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Late glacial and post-glacial deposits of the Navamuño peatbog (Iberian Central System): Chronology and paleoenvironmental implications

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ABSTRACT

The Navamuño peatbog (Sierra de Béjar, western Spain) is a ~14 ha pseudo-endorheic depression with boundaries defined by a lateral moraine of the Cuerpo de Hombre paleoglacier and fault-line scarps on granite bedrock. The stratigraphy of the Navamuño peatbog system is characterized here using borehole data to a depth of 20 m. An integrated interpretation from direct-push coring, dynamic probing boreholes and handheld auger drillings advances our knowledge of the Navamuño polygenetic infill. Correlating this data with those obtained in other studies of the chronology and evolutionary sequence of the Cuerpo de Hombre paleoglacier has enabled us to establish the sequence of the hydrological system in the Navamuño depression. During the Late Pleistocene (MIS2), the depression was dammed by the Cuerpo de Hombre glacier and fed by its lateral meltwaters, and was filled with glaciolacustrine deposits. The onset of the Holocene in Navamuño is linked to a flat, fluviotorrential plain with episodes of local shallow pond/peat bog sedimentation. This evolutionary sequence is congruent with the age model obtained from available radiocarbon dating, obtaining 19 ages from ~800 cal yr BP (at depth 1.11 m) to ~16800 cal yr BP (at depth 15.90–16.0 m). Finally, the sedimentary record enabled interpretation of the environmental changes occurring in this zone during the late glacial (from the Older Dryas to the Younger Dryas) and postglacial (Holocene) stages, placing them within the paleoclimatic context of the Iberian Peninsula and Mediterranean regions.

1. Introduction

The Mediterranean region is an important corridor crossing the low mid-latitudes to the easternmost Mediterranean region, with current penetration of North Atlantic atmospheric depressions. It played a major role in ongoing climate change during Pleistocene cold stages (Hughes and Woodward, 2008). The atmospheric framework of the last glacial cycle in this region may refer to a polar front positioned off Iberia, in the North Atlantic Ocean (Ruddiman and McIntyre, 1981; Florineth and Schlüchter, 2000; Roucoux et al., 2005) and a westerly atmospheric circulation between North Africa and Europe (Hughes and Woodward, 2017).

Railsback et al. (2011) described the N-S climatic evolution in the Iberian Peninsula during the interglacials and the Holocene. However, in the last glacial cycle oceanic and atmospheric polar fronts were both further south than in the Holocene (Naughton et al., 2009), and thus produced an intense N-S contrast in the Iberian Peninsula.

Latitudinal climatic stratification, as was apparently present during the Holocene (Railsback et al., 2011), would explain how and

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why important chronological differences exist between equivalent glacial stages (e.g. between local MIEs) in various mountain massifs in the Iberian Peninsula (García-Ruiz et al., 2003, 2010; Hughes and Woodward, 2008, 2017). However, to explain these chronological differences in a single mountain massif is still a problem, even between closer paleoglaciers. E.g., in the Iberian Central System (ICS) the MIEs of some paleoglaciers occur during MIS2, clearly coinciding with the LGM or slightly earlier (Palacios et al., 2011, 2012a, 2012b; Carrasco et al., 2015a). However, in other sites from the same area the MIE is much earlier and either corresponds to MIS2 but precedes the LGM by several thousand years (Domínguez-Villar et al., 2013), or occurs during MIS3 (Vieira et al., 2001; Bullón, 2016). These latter chronologies of some ICS paleoglaciers, correlate better with those most frequent obtained in northern and north-east mountain massifs in the Iberian Peninsula for the local MIEs (García-Ruiz et al., 2003; Moreno et al., 2010; Rodríguez-Rodríguez et al., 2015; Serrano et al., 2012, 2017; Delmas, 2015). However, the glacial sequence proposed in these other mountains of Iberia, where pre-MIS3 and even pre-Würm phases are detected (Calvet, 2004; Vidal-Romaní and Fernández-Mosquera, 2006; Lewis et al., 2009; Jiménez-Sánchez et al., 2013; Rodríguez-Rodríguez et al., 2015; Serrano et al., 2017; Turu et al., 2017), completely unlike from the glacial sequence proposed for the ICS (Pedraza et al., 2013; Carrasco et al., 2015a). To provide a regional and supra-regional scale paleoclimate and chronostratigraphy correlations, our research into ICS envisage further exploration of two study approaches: (1) the sedimentary record looking for specific glacial stages, and the paleoenvironmental record using different proxies (LOI, charcoals, magnetic susceptibility, sedimentary facies, type of sedimentary discontinuities, …); (2) AMS ^{14}C chronological data to complement the original data obtained from surface mapping and dating, mainly based on Terrestrial Cosmogenic Nuclide (TCN). Both approaches aim to clarify such glacial evolution differences in the ICS, especially regarding the Mediterranean climate variability.

