Quaternary Science Reviews 83 (2014) 1–10

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

A multiple dating-method approach applied to the Sanabria Lake moraine complex (NW Iberian Peninsula, SW Europe)

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ARTICLE INFO

Article history:
Received 24 May 2013
Received in revised form
15 October 2013
Accepted 17 October 2013
Available online 16 November 2013

Keywords:
Cosmogenic dating
Glacial geomorphology
Ice cap
Last Glacial Maximum
Lateglacial
Sanabria
Iberian Peninsula

ABSTRACT

New evidence in the NW region of the Iberian Peninsula (~42°N 6°W) of a glacial advance coeval with the global Last Glacial Maximum (LGM) of the Marine Isotope Stage 2 has been identified through a dataset of exposure ages based on 23 ^{10}Be concentration measurements carried out on boulder samples taken from a set of latero-frontal moraines. Results span the interval 19.2–15.4 ^{10}Be ka, matching the last deglaciation period when Iberia experienced the coldest and driest conditions of the last 25 ka, and are consistent with Lateglacial chronologies established in other mountain regions from SW Europe. The extent of the LGM stade identified in this work is similar to the local maximum ice extent stade recorded and dated as prior to 33 ka using radiocarbon and optically stimulated luminescence. This work showcases how multiple-dating approaches and detailed geomorphological mapping are required to reconstruct realistic palaeoglacier evolution models.

1. Introduction

Evidence for asynchronism between the maximum advances of mountain glaciers and continental ice sheets is reported worldwide, suggesting that the dynamics of both ice systems responded differently to rapid changes in temperature and/or moisture supply (e.g. Gillespie and Molnar, 1995; Florineth and Schlüchter, 2000; Zreda et al., 2011). Ice sheets grew to their maximum position between 33 and 26.5 ka in response to climatic forcing from decreases in summer insolation, tropical Pacific sea surface temperatures and atmospheric CO_2 levels, and nearly all were at their Last Glacial Maximum (LGM) positions from 26.5 to 19–20 ka corresponding to minima in these forcings (Clark et al., 2009). The latter implies a longer time interval for the LGM episode than previous estimations based on the marine isotope and global sea level records (18 ^{14}C ka BP or 21 ka cal BP; Ehlers and Gibbard, 2007). Regional differences in maximum ice extent (Würmian MIE) and timing between mountain regions and the asynchrony with the global LGM hold significant information on cryosphere dynamics and palaeoclimatic evolution during the Last Glacial cycle. In the mountain regions of southern Europe, two chronological scenarios were proposed (Hughes and Woodward, 2008): (1) a local glacial maximum several thousands of years earlier than the LGM of Marine Isotope Stage 2 (MIS 2) based on evidence from northern Iberian Peninsula, Italian Apennines and Greece dated with radiocarbon, Uranium series, and optically stimulated luminescence (OSL) techniques, and (2) a local glacial maximum close or coeval with the global LGM based on evidence from central Iberian Peninsula, Pyrenees, Maritime Alps and Turkey dated through terrestrial cosmogenic nuclides (TCN). Such contrasting scenarios could be related to regional climate variability, but also to limitations or biases of the applied dating methods, as TCN methods consistently provided the youngest ages and radiocarbon and OSL the oldest ones (Hughes and Woodward, 2008).

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0277-3791/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.quascirev.2013.10.019

In the Iberian Peninsula mountains (Fig. 1), the current knowledge about the extent, timing and number of glacial stades during the Last Glacial cycle (ca last 120 ka) has been recently reviewed (Calvet et al., 2011; Jiménez-Sánchez et al., 2013) and is summarized as follows: (1) in the Pyrenees the Würmian MIE occurred between 97 and 36 ka depending on the valleys considered (Lewis et al., 2009; Pallàs et al., 2010; García-Ruiz et al., 2013), in the Cantabrian Mountains it was prior to 38 ka (Jiménez-Sánchez and Farias, 2002; Jalut et al., 2010; Moreno et al., 2010; Serrano et al., 2012, 2013), and in the Sistema Central occurred between 33 and 26 ka (Vieira, 2008; Palacios et al., 2010, 2012; Carrasco et al., 2013); (2) a new glacial advance took place during the LGM recording a glacial advance similar in extent to previous local MIE in the eastern end of the southern Pyrenees (23–21 ka) (Pallàs et al., 2006, 2010; Delmas et al., 2008) and in the Sistema Central (22–19 ka) (Palacios et al., 2010, 2012; Carrasco et al., 2013) while shorter glacial advances were recorded in the northern Pyrenees (20–18 ka) (Delmas et al., 2011), the western end of the southern Pyrenees (García-Ruiz et al., 2003; Lewis et al., 2009), and the Cantabrian Mountains (almost ice-free conditions in some valleys by 20 ka) (Jiménez-Sánchez and Farias, 2002); (3) frontal moraines coeval with the Oldest Dryas have been dated in the eastern Pyrenees and in the Sistema Central (Pallàs et al., 2006, 2010; Delmas et al., 2009, 2011; Palacios et al., 2010, 2012). In spite of all these new datasets, it remains unclear to what extent the differences in magnitude between local Würmian MIE and LGM stades might result from biases

