The late Neogene-early Quaternary small vertebrate succession from the Almenara-Casablanca karst complex (Castellón, Eastern Spain): Chronologic and paleoclimatic context

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ABSTRACT

Although discontinuous because of their karst nature, the Almenara-Casablanca complex records a very complete small vertebrate succession (amphibians, squamates, insectivores, bats, rodents and lagomorphs), characterized by the richness of their sites, a richness which cannot be expected in sites of fluvio-lacustrine origin. This late Neogene-early Quaternary succession includes the sites of Almenara-Casablanca M (Miocene-Pliocene boundary), Almenara-Casablanca 4 (late Pliocene), Almenara-Casablanca 1 (earliest Pleistocene) and Almenara-Casablanca 3 (late early Pleistocene). In this way, the Almenara-Casablanca succession complements the data from other well know terrestrial Pliocene-Pleistocene sequences in the Iberian Peninsula, most notably that of the Guadix-Baza Basin. The complementation between the almost continuous Pliocene-Pleistocene sequence of the Guadix-Baza Basin and the discontinuous but very rich succession from the Almenara-Casablanca complex enables accurate dating of some of the faunal events that punctuate the Pliocene-early Pleistocene time interval. Furthermore, the assemblages from the Almenara-Casablanca complex contain the evidence of the earliest occurrences of several taxa as well as the persistence of other that had already disappeared from other European regions. Therefore, it provides new evidence for the particular role which the Iberian Peninsula played during the late Neogene and early Quaternary, acting at certain moments as a bridge for the entry of African taxa or, alternatively, as a refuge for other European taxa. This paper provides an updated review of the small vertebrate succession from this complex.

1. Introduction

The Almenara-Casablanca karst complex is located in an abandoned quarry next to the town of Almenara (Castellón, Spain), 30 km north of the city of Valencia, in the eastern sector of the Iberian range (Fig. 1). The promontory, known as Muntanya Blanca, belongs to the coastal ends of Sierra de Espadan range, and it is within a few kilometres of the present Mediterranean coast. The paleokarst developed on limestones of middle Triassic age and led to the formation of a number of fissure infillings, some of them displaying rich vertebrate assemblages including small and large vertebrates (Agustí and Galobart, 1986; Agustí et al., 1987). The set of localities were discovered in 1982 by a team of the Servei Investigacions Arqueològiques Provincials (SIAP) coordinated by F. Gusi. In 1983 a first digging campaign was coordinated by F. Gusi and E. Carbonell. Afterwards, during 1984, 1985 and 1986 the complex was excavated by a joint team of the SIAP and the Institut de Paleontologia M. Crusafont from Sabadell. Most of the fossiliferous outcrops are of Pliocene-Pleistocene age, but the oldest one (Almenara-Casablanca M) can be dated back to the latest Miocene. The Plio-Pleistocene succession includes the sites of Almenara-Casablanca 4 (late Pliocene), Almenara-Casablanca 1 (earliest Pleistocene) and Almenara-Casablanca 3 (late early Pleistocene).
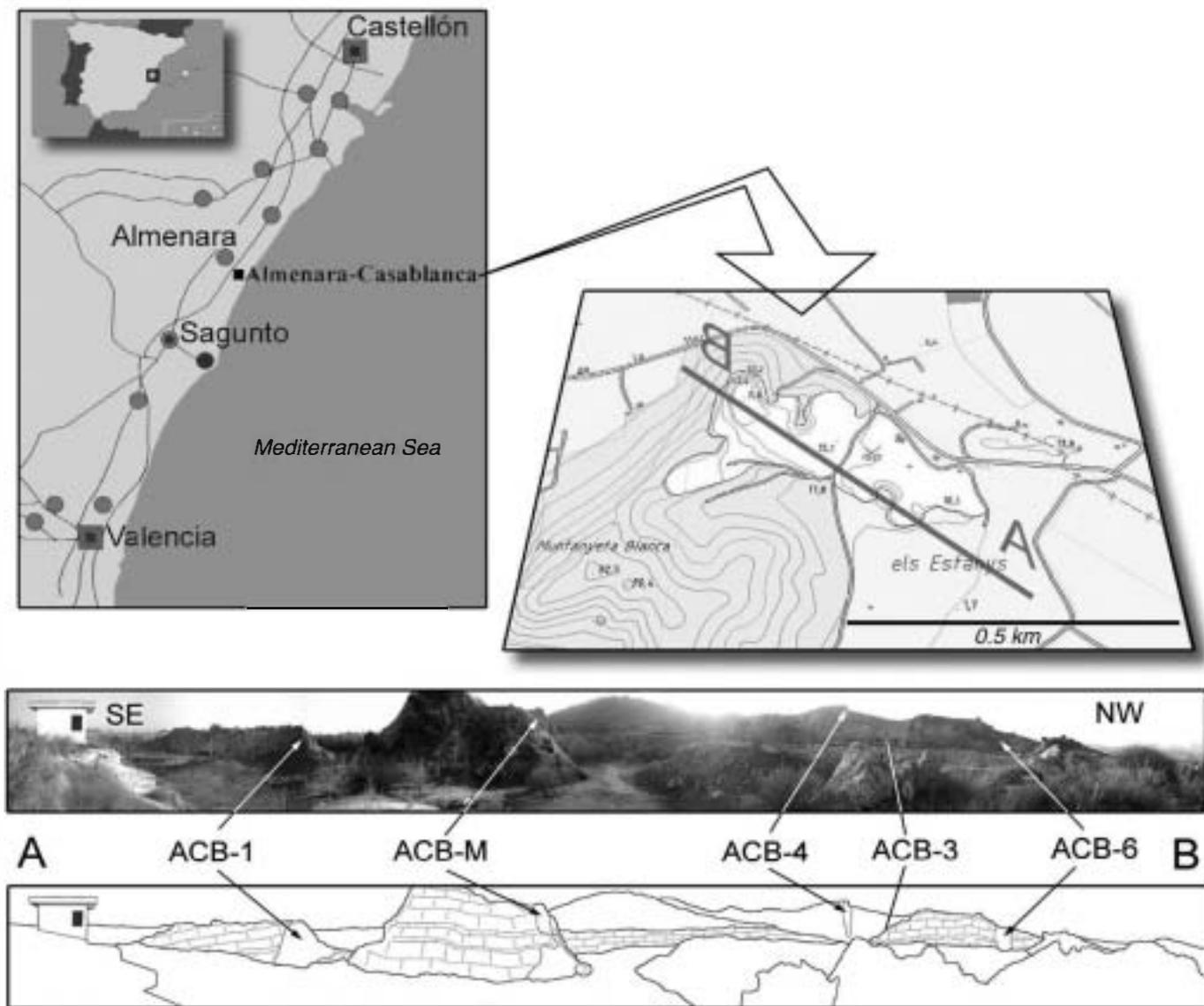
Fig. 1. Geographical location of the karst complex of Almenara-Casablanca with the reference of the different sites inside the outcrop (Castellón, eastern Spain).

