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Quaternary glacial evolution in the Central Cantabrian Mountains (Northern Spain)

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ABSTRACT

The glacial evolution of the Cantabrian Mountains is not well known. Previous studies have focused on the extent of the glacial maximum and the presence of younger features in several massifs. Recently, efforts have been made to date glacial periods, particularly the glacial maximum. This work presents a reconstruction of the glacial evolution in the Cantabrian Mountains, providing data on the environmental characteristics and timing of the different stages from the Quaternary glacial maximum to the Little Ice Age. The study area covers 3000 km^2 between the 4°58′W and 3°34′W and includes eleven massifs of the central area of the Cantabrian Mountains. The selected sectors have an Atlantic and Atlantic-Mediterranean transitional climate and include the highest massifs (above 2600 m) and low-altitude glacierised massifs (lower than 2000 m). Glacial extent and evolution have been reconstructed on the basis of detailed geomorphological and morphostratigraphic mapping. The equilibrium line altitude (palaeo-ELA) has been estimated for the different stages of each tongue. The ELA has been assessed by the AAR and modified Kurowski methods and altitude methods have been considered. A numerical chronological framework is proposed using 17 AMS radiocarbon and one OSL data obtained in lake and bog deposits from three massifs. Four main glacial stages have been differentiated, between 38,000 BP and the Little Ice Age. They correspond to different cold environments, and the number of glacial stages varies from one to four among the different massifs. Conclusions are analysed in the context of the Quaternary glacial evolution of other Iberian mountains.

1. Introduction

During the Quaternary, glaciers developed in almost all mountain systems over 2000 m altitude in the Iberian Peninsula which show features of different glacial stages and different sizes from the recent Pleistocene to the nineteenth century. Only in the areas nearest to the Atlantic coasts, in the north and west of the Iberian Peninsula, did glaciers appear in low-altitude mountain systems. The extent and location of Pleistocene glaciers are well known and documented in many syntheses (p.e. Gómez-Ortiz and Pérez-Alberti, 1998; Pérez Alberti et al., 2004), which provide information from the pioneering studies of Penck (1897) and Obermaier (1914) to recent contributions and reconstruct the evolution and glacial morphostratigraphy in different peninsular massifs. Nevertheless, interest has arisen recently about the significance of glaciers in the European context and the chronology of the different glacial stages as a result of the availability of new dating techniques and growing interest in glaciers for palaeo-environmental reconstructions (Pérez Alberti et al., 2004; Hughes and Woodward, 2008; García-Ruiz et al., 2010). In this sense, there are controversies depending on the dating techniques applied, and the present or past climatic context (Atlantic, Mediterranean). It is therefore of interest to increase knowledge on the Quaternary glacial chronologies of the Iberian Peninsula and their different geographical characteristics. In Southern Europe there are many indications of glacial stages prior to the Last Glacial Maximum (LGM), which could have reached greater extents in both Atlantic and Mediterranean environments (Pérez Alberti et al., 2004; Woodward et al., 2004; Hughes et al., 2006a,b; Allen et al., 2007; Hughes and Woodward, 2008; García-Ruiz et al., 2010; Jalut et al., 2010; Pérez Alberti et al., 2011). Age determinations indicate earlier glaciation with respect to the Last Glacial Maximum (LGM) in northern Europe (Mardones and Jalut, 1983; Jalut et al., 1992, 2010; Vidal-Romaní et al., 1999; Jiménez et al., 2002; García-Ruiz et al., 2003, 2010; Calvet, 2004; González-Sampériz et al., 2006; Moreno et al., 2010) attributed to the southernmost location of the North Atlantic Polar Front during the LGM (Ruddimann and McIntire, 1981; Florineth and Schlüchter, 2000). But not all dates are in agreement and the results of other studies carried out in the Pyrenees or the Central System reveal a possible synchrony between peninsular and European LGM (Pallás et al., 2007; Calvet et al., 2011; Palacios et al., 2011).

In the Cantabrian mountains glacial landforms were attributed to two Quaternary glaciations, Riss and Würm (Penck, 1897; Obermaier, 1914; Nussbaum and Cigax, 1953), although they were later attributed,

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still without numerical age determinations, to a single recent Quaternary glacial period (Martínez de Pisón and Arenillas, 1979; Alonso et al., 1982; Frochoso and Castañón, 1986, 1998; Smart, 1986; Flor and Bailón, 1989; Castañón and Frochoso, 1992, 1996; Martínez de Pisón and Alonso, 1993; Serrano and González-Trueba, 2002; González-Trueba, 2007a, b). More recent studies which include palaeoglacial reconstructions and dates (Jalut et al., 2010; Moreno et al., 2010; Serrano et al., 2011a,b), confirmed that the glacial maximum of the Cantabrian Mountains was prior to the European LGM. Although there are as yet few numerical dates for the Cantabrian Mountains, data available point to a distinct behaviour with respect to European glaciers during the end of MIS 3 and MIS 2. The aim of this contribution is to make a synthesis of studies in the different Cantabrian massifs based on morphostratigraphic reconstructions, ELA estimations and new dates, in order to improve knowledge of the chronological and environmental framework of the different glacial stages.

