

## A Palaeoenvironmental estimate in Askondo (Bizkaia, Spain) using small vertebrates

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### Abstract

The cave of Askondo (Mañaria, Bizkaia, Spain) is an archaeological site on the western flank of Asko Mount. Archaeological excavations in 2011 have provided a prehistoric and historic sequence from the Middle Palaeolithic to the Bronze Age. Circa 3,000 microvertebrate elements (including mammals, reptiles, and amphibians) were recovered, of which 387 were identified to the genus and/or species levels. The small mammal assemblage comprises at least 17 taxa: nine species of rodents (*Glis glis*, *Apodemus sylvaticus-flavicollis*, *Arvicola amphibius*, *Microtus agrestis*, *Microtus arvalis*, *Microtus (Terricola) sp.*, *Microtus oeconomus*, *Chionomys nivalis*, and *Clethrionomys glareolus*), two insectivores (*Sorex araneus-coronatus* and *Talpa sp.*), three amphibians (*Bufo calamita*, *Bufo bufo*, and *Rana temporaria-iberica*), and three reptiles (Lacertidae indet., *Anguis fragilis*, and Colubridae indet.). This assemblage has enabled us to roughly reconstruct the environmental conditions that prevailed in the cave's surrounding area. It evolved from a landscape with considerable woodlands to an arid one, characteristic of cold conditions, at the beginning of the Upper Palaeolithic (ca. 35,300 cal BP). After a short episode of alternating woodland expansion and contraction, the woodlands expanded again at the end of the Solutrean (ca. 21,000 cal BP). Finally, at the top of the sequence, the climate began a warming trend that has led to its current landscape.

**Keywords:** Small vertebrates; Palaeoenvironment; Upper Pleistocene; Holocene; Cantabrian Range; Iberian Peninsula.

### 1. Introduction

Much has been written about the Late Pleistocene and Holocene climate of the Cantabrian Range. The study of microvertebrate remains has proven to be a rich source of information on environmental and ecological conditions (e.g. Cuenca-Bescós *et al.*, 2009; López-García *et al.*, 2011a; Rofes *et al.*, 2013a; Sesé, 2009). However, most research in this field has focused on small mammals, with only a few attempting to include data provided by herpetological remains.

The aim of this paper is to reconstruct the palaeoenvironmental and palaeoclimatic conditions prevailing around Askondo Cave during the Upper Pleistocene and Holocene (60,000–ca. 3,500 cal BP) based on the small vertebrate assemblage. This data enables us to recreate the landscape and the presence of humans during the Middle and Upper Palaeolithic in this region, a work already begun at several sites such as Arlanpe (García-Ibaibarriaga et al., 2013), Baltzola, and Bolinkoba.

## 2. The site

Askondo Cave (also called Azkondo) is situated in Mañaria (Urkiola Nature Park), on the western flank of Asko Mount, at an elevation of 248 masl (metres above sea level; UTM coordinates of X: 527.350; Y: 4.775.430 ETRS89 30N) (Figure 1). Geologically, it opens onto the foothills of the infra-Cretaceous limestones, which contain rudists and corals. The observable karst cavity throughout Askondo Cave has a linear development of 302 m and a total drop of 9 metres.

(INSERT FIGURE 1 HERE)

Askondo is one of the few sites with Palaeolithic rock art in the easternmost provinces of the Bay of Biscay (Garate and Rios-Garaizar, 2011). The first known scientific intervention in Askondo Cave was undertaken in the early 1910s by Galvez Cañero (1912), who found a few archaeological remains. Despite the finding of two *Ursus spelaeus* skulls in 1963 and evidence of other palaeontological remains (such as hyena bones), further work was not undertaken until 2011. In January of that year, several Palaeolithic parietal markings were noted during a visit to the cave involving a project to locate a possible archaeological site (Garate and Rios-Garaizar, 2012).

Currently the cave has a single entrance, 25 m above the course of Urkuleta Stream. Damage caused by a quarry (Kanterazarra) affects the entrance and part of the first chamber. Other alterations have been observed in the surface of the cave, mainly in the inner parts, related to clandestine excavations, entailing partial (but unquantifiable) losses.

An area of 5 m<sup>2</sup> was excavated in 2011. The aim was to document the archaeological record in the cave to evaluate its potential and to search for signs of human activity related to the rock art. The works were conducted in two different zones: the entrance (square U7 in the archaeological grid) and the vestibule (squares O13-O14-N14 and O17) (Figure 2). In U7, only levels 1–5 were excavated, whereas in square O13, 13 archaeological levels (1.70 m deep) were identified. In squares O14, N14, and O17, the works stopped at level 2 due to the presence of a crust. In order to document the complete stratigraphic sequence, a geological test was conducted 52 cm away from the S section of O14 (Figure 2). This test trench provided a detailed overview of the ~6 m deep sedimentary sequence (without reaching the bedrock), where the 13 archaeological layers identified in the excavation pit correspond to the upper third of this sedimentary deposit (Garate and Rios-Garaizar, 2012; Iriarte *et al.*, 2012). These levels can be grouped into five chrono-cultural units: Middle Palaeolithic (MP; AAR dates, Torres and Ortiz, 2012), Aurignacian (Aurig.), Gravettian (Grav.; indirect data provided by a piece of bone embedded in the wall suggest a mean age of 27,830 cal BP, while the palaeoecological record suggests a younger age near HE 2, although in both cases it could

correspond to a Gravettian chronocultural period), Solutrean (Sol), and Bronze Age (BA) (Table 1). The cultural affiliations of the successive levels, especially in those cases for which we have no direct dating, were established on the basis of their different lithic, bone and/or pottery industries.

(INSERT FIGURE 2 HERE)

(INSERT TABLE 1 HERE)

### 3. Material and methods

#### 3.1. Fieldwork and collecting techniques

The palaeontological material analysed consists of disarticulated skeletal fragments (teeth, isolated mandibles, skull fragments, and post-cranial bones) of small vertebrates, although other faunal remains have been identified as well (Table 2). Sediments were recovered from at least 0.5 m<sup>2</sup> for all the stratigraphic units. In square O13, all the identified levels have been sampled, whereas the rest of the squares only provided samples corresponding to levels 1 to 3 (except U7, which was sterile in microvertebrate remains). The correlation between different squares was established based on their archaeological remains. The 409.5kg of sediment were water-screened using a stack of sieves of decreasing mesh size (4 mm to 0.5 mm). The microfossils were separated from residue coarser than 0.5 mm, classified, and studied with the aid of a binocular microscope (Nikon SMZ-U). This assemblage includes a total of 2,918 fragments, of which 387 were identified to the genus and/or species level following the general criteria of small-vertebrate palaeontology.

(INSERT TABLE 2 HERE)

#### 3.2. Systematic attribution and quantification

Each species was identified based on cranial and post-cranial diagnostic elements: isolated teeth for the Gliridae and Murinae (Daams, 1981 and Pasquier, 1974 respectively); first lower molars for the Arvicolinae (Heinrich, 1982; Van der Meulen, 1973); mandibles, maxillae, isolated teeth, and post-cranial skeleton for the Talpidae and the Soricidae (Reumer, 1984); skull elements for the Lacertidae (Blain, 2009); and cranial and post-cranial skeleton for the amphibians (Bailon, 1999). The taxonomic classification for small mammals follows Wilson and Reeder (2005) and Tesakov et al. (2010), whereas that for amphibians and reptiles follows Carretero *et al.* (2011).

The relative ratios of fossil species were established with the minimum number of individuals (MNI) and used as a quantitative measure to reconstruct the palaeoenvironment (Table 3). To determine the MNI, a diagnostic tooth (e.g. first lower molar in arvicolines) or post-cranial elements were considered, taking into account laterality and sex whenever possible.