2. Almenara-Casablanca M (ACB M, latest Miocene)

This site, originally referred to as "Casablanca 2", was first sampled in 1983. It is formed of yellowish clays which contained abundant bone fragments. Sieving of several tones of sediment led to the recovery of a rich small mammal assemblage (Tables 1 and 2) which is mainly composed of murids (*Apodemus gudrunae, Occitanomys* cf. *adroveri, Castillomys crusafonti, Paraethomys meini, Stephanomys ramblensis*), cricetids (*Ruscinomys lasallei, Apocricetus alberti, Blancomys* sp.) and glirids (*Eliomys truci*; Agustí and Galobart, 1986; Agustí, 1989, 1990; Agustí and Casanovas-Vilar, 2003). This assemblage clearly corresponds to the latest Miocene (MN 13), therefore indicating a karstification phase much older than the other fissure infillings from the complex. Even more surprising was the fact that this typical late Miocene assemblage included a number of rodent species of African and Asian affinities, such as the myocricetodontines *Myocricetodon jaegeri* and *Calomyscus* sp., and the gerbils *Debruijnimys almenarensis* and *Pseudomeriones abbreviatus* (Agustí, 1989, 1990, 1991; Agustí and Casanovas-Vilar, 2003). The presence of *Pseudomeriones abbreviatus* is particularly significant, since this species was originally

described from China, and no previous European record existed. Unfortunately, insectivores are quite rare and only include *Parasorex* cf. *ibericus* and *Blarinella* cf. *europaea* (Furió, 2007a). The crocidurinae quoted in previous faunal lists (e.g., Van den Hoek Ostende and Furió, 2005) probably corresponds to contamination with sub-recent material (Furió, 2007b). The few recovered large mammals also show the same mixture of European, Asian and possible African elements: Felidae indet., cf. *Nyctereutes, Pliohyrax graecus,* Bovidae indet. and *Macaca* sp. (Agustí and Galobart, 1986; Pickford et al., 1997; Köhler et al., 2000). *Macaca* sp. corresponds to the earliest occurrence of this genus.

Levels equivalent to Almenara-Casablanca M are recorded in the Negratín series, in the Guadix sub-basin. As in the case of ACB M, the small mammalian fauna from Negratín 1 is characterized, among other elements in common, by the presence of rodents of African origin (*Myocricetodon jaegeri* and *Debruijnimys almenarensis*; Minwer-Barakat et al., 2009). *Debruijnimys almenarensis* has been also found in the continental deposits at the base of the Zorreras Member, in the Sorbas Basin (SE Spain; Martín-Suárez et al., 2000). These continental deposits show reverse polarity and are overlain by marine deposits of early Pliocene age, referred

Table 1

Distribution of arvicolids, murids and lagomorphs from the Almenara-Casablanca sites.

	Miocene	Pliocene	Early Pleistocene	
	ACB M	ACB 4	ACB 1	ACB 3
Apodemus gudrunae	x			
Occitanomys cf. adroveri	x			
Castillomys crusafonti	x	x		
Paraethomys meini	x			
Stephanomys ramblensis	x			
Ruscinomys lasallei	x			
Apocricetus alberti	x			
Blancomys sp.	x			
Eliomys truci	x			
Myocricetodon jaegeri	x			
Calomyscus sp.	x			
Debruijnimys almenarensis	x			
Pseudomeriones abbreviatus	x			
Kislangia aff. cappettai		x		
Stephanomys gr. minor		x		
Stephanomys progressus			x	
Apodemus mystacinus	aff.	cf.	x	
Apodemus sp.		x		
Eliomys aff. intermedius		x		
Kislangia gusii			x	
Mimomys medasensis			x	
Mimomys (Tcharinomys) tornensis			x	
Castillomys crusafonti			x	
Eliomys quercinus			x	E. q. helleri
Sciurinae indet.			x	
Mimomys aff. savini				x
Allophaiomys chalinei				x
Iberomys aff. huescarensis				x
Pliomys episcopalis				x
Allocricetus bursae duraciensis				x
Apodemus flavicollis				x
Castillomys rivas				x
Prolagus calpensis			x	x
Oryctolagus sp.			x	x

Table 2

Distribution of insectivores and bats from the Almenara-Casablanca sites.