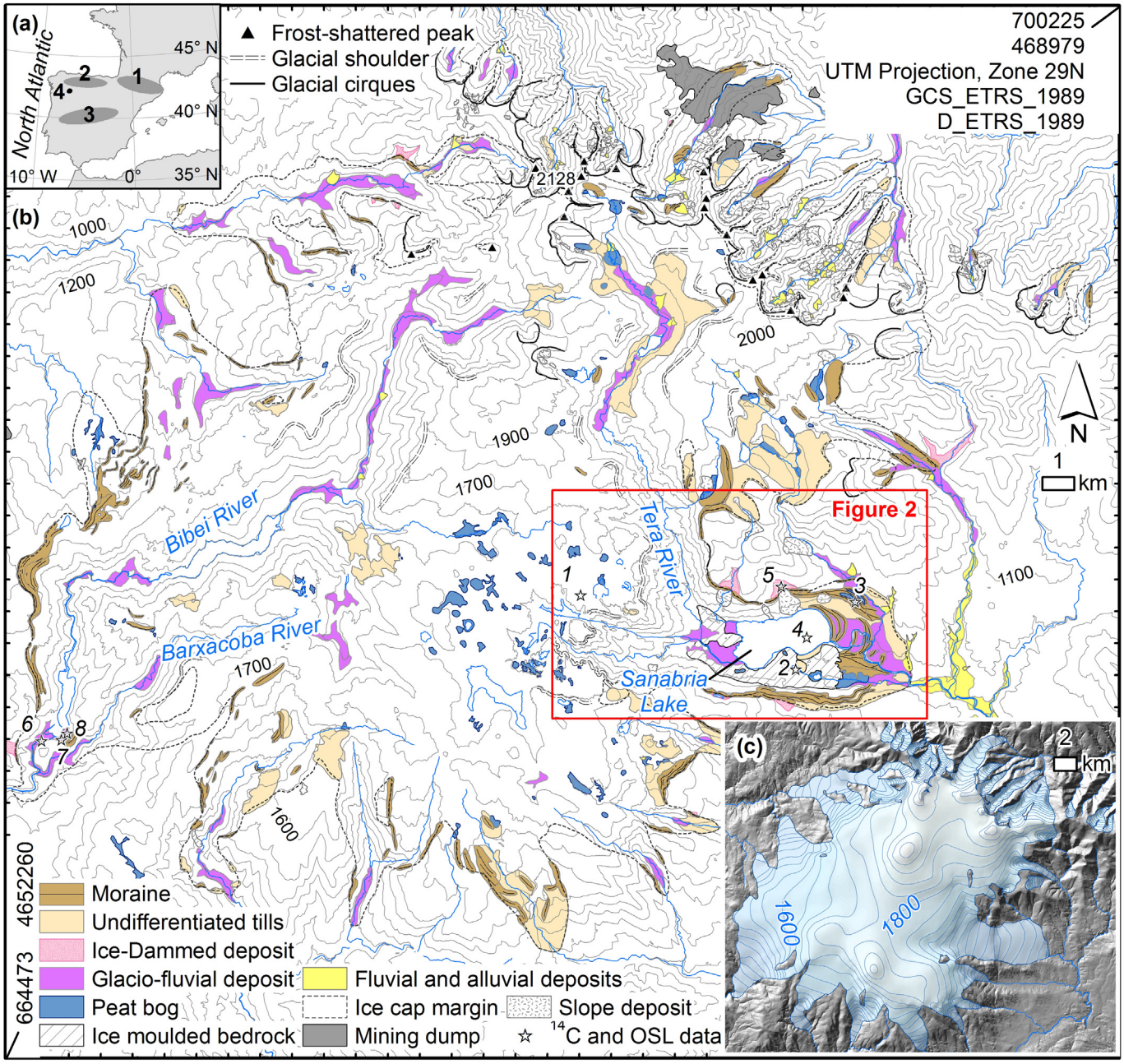

Fig. 1. (a) Setting (1-Pyrenees, 2-Cantabrian Mts., 3-Sistema Central, 4-Trevinca Massif). (b) Geomorphological map of the Trevinca Massif, including published ages: radiocarbon data (1–5) (see also Table 1) and optically stimulated luminescence data (OSL) from Pias site (6–8; Pérez-Alberti et al., 2011). The rectangle indicates Fig. 2 location. (c) Ice cap reconstruction for the local maximum ice extent (MIE).