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Climate and environments during Marine Isotope Stage 11 in the central Iberian Peninsula: the herpetofaunal assemblage from the Acheulean site of Áridos-1, Madrid

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ABSTRACT

The interglacial episodes of the Quaternary Period are currently the focus of a great deal of attention within the scientific community, primarily because they can help us to understand how the climate of the current interglacial may have evolved without human intervention and to assess the impact of these climate changes on ecological systems. In the central Iberian Peninsula, the archaeological site of Áridos-1 (Arganda, Madrid), with numeric dates of 379.7 ± 45 ka obtained by AAR for the upper part of the sedimentological unit of Arganda I, in combination with the evolved state of the small mammals, has been chronologically attributed to Marine Isotope Stage (MIS) 11. Given the diversified faunal assemblages delivered by the 1976 excavations, Áridos-1 is probably one of the best terrestrial candidates for an understanding of the climatic and environmental conditions that prevailed in central Spain during the MIS 11 interglacial. In consequence, the fossil amphibians and squamate reptiles stored in the collections of the Museo Arqueológico Nacional of Madrid have been newly described and quantified in order to apply the mutual climatic range and habitat weighting methods for estimating quantitative data. The Mediterranean climate is shown to have been warmer and wetter than today in central Spain during MIS 11, with the mean annual temperature 1.7 °C higher and mean annual precipitation 223.9 mm higher than at present. The monthly climatic reconstruction shows differences in the distribution of precipitation over the course of the year, with more abundant precipitation during the winter months, at the beginning of spring and at the end of fall (from October to March) and less precipitation than today during the summer months and at the end of spring (from May to August), suggesting stronger rainfall seasonality between winter and summer than currently occurs. Such climate reconstruction is consistent with other European MIS 11 paleoclimatic records. The paleoenvironmental reconstruction based on the herpetofaunal assemblage suggests a patchy landscape with a large representation of dry meadows, scrubland and rocky habitats together with well-evidenced aquatic habitats. Such open environments during a warm and humid forestal period are seen to be connected with the location of the site in a large river valley, where open vegetation would have been partly initiated and certainly maintained by the grazing, browsing, trampling and tree-felling activities of large mammals.

1. Introduction

The Marine Isotope Stage (MIS) 11 warm period (also called MIS 11c) is the longest and warmest interglacial in the last 500 ka, which took place ca 410,000 years ago and lasted for about 32,000 years (from 426 to 394 ka; Desprat et al., 2005; Candy et al., 2014). While numerous continental paleoclimatic records of MIS 11 exist in northern and central Europe (Britain, Germany, the Czech

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Republic, France and Poland), such records are relatively few and far between in southern Europe (Candy et al., 2014), with just a few marine cores on the western margin of the Iberian Peninsula (Desprat et al., 2005; de Abreu et al., 2005; Martrat et al., 2007; Voelker et al., 2010) and the classical lacustrine pollen records from Ioannina and Tenaghi Philippon in Greece (Tzedakis et al., 2001, 2006; Tzedakis, 2005). On land the MIS 11 warm stage has been associated with the Hoxnian interglacial in Britain (Schreve, 2001; Thomas, 2001), the Holsteinian interglacial in northern Europe (Sarnthein et al., 1986; Barabas et al., 1988; Nitychoruk et al., 2006; Koutsodendris et al., 2010), the Praclaux interglacial on the basis of the long Velay pollen sequence in France (Reille et al., 2000; de Beaulieu et al., 2001), and the Vigo interglacial in northwestern Iberia (Desprat et al., 2005). Among the archaeological sites of the Iberian Peninsula, MIS 11 interglacial temperature maxima have been identified at the base of level TD10 of the Gran Dolina site in the Sierra de Atapuerca (Blain et al., 2012a in accordance with the thermoluminescence and electron spin resonance/uranium-series numeric dates provided by; Berger et al., 2008; Rodríguez et al., 2011; Moreno García, 2011; Falguères et al., 2013), and warm/temperate conditions have also been registered from the lower unit (US4 and US3) of the site of Ambrona (Santonja and Pérez-González, 2005), with an age older than 350 ka (Falguères et al., 2006). Given such scarcity of records, the climatic conditions within the Iberian Peninsula are relatively poorly known.