	Miocene	Pliocene	Early Pleistocene	
	ACB M	ACB 4	ACB 1	ACB 3
Parasorex cf. ibericus	x			
Blarinella cf. europaea	x			
Desmana inflata		x	aff.	
Talpa cf. fossilis		x	x	
Myosorex meini		x		
Deinsdorfia doukasi		x		
Sorex minutus		x	x	
Sorex sp.			x	
Beremendia fissidens			x	
Petenyia hungarica			x	
Crocidura sp.				x
Sorex cf. araneus				x
Neomys sp.				x
Rhinolophus ferrumequinum		x	x	
Rhinolophus euryale		x	x	
Rhinolophus hipposideros		x	x	
Myotis myotis		x	x	
Myotis nattereri		x	x	
Myotis emarginatus		x		
Myotis sp. I (small species)		x	x	
Myotis sp. II (small species)			x	
Plecotus sp.		x		
Eptesicus sp.		x		
Pipistrellus sp.		x		
Miniopterus schreibersii		x	x	
Miniopterus sp.		x	x	
Myotis blythi				x
Chiroptera indet.				x

to chron C3r (Martín-Suárez et al., 2000). Therefore, a latest Miocene age is confirmed for the sites of Almenara-Casablanca M and Negratín 1.

The presence of Asian and African elements at Almenara-Casablanca M can be explained on the basis of the set of events associated with the Messinian Salinity Crisis (MSC), between 5.6 and 5.32 Ma (Krijgsman et al., 1999). This crisis involved the desiccation of the Mediterranean and the opening of new intercontinental routes between the two margins of the basin, therefore enhancing the exchange of terrestrial faunas (Agustí and Llenas, 1996; Agustí et al., 2006). The abundance of gerbils probably indicates the presence at that time of very dry, sub-desert conditions in the area. This is also confirmed by the low insectivore diversity.

3. Almenara-Casablanca 4 (ACB 4, late Pliocene)

This site was originally published as Casablanca B by Gil and Sesé (1985). Later, further samplings by a joint team of the SIAP and the Institut de Paleontologia M. Crusafont led also to the recovery of large mammals in this site. Originally, an age equivalent to the site of Almenara-Casablanca 1 (ACB 1) was proposed (Gil and Sesé, 1985; Agustí and Galobart, 1986), therefore assigning Almenara-Casablanca 4 to the MN 17 unit (now, earliest Pleistocene). In 2004 new excavations headed by A. Santos-Cubedo and M. Furió led to a considerable enlargement of the list of small and large mammals. As a result of these new excavations, it was documented the oldest record of the Eurasian badger Meles (Madurell-Malapeira et al., 2009). A second immediate benefit was the analysis of a much larger sample of rodents, which indicated a late Pliocene age (MN 16), as shown by the less derived features of Kislangia aff. cappettai from this site with respect to Kislangia gusii from ACB 1. Besides Kislangia, other rodent species include Stephanomys progressus, Castillomys crusafonti, Apodemus aff. mystacinus, Apodemus sp. and Eliomys aff. intermedius (Table 1).

The insectivores are represented by Desmana inflata, Talpa cf. fossilis, Myosorex meini, Deinsdorfia doukasi and Sorex minutus (Furió, 2007a; Furió et al., 2007; Furió and Mein, 2008). The insectivore assemblage is largely dominated by the white-toothed crocidosoricine shrew Myosorex. The arrival of Deinsdorfia to Spain was probably related with the climatic changes that took place at the Ruscinian-Villanyian boundary (Furió and Mein, 2008). Chiroptera are very diverse and include up to 12 species of the genera Rhinolophus, Myotis, Plecotus, Eptesicus, Pipistrellus and Miniopterus. In this assemblage, rhinolophids are the dominant bats, the middle-sized rhinolophid Rhinolophus euryale being the most abundantly represented. Among the vespertilionids, Miniopterus is the best represented genus, though its remains are less common than in ACB 1. The remaining vespertilionids are represented by few remains (Table 2).

The fauna of amphibians and squamates is also very diverse (Table 3), including anurans (Discoglossus, Pelobates, Pelodytes, Bufo and Pelophylax), amphisbaenids (Blanus cinereus), agamids, gekkonids (Tarentola), lacertids, anguids (Dopasia), colubrids (Coronella and Malpolon) and viperids (Vipera). The presence of Malpolon monspessulanus at ACB4 documents a very early, late Pliocene presence of this African colubrid in the Iberian Peninsula. This species is also cited from the Pliocene and early Pleistocene of France (Bailon, 1991a,b). This evidence contradicts previous ideas based on genetic analysis which assumed a late Pleistocene entry of this species, following a moment of low sea level (Carranza et al., 2006), although these authors do not excluded the possibility of earliest colonization waves from Africa to Europe.

Concerning Dopasia, note that it is used in this work sensu Augé (2005), that considers that all Eurasian and African species (excluding Pseudopus) pertains to genus Dopasia and can be

Table 3
Distribution of amphibians and squamate reptiles from the Almenara-Casablanca sites.