(INSERT TABLE 3 HERE)

#### 3.3. Habitat types and climate categories

To reconstruct the palaeoenvironment at Askondo Cave, we have specified five types of habitat (see Table 3) based on the environmental affinities of different species following Cuenca-Bescós *et al.* (2009) and Rofes *et al.* (2013a). As Askondo has a relatively recent chronology and all the fauna present at the site is extant, it is possible to distribute each taxa according to the habitat(s) they mostly inhabit. The habitats are defined below:

1. Rocky (Ro): species living in open rocky or stony substratum areas, usually above the timberline. In spite of its name, this type of habitat does not necessarily need to be located in high mountainous landscapes.

2. Humid meadow (HM): evergreen meadows with dense pastures, dense plant cover, and suitable topsoil.

3. Grassland (Gr): dry grassland or open meadows with seasonal climate variations associated with relatively harsh conditions.

4. Water (Wa): areas along streams, lakes, ponds, or marshes. These indicate abundant superficial water, either streaming or stagnant.

5. Forest (Fo): from leafy forest to woodland edges. Mature forest including woodland margins and patchy forest with moderate ground cover.

Due to the sensitivity of small animals to climate conditions, their distributions serve as a proxy of climate change; nonetheless, the reconstruction depends on whole assemblages rather than on the presence of only one or two species. Therefore, in order to reconstruct the palaeoclimate, we compare the abundance ratio of rodent species indicative of deciduous forest, warmer and moister environments (*Glis glis*, *Apodemus sylvaticus-flavicollis*, and *Clethrionomys glareolus*) to those of more open terrains such as grasslands (all Arvicolinae described in this paper except *C. glareolus* and *Arvicola amphibius*). A proportional decrease in rodents indicative of woodlands corresponds to a cooling of environmental conditions (they range, if dominant, from severe, steppe climates typical of glacial advances to periods of cool or temperate weather, if not dominant), whereas warming conditions are inferred from an increase in the proportion of these species. Considering the geographic situation of some areas of the Basque Country, and bearing in mind that in these areas the progress of deciduous forests is related to an improvement in climate conditions (Iriarte-Chiapusso and Murelaga, 2012), we proposed that this method is more useful than the “warm vs. cold” climate model (Murelaga *et al.*, 2012, 2009). The remaining species are not useful for the determination of climate evolution and so are omitted in the subsequent analysis.

The habitat and climate identifications of each species were provided by Janeau and Aulagnier (1997), Palomo and Gisbert (2005), Sesé (2005), Cuenca-Bescós *et al.* (2009), and Rofes *et al.* (2013a).

As they are highly digested, low in number and/or lack precise taxonomical (i.e. to the species level) and habitat assignments, the reptile and amphibian elements are not suitable for palaeoenvironmental reconstructions of Askondo Cave although they can be a useful complement (see Section 5.1).

### 3.4. Taphonomic remarks

A complete taphonomic study has not been performed, but some preliminary observations can be made about the composition and modifications (such as fragmentation) of skeletal elements.

The accumulation of small vertebrate remains in karstic cavities is usually generated by the activity of biological agents, commonly nocturnal birds of prey, and by small carnivorous mammals to a lesser extent. The accumulating agent can be determined based on the type of chemical corrosion (Andrews, 1990) as the gastric juices of small mammals attack bones more aggressively.

In Askondo Cave, small mammal remains show light to moderate gastric digestion and scant breakage, indicating that most of the bones were likely accumulated by a category 1 raptor (*sensu* Andrews, 1990). They could correspond to an opportunistic rather than a selective hunter such as a barn owl (*Tyto alba*). The low number of remains is likely due to the location of the test trench, almost 8 m deep in the cave. The remains were probably transported from the initial accumulation area to this one by dragging in a small stream given that the sedimentological features and the bones have no alterations produced by strong fluvial drag, such as rounding or polishing.

For the herpetofaunal remains (and even though in some cases remains in caves may come from *in-situ* mortality), the pattern of skeletal-element frequency, the high percentage of breakage, and the moderate to considerable gastric digestion indicates that the fossils probably come from predation of Categories IV to V on Andrews' scale (1990). Although we are not able to pinpoint the exact predator responsible, likely agents of deposition were small mammalian carnivores such as foxes, wildcats, and/or mustelids (Andrews, 1990; Pinto Llona and Andrews, 1999)

## 4. Results

### 4.1. Small vertebrate assemblage

The Askondo small vertebrate fauna consists of 387 remains (NISP), among which 166 individuals (MNI) have been counted. The faunal list is composed of 17 taxa: one glirid (*Glis glis*), one murid (*Apodemus sylvaticus-flavicollis*), seven arvicolids (*Arvicola amphibius*, *Microtus agrestis*, *Microtus arvalis*, *Microtus (Terricola) sp.*, *Microtus oeconomus*, *Chionomys nivalis*, and *Clethrionomys glareolus*), one talpid (*Talpa sp.*), one soricid (*Sorex araneus-coronatus*), three amphibians (*Bufo calamita*, *Bufo bufo*, and *Rana temporaria-iberica*), and three reptiles (Lacertidae indet., *Anguis fragilis*, Colubridae indet.) (Murelaga *et al.*, 2012). Figure 3 shows selected specimens of nearly all the small vertebrates recovered from Askondo.

Most of the taxa identified are currently present in the area of the Urkiola Natural Park (Aranzadi, 1989), with the exception of *M. oeconomus*, which nowadays has a wide range extending from north-western Europe to Alaska in the east. The common shrew (*S. araneus*) is absent in most of the Iberian Peninsula (although there are some isolated populations in the Pyrenees according to Palomo and Gisbert, 2005) as a result of shrinkage after the Würm glaciation as well as due to the pressure exerted by the progressive expansion of its congeneric

*S. coronatus*). Finally, *B. calamita* has a more southerly distribution, although isolated communities have been found in the northern coastal strip.

(INSERT FIGURE 3 HERE)

#### 4.2. Small mammalian community changes over time

The differences between the assemblages from the lower and upper Askondo units are noteworthy.

(INSERT FIGURE 4 HERE)

There is an increase in the percentages of the MNI and in species diversity (see Table 3) nearing the end of the sequence. Whereas in the lower units (Middle Palaeolithic–Aurignacian) there are 3–5 individuals representing 2–5 species, in the upper units (Solutrean–Bronze Age), the MNI and the diversity increase, reaching a minimum number of 66 small mammals from 11 different taxa in the two uppermost levels. This change is probably related with the climate improvement in the Holocene.

Some species are represented in only one or two levels, such as *C. glareolus* and *C. nivalis*. By contrast, other (*A. sylvaticus-flavicollis*, *M. agrestis*, and *M. arvalis*) are found in practically all the sequence and increased in number towards the uppermost levels (Figure 4).

In the Middle Palaeolithic levels (13–11), the most abundant genera are *A. amphibius* and the group of *M. agrestis-arvalis*, representing 75% of taxa identified in those levels. The remaining species in order of abundance are *A. sylvaticus-flavicollis*, *Talpa* sp., and *G. glis*.

The Aurignacian period can be divided into two parts. In the first part (level 10), the identified species are *M. arvalis* and *C. nivalis* (one of only two levels in which an identifiable element of this latter species has been documented). In the second part (level 9), the most abundant taxa are *A. amphibius* and *M. arvalis*; *C. nivalis* disappears, whereas *M. (Terricola)* sp., *M. oeconomus*, and *S. araneus-coronatus* appear for the first time.

Coinciding with abandonment of the cave by humans and occupation by cave bears (level 8; ca. 29,600 cal BP), the most abundant species is the *M. agrestis-arvalis* group. *M. (Terricola)* sp. and *M. oeconomus* disappear, and *A. sylvaticus-flavicollis* reappears. The subsequent palaeontological levels show a general decline in the number of species present in the fossil record, suffering the most dramatic reduction of the entire sequence. In level 7, *M. oeconomus* reappears and *A. amphibius* disappears. In the next two levels (6–5), the number of specimens reaches the lowest numbers of the entire sequence, with only two species in level 5 (*Talpa* sp. and *M. agrestis*). In this level (5), *S. araneus-coronatus* disappears. These changes are likely due to the presumable reoccupation of the cave by humans (level 5 is probably when the paintings were executed).