2. Study area

The Cantabrian Mountains extend 700 km between the Pyrenees and the Galician mountains, with a broad diversity of landforms and landscapes (Fig. 1). The study area is in the central part of this mountain range and includes its highest massifs (Picos de Europa − 2648 m- and Peña Prieta −2539 m-). This sector forms the division between Atlantic, Cantabrian and Mediterranean basins, and spans the Asturian basement to the west (Fuentes Carrionas, Picos de Europa, Sierra de Cebolleda, 2078 m), and the Mesozoic cover to the east (Alto Campoo, 2174 m; Valdecebollas, 2143 m; Pas Mountains, 1718 m). In the basement Devonian and Carboniferous slates, quarzites, limestones, sandstones and conglomerates alternate. The relief is governed by structure, lithology and differential erosion, configuring isolated massifs and ranges individualised between elongated depressions. Limestones, quarzites and sandstones form positive relief, and slates and turbidites the depressions. The Mesozoic cover is made up of Triassic sandstones and conglomerates with dipping and folded landforms (Peña Labra, Campoo and Valdecebollas). Towards the east Jurassic and Cretaceous marls, sandstones, limestones and turbidites of variable thicknesses alternate (Campoo, Pas Mountains). River courses in the northern side cut structures and individualise massifs, whereas in the south they tend to adapt to structures. Present climate is strongly influenced by the existence of high relief near the sea that hampers the passage of fronts. Thus, there is a hyperhumid oceanic mountain environment on the northern side with rainfall over 2500 mm/year, whereas the south has an Atlantic-Mediterranean transition environment with about 600 mm/year.

The Pleistocene glaciation was limited in this range to the highest massifs (Fig. 1), giving rise to separate but close glacial units. These were of small size compared to the large glaciers that developed towards the east in the Pyrenees or the Alps, but similar in size and distribution to glaciers in other mountains of the Iberian Peninsula, both to west and the south.

3. Methodology

A glaciomorphological map of each area studied was made to a scale of 1/25,000, based on a morphostratigraphic survey, the reconstruction of the Quaternary glaciers and their evolution (Tables 1a, 1b, 1c). The locations of the stepped moraine complexes were analysed and the main relative glacial morphogenetic stages established from accumulative glacial landforms in all massifs. The morphostratigraphic analysis was used to establish the temporal location of each glacier and rock glacier (Lukas, 2006; Hughes, 2010). Correlation between massifs was made including data on orientation, altitude of fronts, glacier length and type and the equilibrium line altitude (ELA). Data on rock glaciers was compiled (Table 2) and used as indicators of cold phases with mountain permafrost (Barsch, 1996; Haeberli et al., 2006) related to glacier

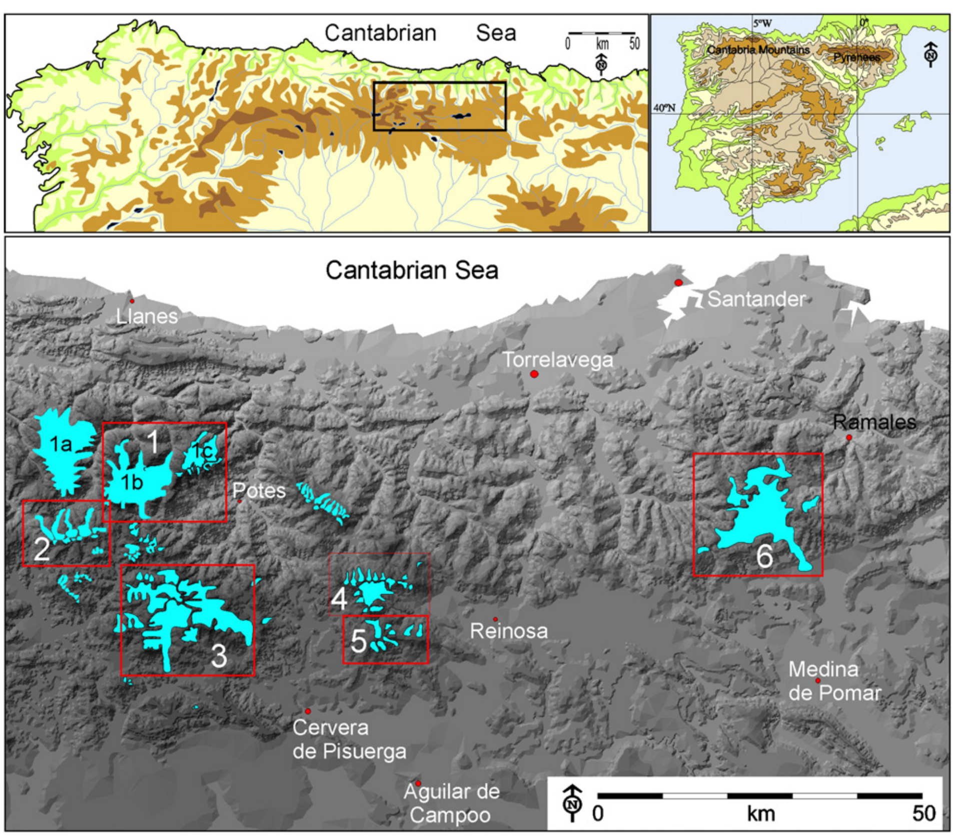

Fig. 1. Location of the studied massifs in the Cantabrian Mountains. 1, Picos de Europa. 1a, Western massif (Cornión), Central Massif (Urriello), Eastern massif (Ándara) 2, Sierra de Cebolleda. 3, Fuentes Carrionas. 4, Campoo. 5, Valdecebollas. 6, Pas Mountains.