	Miocene	Pliocene	Early Pleistocene	
	ACB M	ACB 4	ACB 1	ACB 3
cf. *Discoglossus* sp.		×	×	×
Pelobates cultripes		cf. genus		×
Pelodytes cf. *punctatus*		sp.	×	×
Bufo bufo	×		×	×
Bufo sp.				×
Pelophylax cf. *perezi*		sp.	sp.	×
Blanus cinereus	×		×	×
Agamidae indet.		×	×	
Tarentola sp.		cf. genus	×	
Chalcides cf. *bedriagai*			×	×
Timon cf. *lepidus*	×		×	
Lacertidae indet.	×		×	×
Dopasia sp.	×		cf. genus	
Natrix maura			×	
Natrix natrix				×
Coronella girondica	×		×	×
Malpolon monspessulanus	×		×	×
Rhinechis scalaris			×	×
Vipera latasti	×		×	×

separated from the American species forming the genus *Ophisaurus* sensu stricto. Genus *Hyalosaurus* has been proposed for the African species (Macey et al., 1999).

Fossiliferous levels equivalent to those of Almenara-Casablanca 4 are present in the Guadix-Baza Basin in the section of Zújar (Oms et al., 1999; Agustí et al., 2001b). In particular, the level of ACB 4 can be correlated with the level Zújar 10 of that section. This level is placed within the chron 2An.2n, between 3.20 and 3.11 Ma (Lourens et al., 2004). Joint evidence from the sections of Galera and Zújar (Agustí et al., 1997, 2001a,b) indicates that the first part of the Villanyian mammal age (MN 16a) is placed between the base of the chron 2An.3n and the base of the chron 2An.1n, therefore between 3.59 and 3.03 Ma. Thus, a late Pliocene age can be considered for Almenara-Casablanca 4.

4. Almenara-Casablanca 1 (ACB 1, earliest Pleistocene)

The site of Almenara-Casablanca 1 is by far the richest deposit of the Almenara-Casablanca complex, and the only one where several sedimentary levels can be recognized (Ginés and Pons Moyà, 1986; Pérez Cuevas, 2004; Freixes, 2004). In 1983, a detailed excavation was conducted by F. Gusi and E. Carbonell. As a result of this first digging campaign, supposed Mode 1 tools were recovered from the site. However, posterior morphotechnical analysis lead to the conclusion that the pseudo-industry was not of anthropogenic origin but a product of natural fractures caused by the water action and other geologic agents (Gusi et al., 1986). As a result of several excavations carried out during the years 1983, 1984, 1985 and 1986, a discrete large mammal assemblage was also recovered, including a typical early Pleistocene association with *Canis etruscus*, *Vulpes alopecoides*, *Ursus etruscus*, *Pachycrocuta brevirostris*, *Lynx* sp., *Felis* sp., *Equus stenonis* ssp., Rhinocerotidae indet., *Pseudodama nestii*, *Eucladoceros* sp., *Gazellospira torticornis*, aff. *Procamptoceras brivatense*, *Leptobos* sp. and Ovibovini indet (Soto and Morales, 1985; Agustí et al., 1986, 1987; Agustí and Moyà-Solà, 1991). This association is very interesting since it corresponds to the phase immediately previous to the immigration of *Allophaiomys pliocaenicus* in Western Europe, and places the deposit at the entry of the typical early Pleistocene faunas such as those of the Venta Micena site, in the Guadix-Baza basin (Agustí et al., 1986, 2010).

The Almenara-Casablanca 1 stratigraphy was first introduced in a preliminary work by Ginés and Pons Moyà (1986). This work stated that a detailed study was required to understand the genesis and geometry of the stratigraphic record. The stratigraphy of the site appeared to be a complicated one due to the non-continuity and irregularities of strata and reworking as well. Although the whole outcrop is rather small, these authors stated that important lateral changes are observed between the north and south outcrops. Ginés and Pons Moyà (1986), Agustí and Galobart (1986) and Agustí (1990) have successively revised and simplified the stratigraphy. Esteban Aenlle and López Martínez (1987) used a stratigraphy by 'Carbonell and Martinez' (not referred to in the work) which also displays a simple succession of strata. The recent observation of the section does not allow improvement of any previous study. From examination of the pictures of the outcrops in Ginés and Pons Moyà (1986), the present outcrops are far more weathered and covered by regolith. In any case, the stratigraphy is rather clear for the upper half of the section.

The detailed understanding of Almenara-Casablanca 1 stratigraphy is beyond the scope of this paper, but an attempt to integrate existing data is provided in Fig. 2. Above the blocks shown in Fig. 2 (from 5.5 m upwards), the succession is simple. According to the available literature, this succession starts from level 8 of Esteban Aenlle and López Martínez (1987), level Y of Agustí and Galobart (1986) and level N4 of Agustí (1990). The small mammal assemblage includes a highly diversified rodent association, mainly composed of arvicolids and murids. Arvicolids are represented by three different species (*Kislangia gusii*, *Mimomys medasensis* and *Mimomys (Tcharinomys) tornensis*; Esteban-Aenlle and López-Martínez, 1987; Agustí et al., 1993b), which is also the case for murids (*Stephanomys progressus*, *Apodemus* cf. *mystacinus*, *Castillomys crusafonti*). In the upper levels of this site, *Kislangia gusii* and *Mimomys (Tcharinomys) tornensis* are already absent (Gil and Sesé, 1984), perhaps indicating the last occurrence of these two arvicolids. Moreover, *Stephanomys progressus* is represented by one of the most derived populations of the genus *Stephanomys*, and it probably marks the last occurrence of this taxon as well. The rodent association is completed by *Eliomys quercinus* and Sciurinae indet (Table 1).