From the Solutrean level onwards, both the number of individuals and diversity increased significantly. The record is dominated by *A. sylvaticus-flavicollis*, followed in descending order of MNI by *M. agrestis*, *A. amphibius*, and *S. araneus-coronatus*. *M. oeconomus* and *M. arvalis* declined until their disappearance during the Bronze Age, the former being absent from the

zone in the present day. By contrast, and as previously pointed out by López-García *et al.* (2011a) in the cave of Valdavara-1, the presence of *C. glareolus* only in the upper unit is consistent with other Holocene micromammal assemblages in the northern Iberian Peninsula, such as those of El Mirón (Cuenca-Bescós *et al.*, 2008) and Amalda (Pemán, 1990).

#### 4.3 Palaeoenvironment and palaeoclimate evolution

Based on a study of small mammal fossils recovered in the Askondo stratigraphic sequence, we have reconstructed the habitat and climate distribution, as shown in Figure 5 (constructed by crossing data from Figure 4 and Table 3). The assemblage attests that the environment was clearly dominated by open landscape. Humid meadows and grasslands comprised more than 60% of the habitats in nearly every level (with the exception of levels 2 and 1), determined by the large number of both *M. agrestis* and *M. arvalis* (mean 35%) and *A. amphibius* (mean 16%).

Surprisingly, given the cave's location in a mountainous area (García-Moreno, 2012), rocky landscapes comprise only a very small percentage of this association, mainly noted through the presence in levels 10 and 2 of *C. nivalis*. Particularly noteworthy is the low percentage of species associated with forest cover, basically confirmed by the scarce remains of *G. glis*, *A. sylvaticus-flavicollis*, and *C. glareolus*.

The global panorama represented by the community of small mammals suggests that the landscape surrounding the site was predominantly open during the Middle Palaeolithic, with a prevalence of grasslands and humid meadows (although some taxa related with arboreal vegetation have been also detected). Gradually, as indicated by the disappearance of *G. glis* and *A. sylvaticus-flavicollis*, incipient aridification is noted, reaching significantly drier and harsher conditions at the beginning of the Upper Palaeolithic (ca. 35,300 cal BP).

After level 9, there was a moderate climate recovery reflected by advancing forests. Humidity was probably higher, as indicated by the appearance of the root vole (*M. oeconomus*). Note that at this point the humid meadows reached their maximum values in the sequence.

In level 5, the assemblage documents an expansion of open habitats and the dominance of cold conditions even though the humidity level was probably higher than in the previous cold episode. The scarce diversity and the low minimum number of individuals corroborate these harsher conditions.

During the Upper Solutrean (ca. 21,100 cal BP), a progressive improvement in climate is noted. After a hiatus, towards the Bronze Age (levels 2–1), there is a marked increase in wooded habitats overtaking open dry meadows, the former turning into the dominant habitat at the top of the sequence.

(INSERT FIGURE 5 HERE)

## 5. Discussion: Comparisons with Other Proxies

### 5.1. Amphibian and reptile record

Although nowadays there is a relatively high diversity of both amphibians and squamate reptiles in Urkiola Natural Park, with seven species (two urodeles and five anurans) and ten

reptile species (six saurians and four ophidians) respectively (<http://www.urkiola.net>), there is a remarkable lack of these taxa in the archaeological record of Askondo Cave (Table 4). This relative absence is probably related with the stream-borne accumulation discussed above. We are not able to extract habitat or climate inferences from the imprecise Lacertidae indet. or Colubridae indet., but it is worth mentioning the ecological requirements of the common/Iberian frogs (*R. temporaria-iberica*), and the true toads.

(INSERT TABLE 4 HERE)

The presence of members of the genus *Rana* supports the almost continuous record of forested and humid habitats throughout the sequence. *R. temporaria* is widely distributed in the territory except in coastal areas and the southern and arid regions. This hygrophilous species is typical of temperate humid deciduous forest. On the other hand, *R. iberica* is a monotypic endemic species restricted to the northern Iberian Peninsula that, in the autonomous community of the Basque Country, exclusively inhabits secondary water courses (Aranzadi, 1989). In Askondo, the remains of *R. temporaria-iberica* have been found in levels with high humidity or in levels with no human presence.

Currently, there are two species of the genus *Bufo* in the Iberian Peninsula, but only *B. bufo* inhabits the study area as *B. calamita* prefers areas with a Mediterranean climate. The presence of true toads may be conditioned by the existence of permanent, deep water sources (Pleguezuelos *et al.*, 2002).

Noteworthy is the practical absence of *A. fragilis*, a hygrophilous reptile common in Pleistocene and Holocene archaeological records of the northern Iberian Peninsula, such as Peña Larga (Rofes *et al.*, 2013b), Santimamiñe (Rofes *et al.*, 2013a), Sima del Elefante (Blain *et al.*, 2010), and Valdavara-1 (López-García *et al.*, 2011a). Also remarkable is the scarcity of species related with water sources given that the cave is only 25 m above the course of the Mañaria River.

## 5.2. Large mammal and anthropological record

Askondo Cave has yielded a large mammalian assemblage (Castaños *et al.*, 2012) composed of both wild and domestic taxa (in Holocene levels): seven Artiodactyla species, one Perisodactyla, and four carnivore taxa (Table 2). The site has generated 6,633 macromammal remains, unevenly distributed in the different excavation pits: N14 is virtually sterile, O14 and O17 yielded 1.2% and 2.8% of the faunal content respectively, U7 supplied 9.3% of the content, and the remaining 87.1% was found in square O13.

In terms of the number of specimens and taxa, the cave bear clearly dominates the Pleistocene assemblage. This taxon is also present in Holocene levels, which seems to be due to the re-working of old sediments or the incorporation of transported bones that were originally on the surface in other parts of the cave. These levels have also yielded a few human remains dated to the Bronze Age, probably of the same ten-year-old individual (Gómez-Olivencia, 2012). Garate and Rios-Garaizar (2012) propose two hypotheses for the presence of domestic fauna at the site: these remains could be associated with funeral rites apparently carried out during the formation of level 2 or are traces of sporadic use of the cavity as an occupational site.



In the Palaeolithic layers, the differences in the number of remains (NR) and the anatomical representation and fragmentation document cave occupation alternating between cave bears and groups of Palaeolithic hunter-gatherers from the early Middle Palaeolithic to the Upper Palaeolithic.

Most of the taxa from the Askondo Pleistocene levels are tolerant to a wide range of temperatures and habitats. Nonetheless, some elements suggest different ecosystems in the surrounding landscape. Forest environments are indicated by the presence of *Capreolus capreolus* and, to a lesser extent, by the Bovini. Meanwhile, *Rupicapra pyrenaica* and *Capra pyrenaica* are species characteristic of rocky, mountainous areas, consistent with the cave location.

In Askondo, according to the palaeoenvironmental reconstruction based on small mammals, woodlands began to increase in extent by the end of the Solutrean. However, *C. capreolus* and the Bovini had already been present in significant numbers since the Middle Palaeolithic. Finally, the remains of the chamois and the Iberian wild goat are consistent with the small-mammal results, being more numerous when the climate is more arid and cold (levels 10 and 5).

### 5.3. Other palaeoenvironmental reconstructions with small vertebrates from northern Iberia

In recent years, several studies with palaeoenvironmental and palaeoclimatic approaches to Late Pleistocene and Holocene deposits in northern Iberia have been published on the basis of small-vertebrate assemblages. Chronologically, we can therefore compare our results with different sites that roughly coincide with Askondo in a regional perspective. The studies of close sites such as Aitzbitarte III (Pemán, 2011) have not been taken into account due to methodological differences, even though from a chronological and palaeoenvironmental point of view they present important similarities with Askondo Cave.

