Geomorphology 268 (2016) 233–245

Contents lists available at ScienceDirect

Geomorphology

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

The upper Pleistocene on the northern face of the Guadarrama Mountains (central Spain): Palaeoclimatic phases and glacial activity

Teresa Bullón

Department of Geography, Autonomous University of Madrid (UAM), 28049 Madrid, Spain

ARTICLE INFO

Article history:
Received 12 February 2016
Received in revised form 11 June 2016
Accepted 12 June 2016
Available online 14 June 2016

Keywords:
Glacial landforms
LGM
OSL
Sierra de Guadarrama
Iberian peninsula

ABSTRACT

The present paper provides new information on Pleistocene glacial activity in a mountainous area of the Iberian Central System. A sediment analysis associated with Pleistocene modelling was carried out using: (1) granulometric and morphometric procedures, (2) quartz grain microtexture techniques (SEM) to discriminate between glacial and no glacial origins of sediments, (3) clay X-ray diffraction study to determine intra-Pleistocene climate variability, and (4) optically stimulated luminescence (OSL) absolute dating. The results show that the sediments were formed in two different phases associated with glacial dynamics, one of them was 35–30 ky BP and another was 25–20 ky BP, separated by a short intermediate warm-wet period. Identification of glacial phenomena is new for the northern slopes of the Guadarrama Mountains (facing the north Meseta, Duero basin), although they are not unusual within the general context of the Iberian Central System. From the data provided, we deduce that glaciation in these mountains was much more intense and widespread than had previously been thought because, on the northern slopes, glaciers occupied large areas reaching the base of the mountains. The evidence favours new interpretations of Pleistocene morphology in the centre of the Iberian Peninsula and, by extension, on the southwestern edge of Europe; it also highlights the sensitivity of mountainous areas with regard to Quaternary climate changes.

1. Introduction

The present paper provides new information on Pleistocene glacial activity in a mountainous area of the Iberian Central System. The study consists of the analysis of sediments associated with Pleistocene morphology comprised of high angularity, variety of sizes and different degrees of weathering; the significance thereof was interpreted using the results of different analyses.

An abundant research has been published on the Quaternary geomorphology of the mountains of the Iberian Central System. These studies have differentiated the geomorphology of the Gredos Mountains, with valley glaciers on the northern slopes, from those of the Guadarrama Mountains, which contain glacier cirques mainly on the southern slopes. This study, referring to the northern slope of the Guadarrama Mountains, provides data that enables some of these basic features to be redefined and offers a better understanding of the development of Pleistocene morphological activity and of the associated climatic sequences.

1.1. Regional setting

The Sierra de Guadarrama Mountains are included in the Iberian Central System (Spain) which, with a maximum elevation of 2430 m in Peñalara peak, present a general SW–NE direction and are subdivided into several alignments of summits, which are separated by deep valleys or tectonic basins. The morphostructure is dominated by horsts and grabens bounded by high angle reverse faults. Many of these faults limit existing ancient accident blocks (Variscan and late-Variscan), which were reactivated under the alpine stress field (Tejero et al., 2006). The base of these mountains comprises a large, flat piedmont with an average altitude of 700 m in the southern face (belonging to the Tajo Basin) and 1200 in the northern face (belonging to the Duero basin). Glacial cirques formed on the mountain tops during the Pleistocene. These have been profusely studied since the onset of the twentieth century (Fernández Navarro, 1915; Obermaier and Carandell, 1917; Hernández-Pacheco, 1930; Fränzle, 1959; Pedraza and Centeno, 1987; Bullón, 1988; Sanz, 1988; Martin Duque, 1992).

The study area is located within one of the mountain ranges forming the Guadarrama Mountains, and it is part of a protected natural area in the province of Segovia, managed by the *Castilla y León* Regional Autonomy (Spain). It is commonly known as *Sierra de la Mujer Muerta* (*Dead Woman Mountains*, SMM) owing to its particular profile. It belongs to the the Eresma river headwater area, which is situated in the southern part of the Segovia Province, and it is a tributary of the Duero basin. Its principal topographic features are as follows: a general NE–SW direction, with a maximum altitude of 2196 m and the coordinates 40°48′75″N, 04°06′58″W in *Peña del Oso* (Fig. 1). The profile of the summit

E-mail address: teresa.bullon@uam.es.