Lagomorphs include *Prolagus calpensis* and *Oryctolagus* sp. The third upper premolar (P^3) of *Prolagus calpensis* from ACB1 shows a morphology which is very similar to that of the neotype of this species from Rosia Bay (early Pleistocene, Gibraltar; López-Martínez and Thaler, 1975) and to the samples from the late Pliocene of Moreda (Granada) and Illes Medes (Girona; López-Martínez, 1989). However, as a difference with the material from Rosia Bay and Illes Medes, the third lower premolar (P_3) from this site does not display any labial cut on the anteroconid. This feature is also observed in some P_3 from Castelldefels and Cova de Gràcia (López-Martínez, 1989). The size of the P_3 also falls within the field of variability of *Prolagus* from these sites. On the other hand, *Oryctolagus* sp. is represented by 1 s upper premolar (P^2), one third lower premolar (P_3), one lower molar (M_1), three right talus, one right calcaneus and one left calcaneus, and a juvenile femur. The teeth and postcranial remains of ACB1 are different from those of *Oryctolagus lacosti* (De Marfà and Mein, 2007), but might be related to *Oryctolagus laynensis* (López-Martínez, 1977), *Oryctolagus burgi* (Nocchi and Sala, 1997a, 1997b) and *Oryctolagus giberti* (De Marfà, 2008). However, the morphology of the teeth fall within the field of variability of *Oryctolagus cuniculus*, as it is also the case for their size (Callou, 1997). Therefore, this sample is referred to as *Oryctolagus* sp. The identification in ACB1 of a member of *Oryctolagus* which closely resembles *O. cuniculus* indicates that the differentiation of the current species may have taken place in the early Pleistocene, and not in the middle Pleistocene as has been assumed.

NORTH SECTION   SOUTH SECTION   UNITS & SITES
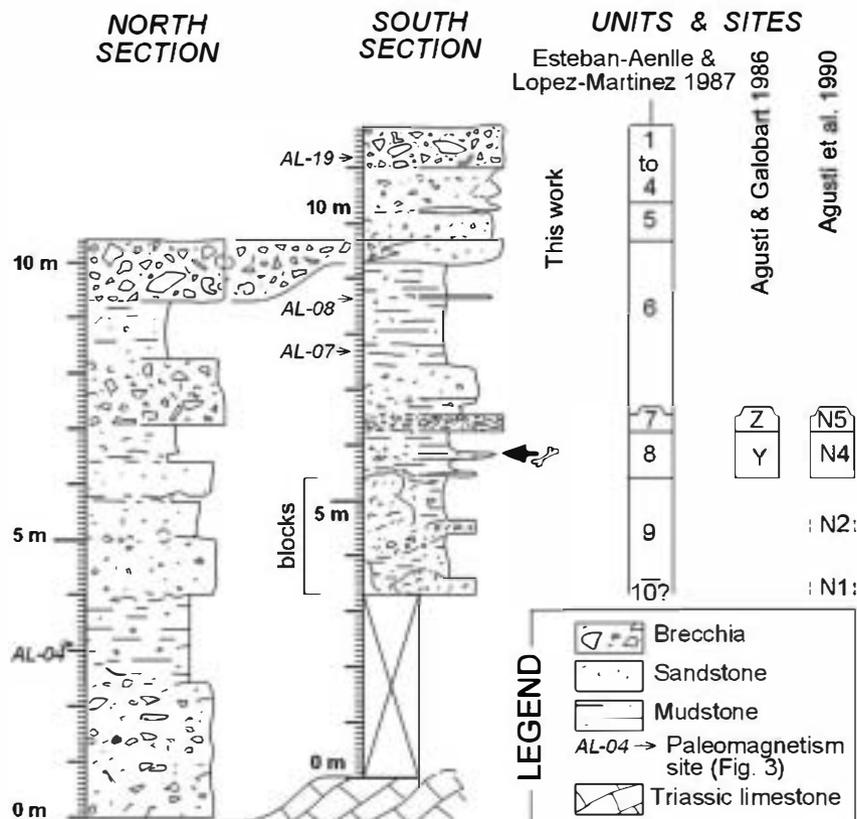Esteban-Aenlle & Lopez-Martinez 1987

Fig. 2. Almenara-Casablanca 1 section with stratigraphic units according to several authors.

As with other small mammals, insectivores in ACB1 are also very diverse (Table 2), and include *Talpa* cf. *fossilis*, *Desmana* aff. *inflata*, *Myosorex meini*, *Sorex minutus*, *Sorex* sp., *Beremendia fissidens* and *Petenyia hungarica* (Furió, 2007a). The soricid assemblage is the richest one known in Spain for ages close to the Plio-Pleistocene boundary, and includes some infrequent forms in the southwest of Europe, such as *Petenyia hungarica* and *Beremendia fissidens*. Apart from ACB1, *Petenyia* has only been found in Spain in the early Villanyian localities (MN 16) of Moreda and Tollo de Chiclana 13, which may be a consequence of the particular climatic and ecological conditions which were present in southern Europe at this time interval (Minwer-Barakat et al., 2010). A recent paleobiological analysis has shown that *Beremendia fissidens* was able to survive in different kind of environments, even in unpredictable ones (Furió et al., 2010).