In the well-known El Mirón Cave (in the Ason River valley, Ramales de la Victoria, Cantabria), the base of the sequence has been radiocarbon-dated to circa 41,000 cal BP. The palaeoenvironmental reconstruction carried out with small mammals (Cuenca-Bescós *et al.*, 2009) shows an open landscape with high humidity, a similar pattern of habitat to that found at Askondo.

The transition from the Middle Palaeolithic (Mousterian) to the Upper Palaeolithic (Aurignacian) has been recorded in Cueva del Conde, a large cavity 180 masl in the Nalón River valley (Santo Adriano, Asturias). The small vertebrate assemblage indicates a patchy landscape dominated by humid meadows and woodland areas, while the temperature and precipitation parameters were slightly more severe than in the present day in the area (López-García *et al.*, 2011b). The sequence differs slightly as that of Askondo is characterized by a harsh climate.

To study the Gravettian chrono-cultural period, we have taken the data for level 128 from El Mirón. At this stage, the small mammals indicate a contraction of humid meadows as they were taken over by montane and dry grassland habitats (Cuenca-Bescós *et al.*, 2009). As stated above, at this period Askondo Cave was occupied by cave bears, and the data of level 5 is

indirect. Levels 8 and 7 indicate less harsh conditions although, at the end of the period, the small mammal assemblage is typical of cold climates.

In contrast with the situation at El Mirón (Cuenca-Bescós *et al.*, 2009), where no taxa indicative of woodland environment were recorded in the Solutrean, in Askondo forests started to spread at this stage, becoming the dominant landscape in the Bronze Age, as in many archaeological sites of this period (El Mirón, Cuenca-Bescós *et al.*, 2009; Santimamiñe, Rofes *et al.* 2013a; El Mirador, Bañuls-Cardona *et al.*, 2013).

#### 5.4. NGRIP $\delta^{18}\text{O}$ curve and diverse climate events

We have correlated our data on habitat and climate distribution with the calibrated radiocarbon ages (given in Table 1) with the  $\delta^{18}\text{O}$  curve obtained from NorthGRIP ice cores including the Greenland Ice Core Chronology (GICC05) timescale (see Figure 5), which is considered the “regional stratotype” for the North Atlantic region (Svensson *et al.*, 2008; Austin *et al.*, 2012). We also compare our results with several well-known climate events such as cold Heinrich Events (HE) or warm Greenland Interstadial (GI) events.

Towards the end of the Marine Isotope Stage (MIS) 3, the colder peak inferred from the small vertebrate assemblage in level 10 (ca. 35,300 cal BP) could correspond to a colder trend identified after the warm event GI-7 in the NGRIP-GICC05 isotopic curve. Similarly, the colder peak indicated in our palaeoclimatic curve for level 9 could be correlated with the beginning of HE 3. By contrast, the transitory warming detected towards level 8 (ca. 29,600 cal BP) seems to correspond with the warmer tendency detected after the HE 3 event in the NGRIP-GICC05 record that culminated in the GI-4 warm event.

At the beginning of the MIS 2 (levels 7–6), small vertebrate assemblages indicate relatively temperate climate conditions. The colder peak observed in level 5 seems to correspond with the HE 2 identified in the NGRIP-GICC05 isotopic curve (dated at ca. 23,700 cal BP). However, the warming trend determined towards level 4 (ca. 21,100 cal BP) points to the development of warmer climate conditions during the Last Glacial Maximum (LGM) compared with those at the beginning of MIS 2. This interpretation is coherent with the observations of Roucoux *et al.* (2005), who considered the LGM in the Iberian Peninsula as a rather warmer and moister event than some MIS 3 stadial events.

Regarding the Holocene, a trend towards warmer and moister climate conditions, similar to that registered nowadays, has been inferred.

#### 5.5. Occupational dynamics of the cave

The Middle Palaeolithic levels (13–11) of the Askondo test trench have yielded scant lithic evidence: one, two, and four respectively (Garate and Rios-Garaizar, 2012). These remains, together with the finding of diverse herbivore bones (such as those of Bovini, *C. pyrenaic*, or *Cervus elaphus*) with human intervention traces, confirm a sporadic use of the cave by Middle Palaeolithic hunter-gatherers during a mainly temperate and moist period.

The archaeological record of the Aurignacian period (levels 10–9) has provided more remains than previous levels. The lithic industry is significantly more abundant, documenting two short

episodes of bladelet knapping. Numerous unidentifiable bone fragments with varying cremation scales has suggested their use as fuel, which could be explained by the lack of trees in the surrounding area (this practice was fairly common in the Mousterian and Aurignacian periods, as reported by Yravedra *et al.*, 2005). This situation is consistent with the palaeoenvironmental reconstruction based on small mammals, which indicates an open landscape with little tree covering typical of harsh climates.

After a phase of abandonment of the cavity by humans and reoccupation by cave bears (level 8, ca. 29,600 cal BP), Askondo was re-occupied by humans in level 5, as indicated by human activity remains related with animal processing and the production of stone tools. The small mammal assemblage points to a certain climate improvement in level 7, prior to the aridification recorded in levels 6 and 5.

At the end of the Upper Solutrean there is a small clast level and some faunal remains. Based on the small vertebrates, the people inhabiting the cave in this period probably witnessed the first steps towards a woodland recovery in the surrounding area.

Finally, during the Bronze Age, small fires were made, animals were consumed (chamois, wild boar, deer) and a set of human remains (belonging to a 10-year-old individual) were deposited. It therefore seems that one of the uses of the cave during this time was for burials. Unlike nearby sites, such as Santimamiñe (Rofes *et al.*, 2013a) or Peña Larga (Rofes *et al.*, 2013b), the woodland did not decrease. Indeed, an increase in species associated with this habitat is noted, perhaps due to the aforementioned location of the cave in a mountainous area.

## **6. Summary and Conclusions**

The Askondo Cave small vertebrates enable us to reconstruct the environmental conditions that prevailed in the surrounding area of the cavity and provide us with new data on conditions in the NE Iberian Peninsula during the Late Pleistocene and Holocene.

The almost 6 m deep sedimentary test trench, divided into 13 archaeological levels, has provided a discontinuous prehistoric and historic sequence, comprising Middle Palaeolithic, Aurignacian, Gravettian, Solutrean, and Bronze Age chrono-cultural units. A minimum of 166 small mammals, amphibians, and reptiles were identified either to genus or species level, representing at least 17 taxa. The small-vertebrate assemblage mainly accumulated naturally due to raptors, although herpetofaunal remains may correspond to the action of small burrowing carnivores.

The palaeoenvironmental reconstruction based on small mammals roughly coincides in general interpretations with other habitat and climate proxies, such as herpetological remains and the record of large mammals on the local scale, other long-term palaeoenvironmental reconstructions from northern Iberia on the regional scale, and an ice core from central Greenland and well-known north Atlantic and continental climate episodes on the global scale.

The conditions inferred by small mammals during the Middle Palaeolithic in the vicinity of the cave were predominantly temperate, marked by a deciduous forest landscape. The conditions shifted to an open landscape and dry and harsh conditions at the beginning of the Upper Palaeolithic. At nearly 29,600 cal BP, the woodland areas expanded once again, and were then

replaced by mostly cold and humid conditions. At the end of the Solutrean, small mammals indicate temperate conditions and a patchy landscape. After a hiatus, the sequence ends with a general warming and woodland expansion during the Holocene.