2. Main scope

Dating lacustrine records in a similar geomorphological context like Navamuño can provide useful paleoenvironmental information (i.e. González-Sampériz et al., 2006; Jalut et al., 2010), and can be used to solve TNC uncertainties, or complement glacial correlations at a local, regional, or even global scale. Similar experience has proven very useful for establishing some glacial stages (Carrasco et al., 2015a) with the Cueva del Águila (Domínguez-Villar et al., 2013), where a climate record compiled from speleothems is currently available. Well-contrasted paleoenvironmental data is available in central and western Iberia providing a general base reference for glacial records (see e.g.: Jalut et al., 1992, 2010; Harrison and Digerfeldt, 1993; Naughton et al., 2009; Moreno et al., 2012; Aranbarri et al., 2014; González-Sampériz et al., 2017).

Unfortunately, any useful lacustrine records from the ICS are available. Those that are related with glacial geomorphology are limited in thickness and only provide data on postglacial stages (see e.g.: Ruiz-Zapata and Acaso-Deltell, 1981, 1984; Ruiz-Zapata et al., 1996, 2011; Franco-Múgica et al., 1998; Rubiales et al., 2007; López-Sáez et al., 2014, 2016; Abel-Schaad et al., 2014; Sánchez-López et al., 2016; Génova et al., 2016). For that reason, any available information about ICS glacial features is mainly based in geomorphological mapping, backed by TCN dating. However, paleopalynological studies of hydro-peat sediments in the Navamuño starts quite soon (Atienza, 1993) reaching 3 m depth and up to ~6 ka BP. Far after Ruiz-Zapata et al. (2011) improved until 4.5 m depth but less further in time (up to ~5.1 ka BP). All these results are similar to those obtained in some places from the ICS, although none of the boreholes in this depression reached the bedrock. Taking into account this background, systematic studies were undertaken using geological and geophysical surveys to investigate the geometry and structure of Navamuño depression, its relationship with the Cuerpo de Hombre paleoglacier and magnitude of the infill by Carrasco et al. (2008). These studies reveal a minimum sedimentary infill over 40 m deep, and therefore appropriate for paleoenvironmental and chronological studies of the last glacial cycle (Carrasco et al., 2015b). Only a systematic research that applies multiple subsoil investigation procedures (geophysical and mechanical test probes supported by ^{14}C dating) can provide an integrated sedimentological, chronological and environmental study of the Navamuño deposits. This study also enlarges the knowledge about relationships between the Navamuño depression and the former Cuerpo de Hombre glacier.

3. Study area

The Navamuño Depression (ND) is a small depression (~14 Ha) on the western slopes of Sierra de Béjar (W Spain), associated with the large fault-corridor type Hervas-Sorihuela depression and the Cuerpo de Hombre paleoglacier (Carrasco et al., 2015a, 2015b). The ND presents characteristic traits of *navas* in the ICS, i.e.: flat, treeless, sometimes marshy ground (or peatbog) and generally situated between mountains (Fig. 1). The ND is limited to the east by the left lateral moraine of the Cuerpo de Hombre paleoglacier, responsible for the obstruction and consequent filling of the depression in the upper Pleistocene. The other limits are related to fault-line scarps on monzogranites and granodiorites of one of the great granitic batholiths of the Iberian Massif (Villaseca et al., 1999; Villaseca, 2003), locally transformed by weathering processes (grus, regolith and spheroidal weathering formations). The current geomorphological processes in this area are characterized by an attenuated periglacial environment characteristic of a Mediterranean mountain climate with very slight Atlantic influence (AEMET/IM, 2011).

The bottom of the depression is an alluvial plain drained by two channel systems, which present networked patterns, depending on the zone (Fig. 2). Except for some locally flooded strips, the channels are well defined, Except for some locally flooded strips, with thalwegs entrenched in the alluvial plain between 0.5 m (southern zone) and 1.5 m (northern zone). The drainage network in the depression emerges from the southern border with two simple, moderately confined channels, which on reaching the plain expand into a system of multiple channels forming two alluvial fans. This process interconnects both networks in the centre of the depression and finally they converge at the northern edge to form a single outflow channel (Arroyo de Navamuño). This torrent is fed by superficial waters but also by groundwater interception along the whole path through the Cuerpo de Hombre river confluence. The confined channels in the south of the depression are located on both sides of a terrace-like platform adjoining the Cuerpo de Hombre paleoglacier lateral moraine. This morphological unit corresponds to an alluvial deposit system originated in the marginal meltwaters of the ancient glacier, identified as a marginal or kame terrace (Carrasco et al., 2015a). Thus, ND presents a drainage system with two well-defined supply sources: the western slope drainage basin (Arroyo del Puerto de Navamuño) and the eastern slope drainage basin forming the left lateral moraine of the Cuerpo de Hombre paleoglacier (Arroyo del Refugio). These two drainage systems have been well differentiated quite early in the former relief, and therefore have been responsible for the infill path of the depression.

4. Methods

4.1. Dynamic probing super heavy (DPSH)

Previously to coring, we proceeded to investigate the thickness

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