Regarding the bat representation, although a high abundance of remains is observed in ACB 1, only three genera (*Rhinolophus*, *Myotis* and *Miniopterus*) and nine species are represented in the material (Table 2), a lower number than in ACB 4. The assemblage is dominated by the vespertilionids, *Miniopterus* being the best represented genus in number of remains, followed by *Myotis*. Among the rhinolophids, the middle-sized species *R. euryale* is somewhat more abundant than the large *R. ferrumequinum*, while the smallest species, *R. hipposideros*, is represented by very few remains. As a whole, the ACB 1 assemblage presents a higher proportion of vespertilionid remains than would be expected for a karst site.

As noted for ACB 4, the representation of amphibians, squamates and chelonids in ACB 1 is also very diverse (Table 3), including anurans (*Discoglossus*, *Pelodytes*, *Bufo* and *Pelophylax*) amphisbaenids (*Blanus cinereus*), agamids, gekkonids (*Tarentola*), scincids (*Chalcides* cf. *bedriagai*), anguids (*Dopasia*), lacertids (*Timon* and *Podarcis/Psammodromus*), colubrids (*Natrix maura*, *N. monspessulanus* and *Rhinechis scalaris*) and viperids (*Vipera latasti*).

Chelonids are represented by testudinids (*Testudo* sp. and Testudinidae indet.) and emydids (Jiménez-Fuentes, 1985). ACB 1 records the last occurrence of agamids in the Iberian Peninsula. Thus, no record of this group has been reported so far in other early Pleistocene localities from Europe. Most probably, the warm and dry conditions of Spain and southern France favoured their persistence in the earliest Pleistocene, as indicated by their frequent presence in a number of karst sites from these areas (Bailon, 1987, 1989, 1991a; Blain, 2005, 2009; Bailon and Blain, 2007; Agustí et al., 2009). After that, the set of climatic events linked to the transition between the earliest and the early Pleistocene at around 1.8 Ma, probably led to the final disappearance of the family in the European latitudes. Similarly, the presence of *Dopasia* at ACB 4 and ACB 1 suggests a gradual retreat of this genus towards the south of the Iberian Peninsula. *Dopasia* (formerly *Ophisaurus* sensu lato) belongs to an Eurasian and African group, and has been noted in the late Pliocene sites of Balaruc II, in southern France, and Illes Medes in northeastern Spain (Bailon, 1991a). It is still present in the late early Pleistocene sites of Quibas (Mancheño et al., 2009) and Barranco León (Blain, 2005, 2009; Bailon and Blain, 2007). Barranco León probably corresponds to the last occurrence of *Dopasia* in Europe, as this genus is already absent in the late early Pleistocene site of Cueva Victoria, also in southern Spain (Blain et al., 2008). The gradual retreat of the range of *Dopasia* was probably caused by the climatic deterioration that took place across the late Pliocene and the early Pleistocene (Blain, 2005, 2009; Bailon and Blain, 2007).

As happened with ACB 4, levels equivalent to ACB 1 are present in the sections of Zújar and Galera in the Guadix-Baza Basin (Agustí et al., 1997, 2001b, 2010; Oms et al., 1999). As in the case of ACB 1, all these levels are characterized by the presence of the arvicolid species *Kislangia gusii* (Agustí et al., 1993b). In order to achieve a better constraint and correlation of the ACB 1 with other sites of similar age, a paleomagnetic analysis was carried out in this section

(Fig. 2). A preliminary study after sampling 20 levels scattered throughout the north and south outcrops was developed in order to observe the general paleomagnetic features. Sampling was carried out with an electric drill used to obtain fine grained lithologies (basically red mudstones). One or two samples per level were demagnetized by using thermal stepwise demagnetization. Measuring was carried out with a shielded triaxial cryogenic magnetometer (2G). Demagnetization involved from 11 to 15 steps, from room temperature up to 600 °C (Fig. 3). A bridge suscepti-bilimeter was used to detect any sudden susceptibility variation during all the process. A rather stable demagnetization behavior was observed, displaying up to three components. First, a viscous temperature was generally observed and fully demagnetized at temperatures below 150 °C. A low temperature component was generally found and demagnetized between 150 and around 350 °C. At higher temperatures a third component directed to full demagnetization was always present. A general stable demagneti-zation was observed, but in some cases high temperature compo-nent might display a non-consistent orientation (such as being south directed and upwards plunging or vice-versa). This could be the result of removed blocks (a fact sometimes difficult to asses) or/ and to an acquisition processes here not studied. In any case, not a single normal polarity is observed in the sampled materials. All consistent polarities in the Almenara-Casablanca cave-infilling were clearly reversed.

The observed reverse polarity perfectly fits the results which have been obtained for the biostratigraphically equivalent levels of the sections of Galera and Zújar in the Guadix-Baza Basin. There-fore, the levels of Galera 2 and Zújar 14 (Agustí et al., 1993a,b, 1997, 2001b) again characterized by the presence of the arvicolid Kislangia gusii, are placed within the geomagnetic chron 2r. The reverse polarity of the section of Almenara-Casablanca 1 can be, therefore, correlated with this chron and a lower Matuyama, pre-Olduvai age can be inferred for the large and small mammal succession from this site.