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Figure 1  
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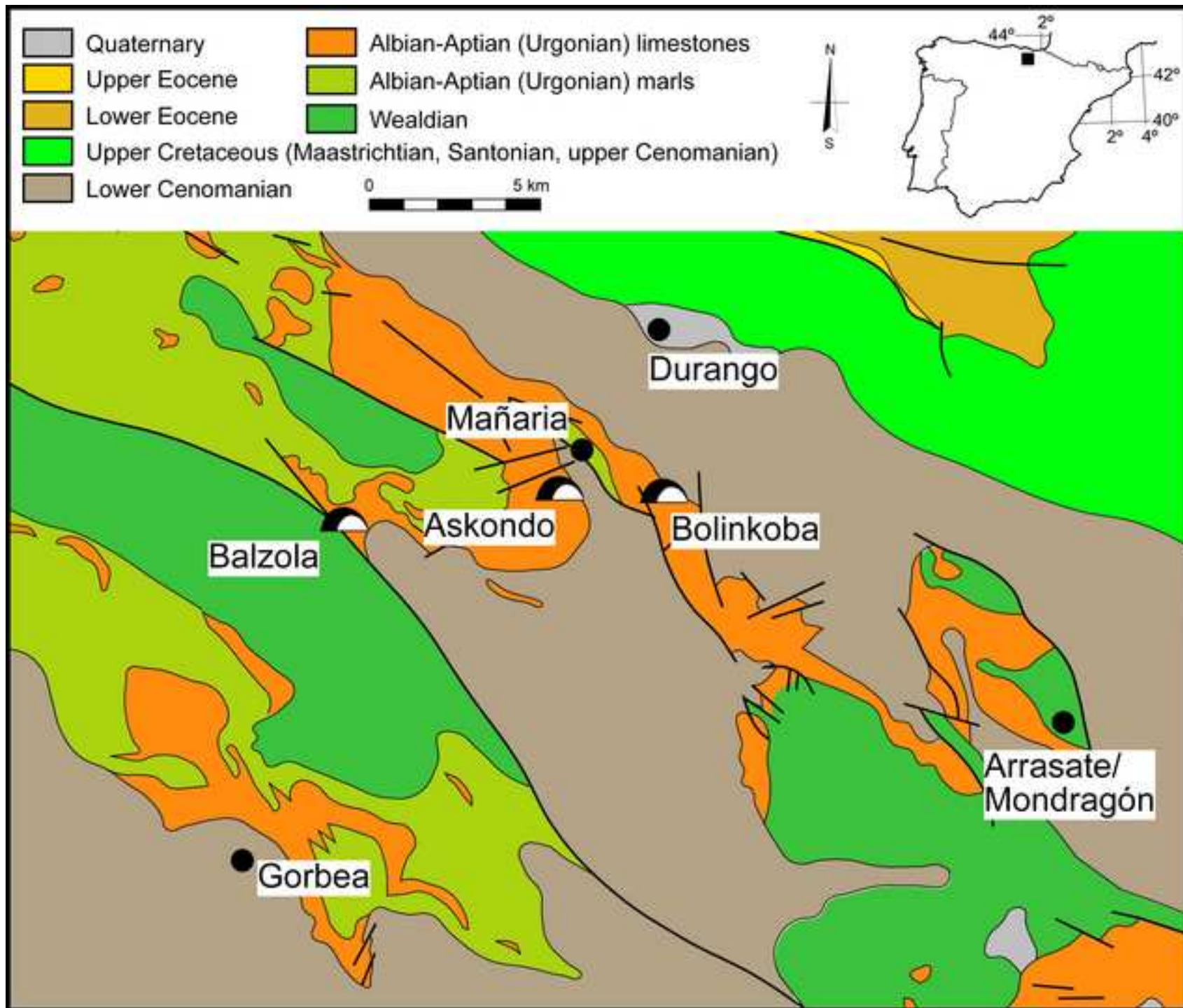


