favouring the formation and enlargement of sub-horizontal passages. As a consequence of water table lowering, an extensive flowstone formed under vadose conditions on the floor of the passages in the upper level. The base-level drop recorded by the development of terrace T3 of the Arlanzón River (+70–78 m) led to the formation of passages with keyhole cross sections in the distal sectors of the upper-level passages. In the Salón del Coro, this erosion process favoured the collapse of the roof and the walls (Ortega et al. 2013).

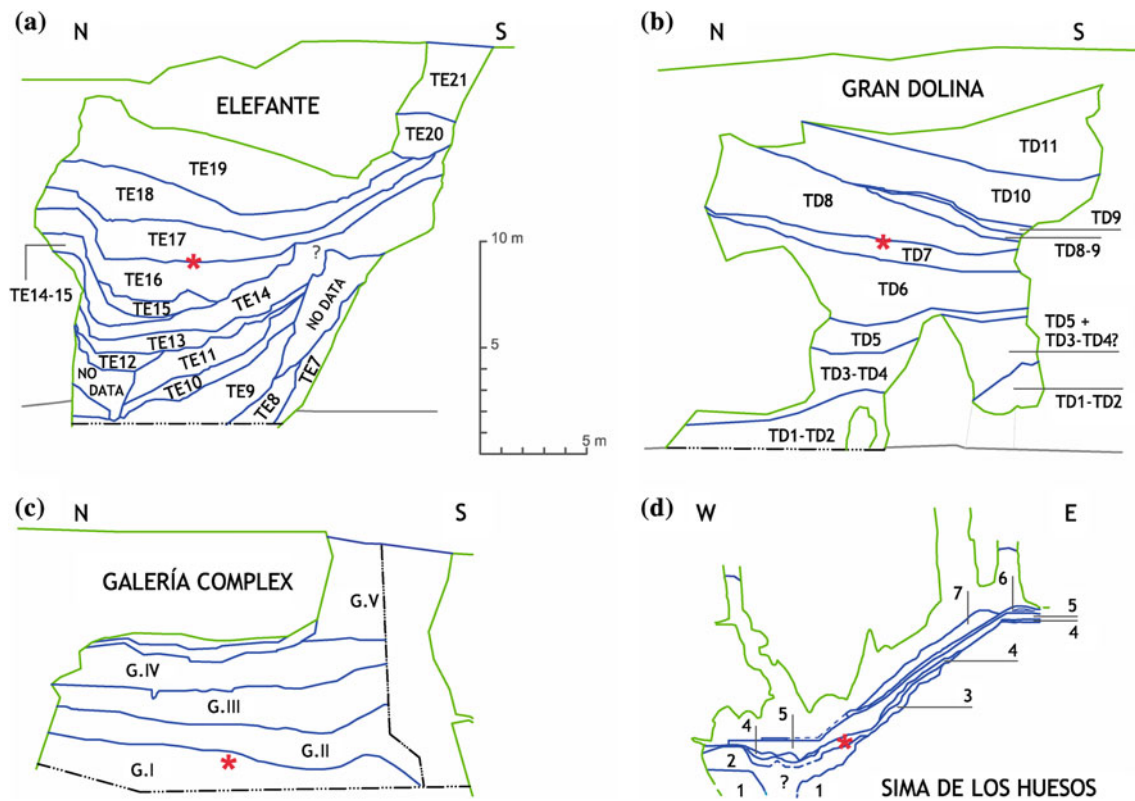


Fig. 8.6 Stratigraphic sequences of the Pleistocene Atapuerca sites. **a** Elefante site. **b** Gran Dolina site (Modified from Rodríguez et al. 2011). **c** Galería site (Modified from Ortega 2009). **e** Sima de los Huesos. 1 Reworked marls; 2 Sands and silts; 3 Red clay; 4 and 5

Fossiliferous clay breccias; 6 Speleothem; 7 Mud breccia with bat guano (Modified from Bischoff et al. 2007). The asterisk marks the position of the Matuyama-Brunhes boundary