http://dx.doi.org/10.1016/j.geomorph.2016.06.015

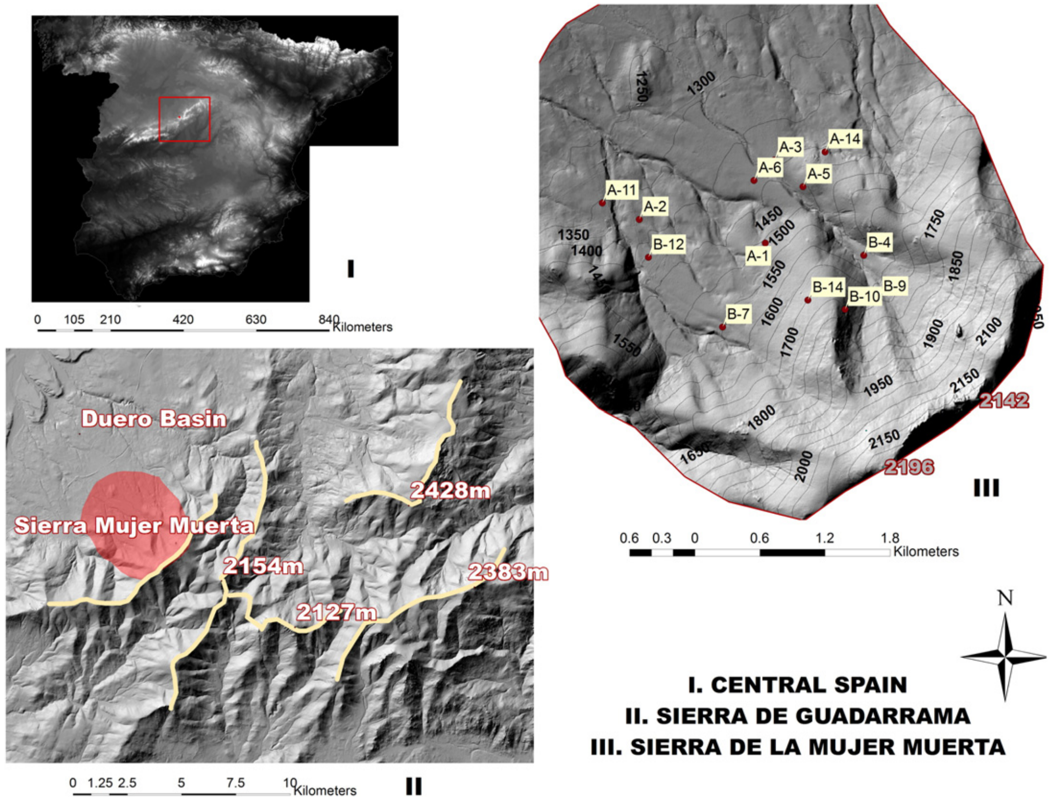

Fig. 1. Study area and sampling collection points. Image 5-m MDT_LiDAR. *Instituto Geográfico Nacional* (*IGN*).

surface is sharp and narrow, measuring 2.54 km long, and frames two catchments connected by torrential outflow channels, which are separated by long flat watersheds. Our research was conducted on the NW slope of this range; it is 2 km long and presents an average slope of 30%, and through a narrow piedmont, it connects with the plains of the sedimentary basin of the Duero river. The local rock consists of feldspar-quartz gneiss, presenting a high degree of metamorphism and an occasional small granitic intrusion.

The SMM most noteworthy sedimentary feature involves a series of poorly classified debris fans covering the base of the mountain. These contain a sand-silt-clay matrix that binds a large amount of pebbles and cobbles and scarcely rounded blocks, many of which are >1000 mm in length and present intense weathering and a general reddish-yellowish colour. Likewise, there exists another series of accumulations showing less intense weathering, which could be the remains of different morphological and chronological activity. The higher slopes are covered by stone streams comprised of large angular blocks, along with some small nivation hollows at different altitudes and at different orientations (Bullón, 1977, 1988).

The importance of the periglacial activity of this mountain range is undisputed and the originality of many of its morphological and sedimentary characteristics reveals that the Pleistocene activity has been intense. Nevertheless, little research has been done recently, so the obscure data referring to the SMM pose a scientific challenge, that need to be solved.

1.2. The Pleistocene period in the Mediterranean and Iberia: state of the art

The incorporation of absolute datings to research on glaciation in the Pleistocene in recent years has allowed general interpretations to be put forward for a diversity of partial findings. This synthesising effort reveals the specificity of glaciation in the Mediterranean mountains, for the chronologies they display and for their sensitivity, expressing climate variability that remains concealed in other greater glacial masses (Hughes and Woodward, 2008; Hughes et al., 2010, 2013).

Datings of Iberian glaciers show a wide range of variability, perhaps caused by the methods employed (Calvet et al., 2011), but possibly indicative of each mountain range's relative independence from the Pleistocene environment. The Pyrenees have notable asynchronies between its eastern and western parts that may be the result of different reactions to atmospheric dynamics, whose intensity would have varied according to geographical position, topography, and exposure conditions (Delmas et al., 2011, 2012). However, a glaciation between 90 and 80 ky BP is generally accepted on this mountain range, followed by two glaciations in isotope stages 4 and 3, respectively, which correspond chronologically with well-documented fluvial terraces, and a final phase occurred in 22–18 ky BP (García Ruiz et al., 2003, 2010).

In the Picos de Europa region, a great glaciation occurred before the Last Glacial Maximum (LGM), although the latter is most commonly

Table 1
Percentage values of the granulometric groups.

	A-1	A-2	A-3	A-5	A-6	B-4	B-7	B-9	B-10	B-14
Gravel	41.2	18.4	24.6	42.2	43.9	25	39.83	8.53	10.23	13.77
Sand	32.95	51.2	33.2	29.7	35.2	38.2	28.75	63.41	55.36	56.61
Silt	25.63	30.4	42.2	28.1	20.9	36.8	31.42	28.06	34.41	29.62
Coarse/fine silt	0.73	0.29	0.48	0.93	0.47	1.43	0.58	0.74	0.44	0.61