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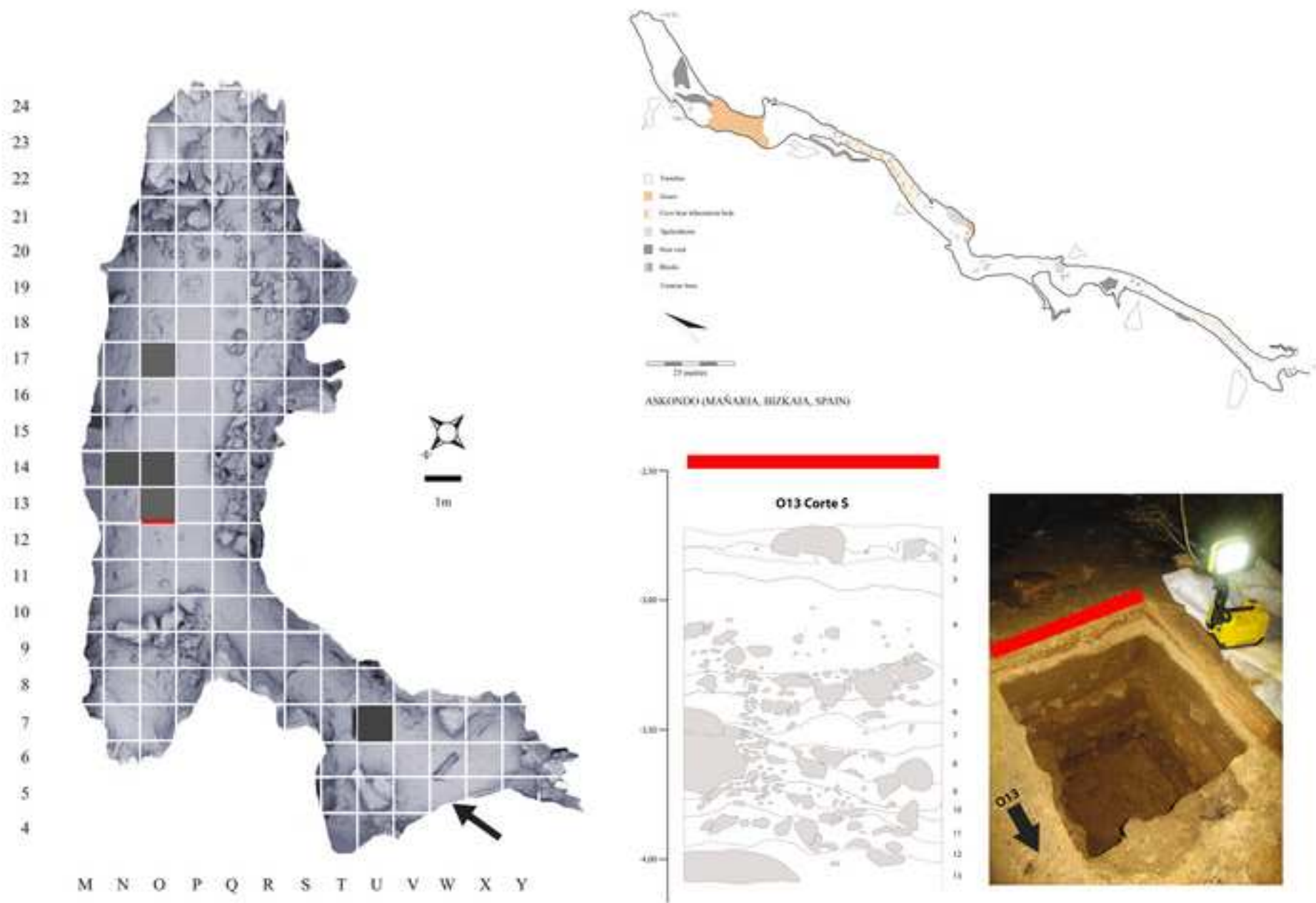
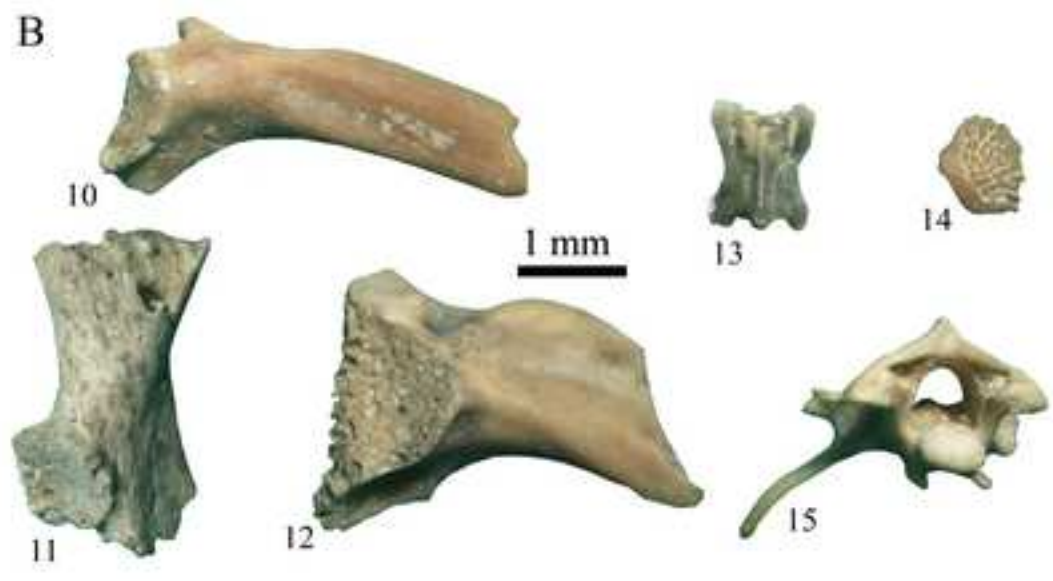
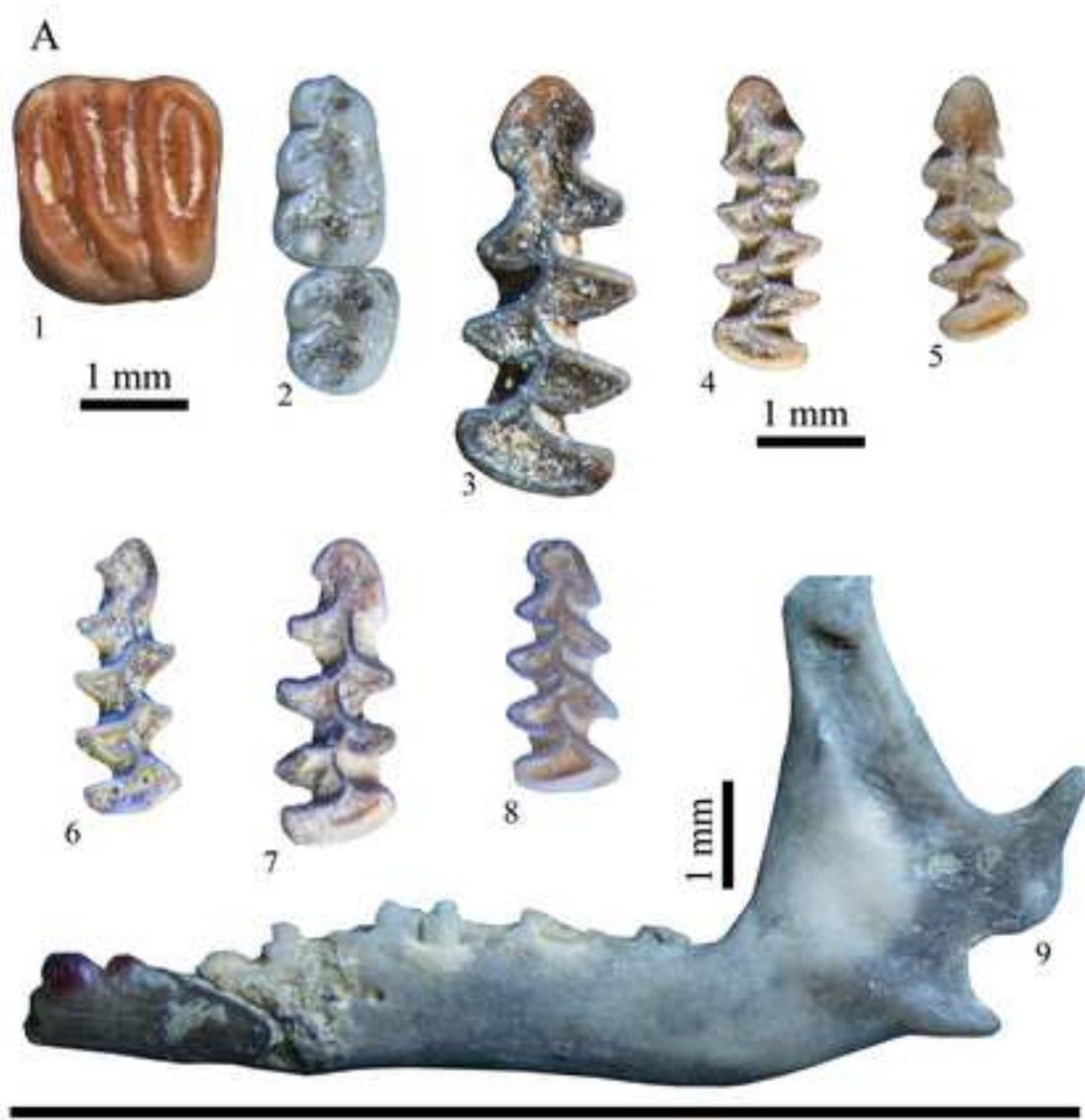