The intermediate level has been related to the period of base-level stability corresponding to the Arlanzón River terrace T3 (+70–78 m), which developed at about 1.14 ± 0.13 Ma (ESR date, Moreno et al. 2012). This drop in base level caused a change to vadose conditions in the second level, favouring the entry of surface sediments in their distal sectors (Cíclopes, Elefante and Dolina) (Ortega et al. 2013). Cíclopes Chamber, corresponding to this phase, has a sedimentary fill consisting of breccias and fluvial sands and silts with reverse polarity attributed to the Matuyama Chron (Parés et al. 2010; Fig. 8.4d). In addition, the lowest units in the Elefante fill (TE9, TE7) yielded a ca. 1.2 Ma age (Carbonell et al. 2008) and represents the first entry of hominids, animals and sediments from the surface. New occupations ascribed to *H. antecessor* and the associated sedimentary phases took place at the end of the Early Pleistocene (Carbonell et al. 2001; Ollé et al. 2013). The infill of Dolina and Elefante continued with the massive entry of debris flows and alluvial sediments, recording the Brunhes-

Matuyama reversal in Dolina (TD7) and Elefante (TE16–TE17) (Parés and Pérez-González 1995; Carbonell et al. 2008). The period of base-level stability recorded by terrace T4 (+60–67 m) led to the formation of the Galería Complex.

The roofs of the lower level largely coincide with terrace T5, which would have controlled the development of this level (Sima de los Huesos, Cueva del Silo, Cueva Peluda and Cueva del Compressor), in which fluvial sediments incorporated by the Arlanzón fluvial system have been described (Ortega 2009). This input is associated with the enlargement of the lower-level conduits, causing the subsidence and deformation of the Lower Pleistocene Elefante sedimentary units (TE7 to TE17). This suggests a Middle Pleistocene age for the fluvial sediments in Cueva del Silo, which can be altitudinally correlated with terrace T6 (+44–46 m).

The youngest water table-controlled cave level is related to terrace T7 (+38–40 m), which produced a small cave sub-level represented by the lower passages in the Silo, Compressor and Peluda caves (978 m a.s.l.) and caused the incision of the

fluvial deposits accumulated inside Cueva del Silo-Peluda. With the base-level drop recorded by T8 terrace (+26–35 m), the multilevel cave system became totally disconnected from and perched above the Arlanzón River network.

A third cultural phase corresponds to the Middle Pleistocene, when *H. heidelbergensis* used the cave entrances of the intermediate level at Elefante (TE19), Dolina (TD10), Galería Complex (TGII–III) and Sima de los Huesos inside Cueva Mayor (Ollé et al. 2013). All this evidence reveals the significance of the human occupation. Stratigraphic and biostratigraphic studies have shown that entrance sectors in the intermediate level were filled to the roof in the late Middle Pleistocene (Carbonell et al. 2001; Cuenca-Bescós et al. 2010; Rodríguez et al. 2011) when the Sima de los Huesos became isolated from the outside environment (Bischoff et al. 1997; García and Arsuaga 2011). In the Upper Pleistocene, the karst of San Vicente Hill became inactive and was completely perched, with only minimal animal and human activity being documented. A fourth phase of human occupation took place in recent prehistoric times, when all the open caves in San Vicente Hill were used for diverse purposes (Ortega 2009).

8.6 Conclusions

The Atapuerca cave system consists of a series of sub-horizontal passages (water table caves) with drainage directions from south to north, oriented roughly parallel to the strike of the folded carbonate formations. The passages intersect the surface in the northern sector, where resurgences or springs were active at the head of the Pico River during the Pleistocene. The passages are arranged in three main levels, connected to each other by shafts and chambers, and perched around +90, +70 and +60 m above the modern Arlanzón River. These water table caves can be correlated altitudinally with different terrace levels. The different passages show a progressive westward shift and correlate with the episodic downcutting of the regional base level. Throughout their evolution, the caves have changed progressively into vadose conditions, allowing the entrance of fauna and hominids, whose remains have been preserved in Early and Middle Pleistocene sedimentary sequences filling the cave entrances, such as the Trinchera sites (Dolina, Galería and Elefante), or in the interior of the caves, like the Cueva Mayor sites (Sima de los Huesos).

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