The archaeological site of Áridos-1 is situated on the left bank of the Jarama river to the southeast of Madrid (Fig. 1). The site is located within muddy overbank deposits and secondary pebble and sandy low-energy channels that existed in the wide alluvial plain of the meandriform Jarama river (Pérez-González, 1980a,b; Pérez-González and Uribelarrea, 2002, Fig. 2). An area of 112 m^2 was excavated, exposing two paleosurfaces (Santonja and Querol, 1980a). The disarticulated remains of a subadult *Elephas* (*Paleoloxodon*) *antiquus* were found on the older paleosurface, concentrated within an area of 50 m^2 (Soto Rodríguez, 1980; Santonja and Querol, 1980b). A total of 333 lithic pieces and mandibular fragments of two bovids were also found (Santonja and Querol, 1980a). The lithic assemblage is characterized by an abundance of flakes, and some refitting was successfully carried out. Despite the absence of cut marks (Díez Fernández-Lomana, 1992), the association of the stone tools and bones has been proved through geological and spatial analysis and the identification of polishing caused by wear from meat cutting on the edges of several artifacts (Ollé Canellas, 2005). Separated from this occupation surface by 8–10 cm, numerous microvertebrate remains, a few scattered bones of larger mammals and perhaps two flakes were found. Dates obtained by AAR (amino acid racemization) (379.7 ±45 ka) for the upper part of the Arganda I unit containing the site indicate that Áridos-1 could be assigned to MIS 11 (Panera et al., 2011). The herpetofaunal remains from Áridos-1 were originally described in three articles: Sanchíz and Sanz (1980) for the amphibians, Sanz and Sanchíz (1980) for the squamates, and Jiménez Fuentes (1980) for the chelonians. The list of anurans has subsequently been updated by Martín and Sanchíz (2012) in accordance with the new systematic nomenclature. The aim of the present paper is therefore to revise the taxonomic attribution of these fossils and to provide a precise analysis of their implications for the climatic and environmental conditions that prevailed in the central Iberian Peninsula during MIS 11.

2. Material and methods

2.1. Systematic revision

The paleontological and archaeological material from the site of Áridos-1 is stored in the collection of the Museo Arqueológico Nacional (MAN) in Madrid (Spain). We have had access to these collections in order to revise the taxonomic attribution of the herpetofaunal remains and count the number of remains and thus assess the minimum number of individuals (Table 1). The amphibian and squamate fossil remains consist mostly of disarticulated elements collected by water-screening the sediments obtained during the archaeological excavations at the site of Áridos-1 in the late 1970s. Some elements (mainly reptile vertebrae) are indeed articulated. The chelonian fossil remains have not been revised but have been included in our paleoclimatic and paleoenvironmental interpretation according to the quantification made by Jiménez Fuentes (1980). The general taxonomical criteria follow Szyndlar (1984), Bailon (1991, 1999), Barahona Quintana (1996), Barahona and Barbadillo (1997), Holman (1998), Gleed-Owen (1998), Blain (2005, 2009), Blain et al. (2007, 2011) and López-García et al. (2011). Comparisons were drawn using the dry skeleton collections of the Museo Nacional de Ciencias Naturales (MNCN, Madrid, Spain) and our personal collections.

2.2. Climatic reconstruction

Paleoclimatic interpretations are based on the presence of herpetofaunal species from Áridos-1. The mutual climatic range (MCR) method (see Blain et al., 2009) is used to quantify paleotemperatures and paleoprecipitation, whereby we simply identify the geographic region (divided into 10 × 10 km UTM squares) where all the species present in a locality or in a stratigraphical level currently live. Careful attention is paid to ensure that the real current distribution corresponds to the potential ecological/climatic distribution and is not strongly affected by other limiting or perturbing parameters such as urban development, landscape anthropization, predation, competition with other species, etc.

Analysis of the MCR in each level is based on the distribution atlases of the Iberian herpetofauna (Godinho et al., 1999; Pleguezuelos et al., 2004), divided into 10 × 10 km UTM squares. Climatic parameters have been estimated for each 10 × 10 km UTM square, using various climatic maps of the Iberian Peninsula (Ninyerola et al., 2005). A total of 26 climatic parameters have been calculated for this study (Table 2).

For comparison with current climatic data, we used the record from weather station 3182E of Arganda 'Comunidad' (Ninyerola et al., 2005), located close to the archaeological locality and very near to the Jarama river (X,Y: 457113.0, 4462795.9; longitude, latitude: −3° 30′ 16.9992″, 40° 18′ 50.0004″).

To measure aridity we used the Gaussen, Lautensach-Meyer, Dantin-Revenga and De Martonne indexes. The Gaussen index ($P < 2 \times T$) dictates that a month is dry if the pluviometric level for that month (P), measured in mm, is less than twice the value of the average temperature in °C for that month (T). The Lautensach-Mayer index is a classification of climates based on the number of dry months according to the Gaussen index. The Dantin-Revenga index is calculated as (100 × MAT/MAP), and the De Martonne aridity index as MAP/(MAT + 10), where MAT = mean annual temperature and MAP = mean annual precipitation.

2.3. Environmental reconstruction

In order to reconstruct the environment, we used the method of habitat weighting (see Blain et al., 2008), distributing each amphibian and reptile taxon in the habitat(s) where it is possible to find them at present in the Iberian Peninsula. Because Spanish Pleistocene amphibians and reptiles are considered specifically identical to modern populations, the current species habitat distribution may be used for the habitat weighting. The habitats were divided into five types: open land in which dry and wet meadows