Figure 3  
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**Figure 4**  
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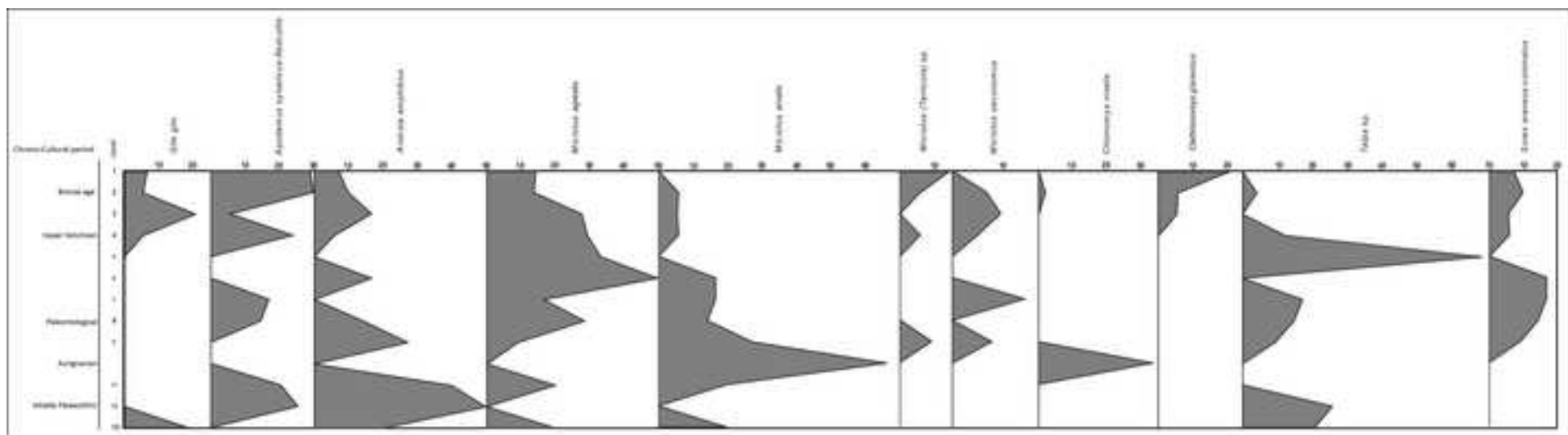
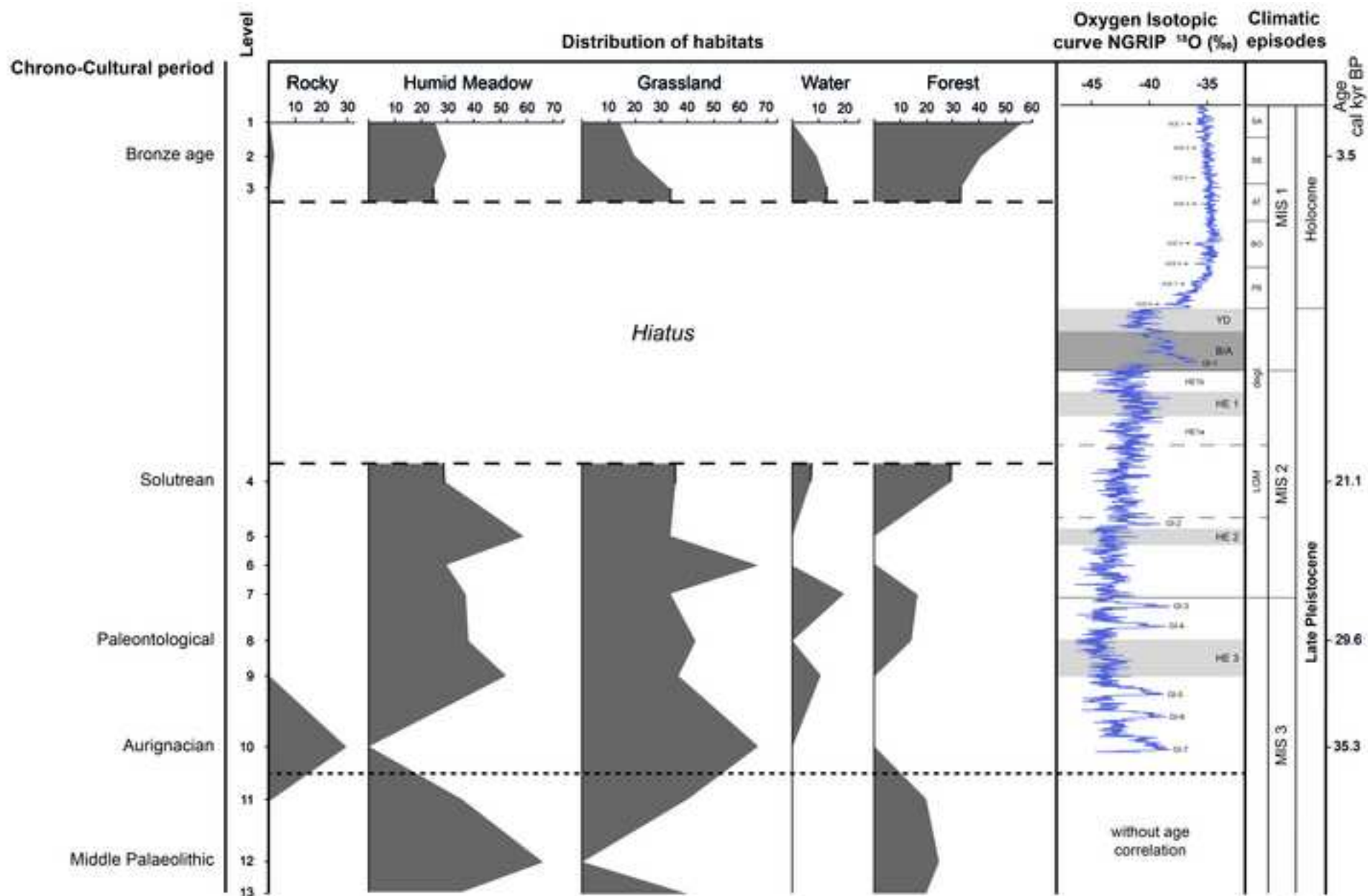




Figure 5  
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**Figure 1**

Geographical location of Askondo Cave (Mañaria, Bizkaia, Spain) and the approximate location of some archaeological sites (Mdt 25 obtained from the IGN).

**Figure 2**

A: General plan of Askondo Cave (Mañaria, Bizkaia, Spain) showing the excavations (grey). B: The stratigraphic sequence of the test trench. The black arrow indicates the north of the excavation grid, which is not actual geographic north.

**Figure 3**

Some small vertebrate fossil remains from Askondo (Mañaria, Bizkaia, Spain). **A)** Small mammals (in occlusal view): *Glis glis* (1) right M1 or M2; *Apodemus sylvaticus-flavicollis* (2) right m1-2; *Arvicola amphibius* (3) left m1; *Microtus agrestis* (4) left m1; *Microtus (Terricola)* sp. (5) right m1; *Microtus oeconomus* (6) right m1; *Chionomys nivalis* (7) right m1; *Clethrionomys glareolus* (8) right m1; *Sorex araneus-coronatus* (9) left mandible in lateral view. **B)** Herpetofauna: *Bufo calamita* (10) incomplete right ilium in lateral view; *Bufo bufo* (11) incomplete scapula in dorsal view; *Rana temporaria-iberica* (12) incomplete right ilium in lateral view; Lacertidae indet. (13) trunk vertebrae in ventral view; *Anguis fragilis* (14) osteoderm; Colubridae indet. (15) caudal vertebrae in ventral view. Scale bar = 1 mm.

**Figure 4**

Relative variations in the abundance of small mammals from Askondo (Mañaria, Bizkaia, Spain) from the Middle Palaeolithic to the Bronze Age, expressed in terms of the percentage of the minimum number of individuals (MNI). From left to right, the columns represent the chronological periods defined by their archaeological contents, the stratigraphic levels, and the ten taxa recorded at the site (% of the MNIs given at the top of each column).

**Figure 5**

Palaeoenvironmental evolution of Askondo Cave (Mañaria, Bizkaia, Spain). From left to right, columns represent the cultural periods, stratigraphic levels, habitat distribution, NGRIP  $\delta^{18}\text{O}$  curve with some well-known north Atlantic and continental climate episodes, and our ages expressed in cal kyr BP. SA, Subatlantic; SB, Subboreal; AT, Atlantic; BO, Boreal; PB, Preboreal; MIS, Marine Isotope Stages; HCE, Holocene Cooling Event; YD, Younger Dryas; B/A, Bölling/Alleröd; GI, Greenland Interstadial; HE, Heinrich event; LGM, Last Glacial Maximum. The limits of the Marine Isotope Stage are based on Lisiecki L.E. and Raymo M.E. (2005).

**Table 1**

List of radiocarbon dates from Askondo including cultural periods, chrono-stratigraphic units, laboratory codes, and the elements from where the samples were taken.

Cultural period	Level	Radiocarbon age		Mean prob.	Lab code	Sample
		<sup>14</sup> C yr BP	Cal yr BP 2σ			
Bronze age	2	3,290±40	3,613-3,408	3,518	Beta-303669	Human incisor
Upper Solutrean	4	17,490±90	21,435-20,838	21,131	Beta-316473	Burned bone
Paleontological	8	25,450±110	29,921-29,171	29,545	Beta-320949	Cave bear vertebra
Aurignacian	10	31,440±190	35,790-34,860	35,321	Beta-303670	Burned bone
Middle Palaeolithic	12	> 41,400			Beta-313144	Large bovid tibia
Gravettian*	Driven bone	23,760±110	29,055-27,621	27,830	Beta-303671	Ungulate tibia

Dates were calibrated at 95.4% confidence intervals (2σ) using the IntCal13 data set (Reimer *et al.*, 2013) and OxCal4.2 calibration software (Bronk Ramsey, 2009). \*Data not taken into account to our age model.