5. Almenara-Casablanca 3 (ACB 3, late early Pleistocene)

This small deposit was discovered during investigations in 1984 and has provided a diversified small vertebrate assemblage. The rodent association includes a diversified list of arvicolids (Mimomys aff. savini, Allophaiomys chalinei, Iberomys aff. huescarensis, Pliomys episcopalis), cricetids (Allocricetus bursae duraciensis), murids (Apodemus flavicollis, Apodemus mystacinus, Castillomys rivas) and glirids (Eliomys quercinus helleri; Agustí and Galobart, 1986; Agustí,

1991; Martín-Suárez and Mein, 1991; Santos-Cubedo, 2003). This association indicates a late early Pleistocene age.

Lagomorphs are represented by Prolagus sp. and Oryctolagus sp. With respect to Prolagus, there is only a third lower premolar (P_3) which presents peculiar features and does not allow a specific assignment. In a similar way, the leporid from ACB3 cannot be assigned to any species, provided the scarcity of the available material. The morphology of the P_3 permits its assignment to genus Oryctolagus (De Marfà, 2009).

The insectivore and bat representation includes Crocidura sp., Sorex cf. araneus, Neomys sp., Myotis blythi and Chiroptera indet (Furió, 2007a; Furió et al., 2005). Neomys is represented by just an upper incisor, two fourth upper premolars, one second upper molar, three third lower molars and a fragment of a hemimandible, so its specific ascription is quite difficult. However, this is enough to determine it as the oldest justified record of the genus in Spain (Furió, 2007a). The presence of Crocidura is significant from a bio-stratigraphical point of view, as Crocidura kornfeldi was the first crocidurinae which arrived in Europe (Reumer, 1984; Rzebik-Kowalska, 1995). The first occurrences in this continent corre-spond to early Pliocene sites, but the genus did not arrive in the Iberian Peninsula until the early Pleistocene (Furió, 2007b; Furió et al., 2007). In Sima del Elefante, one of the oldest occurrences of the genus in Spain, the species present is actually C. kornfeldi, and the form present in ACB 3 is fairly similar in morphology, but not in its measurements, to this same species (Rofes and Cuenca-Bescós, in press).

The amphibian and squamate representation is mainly com-posed of anurans (cf. Discoglossus, Pelobates cultripes, Pelodytes cf. punctatus, Bufo bufo, Bufo sp. and Pelophylax cf. perezi), amphis-baenids (Blanus cinereus), lizards (Chalcides cf. bedriagai and Lac-ertidae indet.) and a varied list of snakes (Natrix natrix, C. girondica, M. monspessulanus, Rh. scalaris and V. latasti). Exotic elements such as agamids or anguids are absent (Blain et al., 2007; Bailon and Blain, 2007; Agustí et al., 2009), and also the gekkonid Tarentola that may suggest a probable cooling of the climate in relation with ACB 4 and ACB 1.

The arvicolid association is close to those of a number of sites of late early Pleistocene age. The presence of Iberomys aff. huescarensis indicates an age younger than the levels of Fuente Nueva 3 and Barranco León, in the Guadix-Baza Basin, which record the oldest human evidence in Western Europe (Martínez-Navarro et al., 1997; Oms et al., 2000; Agustí and Madurell, 2003; Toro et al., 2003). ACB 3 can be correlated with other somewhat younger levels in that basin, such as Huéscar 1, Puerto Lobo and Loma Quemada (Mazo
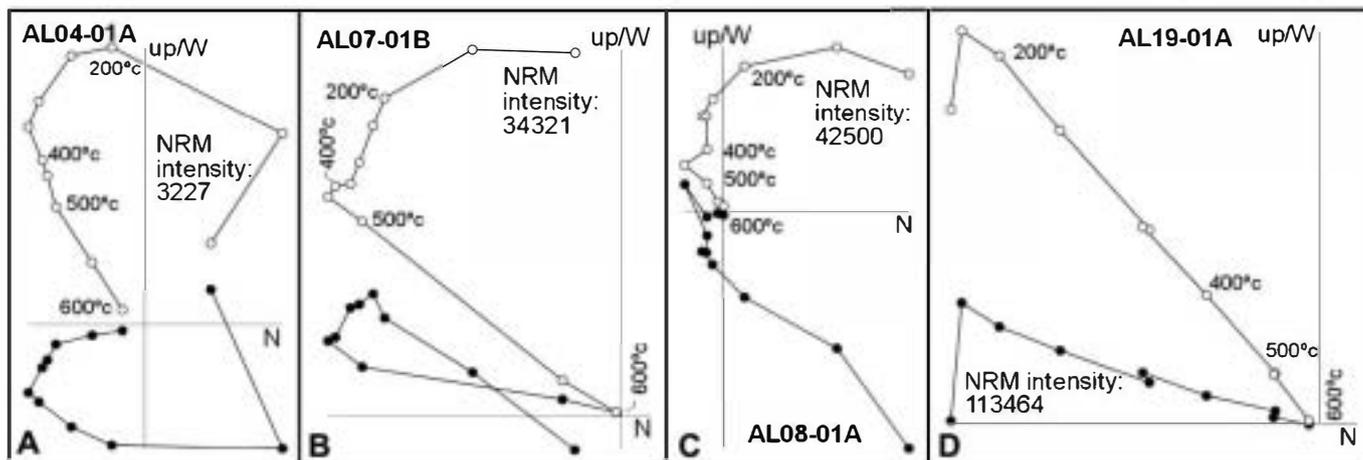