**Table 2**

Faunal remains from Askondo Cave (Mañaria, Bizkaia, Spain)

<b>Artiodactyla</b>	<b>Perissodactyla</b>	<b>Rodentia</b>	<b>Eulipotyphla</b>	<b>Squamata</b>
<i>Bos taurus</i>	<i>Equus caballus</i>	<i>Glis glis</i>	<i>Talpa</i> sp.	<i>Anguis fragilis</i>
<i>Capra pyrenaica</i>		<i>Apodemus sylvaticus-flavicollis</i>	<i>Sorex araneus-coronatus</i>	Lacertidae indet.
<i>Capreolus capreolus</i>	<b>Carnivora</b>	<i>Arvicola amphibius</i>		Colubridae indet.
<i>Cervus elaphus</i>	<i>Canis lupus</i>	<i>Microtus agrestis</i>	<b>Anura</b>	
<i>Ovis aries/Capra hircus</i>	<i>Crocuta crocuta</i>	<i>Microtus arvalis</i>	<i>Bufo calamita</i>	
<i>Rupicapra pyrenaica</i>	<i>Ursus spelaeus</i>	<i>Microtus (Terricola) sp.</i>	<i>Bufo bufo</i>	
<i>Sus domesticus</i>	<i>Vulpes vulpes</i>	<i>Microtus oeconomus</i>	<i>Rana temporaria-iberica</i>	
		<i>Chionomys nivalis</i>		
		<i>Clethrionomys glareolus</i>		

Note that these correspond to the total of the Pleistocene and Holocene levels.





**Table 4**

Number of identified specimens (NISP) and minimum number of individuals (MNI) of the herpetofaunal species from Askondo organized by cultural periods and chrono-stratigraphic units (\*not cultural).

Cultural period	BA		BA		Ho		Grav.?		*		*		*		Aurig.		MP	
Level	1		2		3		5		6		7		8		9		13	
	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI
Bufonidae	1	1	3	2	1	1												
<i>Rana temporaria-iberica</i>			8	1	3	1	4	1	4	1	8	1	20	1	33	1	7	1
<i>Anguis fragilis</i>	20	1																
Lacertidae			1	1			1	1			1	1	1	1	1	1		
Colubridae	8	1																
Totals	29	3	12	4	4	2	5	2	4	1	9	2	21	2	34	2	7	1
Nº of species	3		2		3		2		1		2		2		2		1	

Reviewers' comments:

**Reviewer #2:** Title: I should change reconstruction for proxy (or estimating paleoenvironmental reconstruction), because it is difficult to assert that we "reconstruct" the paleoenvironment. We really do not "reconstruct" but it is an estimating process using different criteria and data.

Done

Writing: The article has a good structure, figures and tables. Despite there are some sentences that are difficult to understand, the article is in general well written, though an amelioration of the final English version is needed. Done

Technical: In general, not being a work in the taxonomy and systematics of rodents, I do not see the utility of using subgenera, which are confusing, and subjected to systematic changes all the time, given that phylogenetic studies are in progress elsewhere. Done

When I highlight with green colour, or with the text corrector; comments are in the pdf of the document:

- 1) not clear what it means Done
- 2) layers? Strata? Done
- 3) , Castillo? Michaux? not Daams, because he was specialists in Glirids not in murines. Done
- 4) ?????? Carretero et al are not anuran or caudata specialist, please refer to original works.

As is emphasized in the mention paper, the authors of the article Carretero et al. are part of the Standing Committee on Taxonomy of Spanish Herpetological Association, part of the CIBIO of the University of Porto and the Dep. Biology of the University of Barcelona and specialized in Herpetology. So we consider that they are reliable specialist to be cited.

- 5) Please, explain a bit the next sentence: As stated before, this is probably related with the origin of the accumulations, probably produced by small mammalian carnivores. How do you distinguish water erosion from digestion? Done

- 6) The NISP (Number of Identified Specimens) is also provided (Table 3), given (the sentence continuous in the next point)

- 7) that for some authors is a better method to quantify the samples (Grayson, 1984; Marshall and Pilgram, 1993). Why? It depends on the objectives of the study. Seeing that our explanation was confusing and did not provide relevant data, we decided to mention only the NMI in the text, even if we still provide NISP in the Table 3.

- 8) There is not any explanation of the richness of the material, nor information about how many in volume or in mass the excavated sediments represent. Thus we don't know if the number of remains is low or high. At the beginning the authors say around 3000 remains (2918)...this must be further explained. Done

- 9) Taxonomy: at the beginning you say families Cricetidae, etc, though elsewhere in the text (I highlighted some sentences) you use the subfamily name Arvicolinae, which is taxonomically correct though very confusing. I should avoid these terms and use the more general Order or Family. Or just the species Xxx xxx. Done I propose you an initial table with the taxa, ordered systematically. We consider that Table 2 is clear enough to include other table

10) Discussion: there are some repetitive sentences, i.e.: As stated before, this is probably related with the origin of the accumulations, probably produced by small mammalian carnivores.... **Done**

11) Revise the references, i.e. Meulen, not van der Meulen; **There is not any rule in the "Author information pack" about how to cite in these cases. However, in the APA Publication Manual they stand for keeping the author's original capitalization even in reference list entries.** Grayson, Wilson & Reeder and others lacks number of pp. **According to the "Author information pack" in the case of monographs number of pp. is not needed.**

Figures and tables & captions

1. Figures are beautiful.
2. In fig 1. I would appreciate a geological map too, maybe a very general one. **Done**
3. Captions, as I say in the main text avoid the use of subgenera etc... **Done**

**Reviewer #1:** I found the manuscript interesting and easy to read. I have no criticisms with regards to the content. The work is a typical case study, important and interesting, well written, certainly appropriate for publication in Quaternary International. Overall the data are well presented and the conclusions are supported by the data. I really enjoyed reading this paper. This is a well-designed and structured research study that presents new data on the reconstruction of palaeoenvironment and palaeoclimate on the basis of small mammal assemblages in Askondo (Spain). The pictures and tables are clear, concise and useful. This study is particularly interesting regarding the better understanding of environmental and climatic fluctuations of the Late Pleistocene and Holocene in northernmost Spain. However, some points and presented opinions need explanation.

Additional comments:

1. The Authors included the Late Glacial to MIS 2 (Fig. 5). As far as I know since 2010 the subcommission of Quaternary Stratigraphy of International Commission of Stratigraphy of INQUA dropped other lists of MIS dates and started using the Lisiecki and Raymo (2005) LR04 Benthic Stack, as updated. Therefore at present the start date for MIS 1 is rather ca. 14.7 cal ka BP (the beginning of Late Glacial) and not the beginning of the Holocene (11.6 cal ka BP) (e.g. Svensson et al., 2006). The Authors should explain why they prefer to use the abandoned scheme or change the scheme. **Done**
2. The Authors use for the bank vole the name *Myodes glareolus* following Wilson and Reeder (2005). However, at present it seems that we have to return to the previous generic name *Clethrionomys*, which appeared to be valid (Tesakov et al., 2010). **Done**
3. Two references quoted in the text are missing in References: Andersen et al. (2006) and Cuenca-Bescos et al. (2008). **Done**

Literature cited:

Svensson A, K.K. Andersen, M. Bilger, H.B. Clausen, D. Dahl-Jensen, S.M. Davies, S.J. Johnsen, R.

Muscheler, S.O. Rasmussen, R. Röthlisberger, U. Ruth, J.P. Steffensen, B.M. Vinther. 2006. The Greenland Ice Core Chronology 2005, 15-42 ka. Part 2: comparison to other records. *Quaternary Science Reviews* 25: 3258-3267.

Lisiecki L.E., Raymo M.E. 2005. A Pliocene-Pleistocene stack of 57 globally distributed benthic  $\delta^{18}O$  records. *Paleoceanography*, 20: PA 1003.

Tesakov A.S., Lebedev V.S., Bannikova A.A., Abramson N.I. 2010. *Clethrionomys Tilesius*, 1850 is the valid generic name for the red-backed voles and *Myodes Pallas*, 1811 is a junior synonym of *Lemmus Link*, 1795. *Russian Journal of Theriology*, 9 (2): 83-86.

Wilson D. E., Reeder DA. M. 2005. *Mammal species of the World. A taxonomic and geographic reference. Third edition Vol. 2*, The Johns Hopkins University Press, Baltimore.