Fig. 3. Orthogonal demagnetization plots for selected geomagnetic samples from Almenara-Casablanca 1. A, B,

et al., 1985; Agusti, 1986; Agustí and Moyà-Solà, 1991). A similar association is also found in other sites with human presence, such as Sima del Elefante (Cuenca-Bescós et al., 2001) and Cueva Victoria (Carbonell et al., 1981; Alcalde et al., 1981; Agustí, 1982; Gibert et al., 2006; Blain et al., 2008). These localities share with ACB 3 the presence of *Allophaiomys chalinei*, a typical late early Pleistocene microtine from the Iberian Peninsula (Alcalde et al., 1981; Agustí, 1992). A combination of biostratigraphy (Agustí, 1982) and magnetostratigraphy (Gibert et al., 2006) in Cueva Victoria placed this site just below the Jaramillo subchron, with an estimated age of 1.07 Ma (Blain et al., 2008). Most probably, a similar age can be assumed for ACB 3.

6. Concluding remarks: the paleoenvironmental succession of the Almenara-Casablanca complex

The paleoclimatic data from Almenara-Casablanca M are too scarce to infer detailed climatic parameters, although sub-desert conditions linked to northward extension of north-African biotas due to the Messinian Salinity Crisis can be inferred from the high diversity of myocricetodontines and gerbils (*Myocricetodon jaegeri, Calomyscus* sp., *Debruijnimys almenarensis, Pseudomeriones abbreviatus*) and the low insectivore diversity.

Late Pliocene environments in the area were very different, as shown by the site of Almenara-Casablanca 4. The application of the Mutual Climatic Range (MCR) method to the amphibian and squamate associations, based on the intersection of their recent distributions, permits to estimate a number of climatic parameters (Blain et al., 2009; Agustí et al., 2009). According to this method, mean annual temperature (MAT) for ACB 4 can be estimated to 17.1 ± 1.5 °C ($+0.1$ °C compared to present), with temperature of the coldest month (MTC) at 9.1 ± 2.4 °C (-1.4 °C compared to present) and temperature of the warmest month (MTW) at 24.6 ± 1.1 °C ($+0.1$ °C compared to present). Mean annual precipitation (MAP) is estimated as 711 ± 229 mm ($+261$ mm compared to present). These data are in concordance with the occurrence in ACB 4 of exotic reptiles such as the agamid lizards, which currently live under climate with MAT higher than 15 °C, and anguid lizards (*Dopasia*), which suggest more humid environmental conditions than today. They are also consistent with the presence of the red-toothed shrews *Deinsdorfia* and *Sorex minutus*, which use to live in moist local environments (Reumer, 1984). Moreover, the insectivore assemblage is largely dominated by the white-toothed crocidosoricine shrew *Myosorex*, which indicates rather warm conditions. Within moles, the digging forms of the genus *Talpa* are indicative of soft soils with a constant degree of humidity, while the diving forms of the genus *Desmana* are indicative of the existence of water masses in the surroundings. Among the bats, although the vespertilionids are represented by few remains, the co-existence of *Myotis emarginatus, Plecotus* sp. and *Eptesicus* sp. indicates a quite diverse environment in the vicinity of the locality, with less arid conditions than today and a certain development of wooded areas.

With respect to Almenara-Casablanca 1, the application of the MCR method to the amphibian and squamate association shows that MAT are estimated to 16.5 ± 2.4 °C (-0.5 °C compared to present), with MTC at 9.0 ± 4.0 °C (-1.5 °C compared to present) and MTW at 24.4 ± 1.4 °C (-0.1 °C compared to present). MAP are calculated as 794 ± 184 mm ($+344$ mm compared to present). As in the case of ACB 4, these data are confirmed by the insectivore association, characterized by the co-occurrence of aquatic and burrower moles and the high diversity of shrews, which suggests the dominance of warm conditions with a high degree of humidity in the environment and the presence of some kind of open waters nearby.

In the case of Almenara-Casablanca 3, the application of the MCR method to the amphibian and squamate association suggests that MAT was equal to 14.9 ± 3.6 °C (-2.1 °C in relation with present), with MTC equal to 7.3 ± 4.0 °C (-3.2 °C in relation with present) and MTW equal to 23.9 ± 2.3 °C (-0.6 °C in relation with present). MAP was 683 ± 125 mm ($+233$ mm in relation to present). Among the Soricidae, the overwhelming dominance of *Crocidura* remains (representing around 90% of the soricid assemblage) suggests relatively dry environmental conditions. However, the anecdotic presence of *Sorex* and *Neomys* could be indicative of a small peak of moisture in time or space in the neighbouring area. Currently, the assemblage of these three soricids looks more similar to a recent community than ACB 1. The area is nowadays dominated by a typical Mediterranean climate. Therefore, the conditions during most of the year are too dry for red-toothed shrews, the area being only currently inhabited by white-toothed shrews of the genera *Crocidura* and *Suncus*.

Such MCR intersections for the various localities of the Almenara-Casablanca karst complex suggest a MAT somewhat similar to the present during the late Pliocene-earliest Pleistocene, and cooler at the end of the early Pleistocene (-2.1 °C in ACB 3). Continentality was slightly stronger, as winters were colder (in particular in ACB 3, with -3.2 °C) but summer temperatures remained unchanged. The values for rainfall (MAP) were not so strongly different from those of today, although the values indicate more humid conditions than today for the late Pliocene and the earliest Pleistocene.

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