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Geomorphology of the Ubiñas Massif, Cantabrian Mountains, NW Spain (1:22,000)

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ABSTRACT

A Geomorphological Map of the Ubiñas Massif, Cantabrian Mountains, at a scale 1:22,000 and covering 94.52 km², is presented. The 'Natural Park of Las Ubiñas-La Mesa', a completely deglaciated glaciokarst, containing the highest peaks in this part of the Cantabrian Mountains, has been also declared 'Biosphere Reserve' by UNESCO. A previous geomorphological map (13.17 km²), recording glacial and periglacial, karst, slope, fluvial and anthropic features, is now enlarged to include the whole massif. An initial analysis of the present map, planned as a basic instrument to fulfil the needs of no particular end-users, provides information about rock avalanches during glaciation, preglacial deposits, and the absence of rock glaciers formed by calcareous debris, among other characteristics of the area. This cartography, considered as a fundamental base for environmental management, could be employed as a basis document to obtain other geomorphological derived maps.

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1. Introduction

The Ubiñas Massif, located in the border between the Asturias Province to the north and the León Province to the south (NW Spain, [Figure 1](#)), is a protected area, included in the 'Natural Park of Las Ubiñas-La Mesa' since 2006, and declared by UNESCO as 'Biosphere Reserve' in 2012. Mainly formed by calcareous rocks and aligned in a NW-SE direction, this massif contains the highest peaks of the central part of the Cantabrian Mountains, namely the Fontán Sur (2414 m) and Peña Ubiña La Grande (2411 m). These two peaks constitute part of the main divide in the area; to the north, waters feed the River Nalón which flows northwards into the Bay of Biscay, while the River Luna, to the south, discharges into the River Douro which flows westwards into the Atlantic Ocean.

The area was strongly glaciated during the last glacial cycle and display glacial, periglacial and karst landforms. In addition, numerous slope processes, related to the high relief, are represented by mixed slides, debris cones and talus slopes. The fluvial network in the higher zones is irregularly developed due to karstification and it is also controlled by large landslides. Anthropogenic action has modified many of the lower lands for agricultural activities, most of which are abandoned at present, whereas mountainous areas are variably modified by open-pit coal mining, and related waste dumps, as it can be seen in the NW part of the study area. At present, most of the massif is ascribed to an alpine karstic-nival environment where bare limestones, with overstepped slopes, alternate with pasture meadows.

Geologically, Ubiña Massif is part of the Variscan basement in the Cantabrian Zone, belonging to the Aramo nappe (Bodón-Ponga Unit, [Alonso, Marcos, & Suárez, 2009](#)). The Alpine Orogeny resulted in uplifting and exhumation of the Variscan basement, giving rise to the mountain range known as the Cantabrian Mountains, in which the Variscan structuring in largely preserved with little Alpine overprinting ([Alonso, Pulgar, García-Ramos, & Barba, 1996](#); [Gallastegui, 2000](#); [Pulgar, Alonso, Espina, & Marín, 1999](#)). Altitudes of most of the peaks in the area are around 2000 m, while those in the Ubiña Massif, formed by carboniferous limestones (Barcaliente and Valdeteja formations) are higher than 2400 m. [Alonso, Martínez Abad, and García-Ramos \(2007\)](#) have attributed this difference in height to structural causes considering that, in neighbouring areas, mountains of the same lithology reach lower levels.

The Palaeozoic stratigraphic succession contains two major hiatuses: one from middle Ordovician to lower Silurian and the other comprising part of middle and upper Devonian. The Mesozoic is represented by a terrigenous succession cropping out to the northeast and southeast of Peña Ubiña Pequeña ([Alonso et al., 2007](#)). Most of the bedrock in this area corresponds to limestones (Barcaliente and Valdeteja formations) and siliciclastics (San Emiliano Formation). Finally, Quaternary deposits are widespread patchily covering the bedrock. Apart from the above mentioned authors, an updated map from the IGME, Instituto Geológico y Minero de España (Spanish Geological Survey;

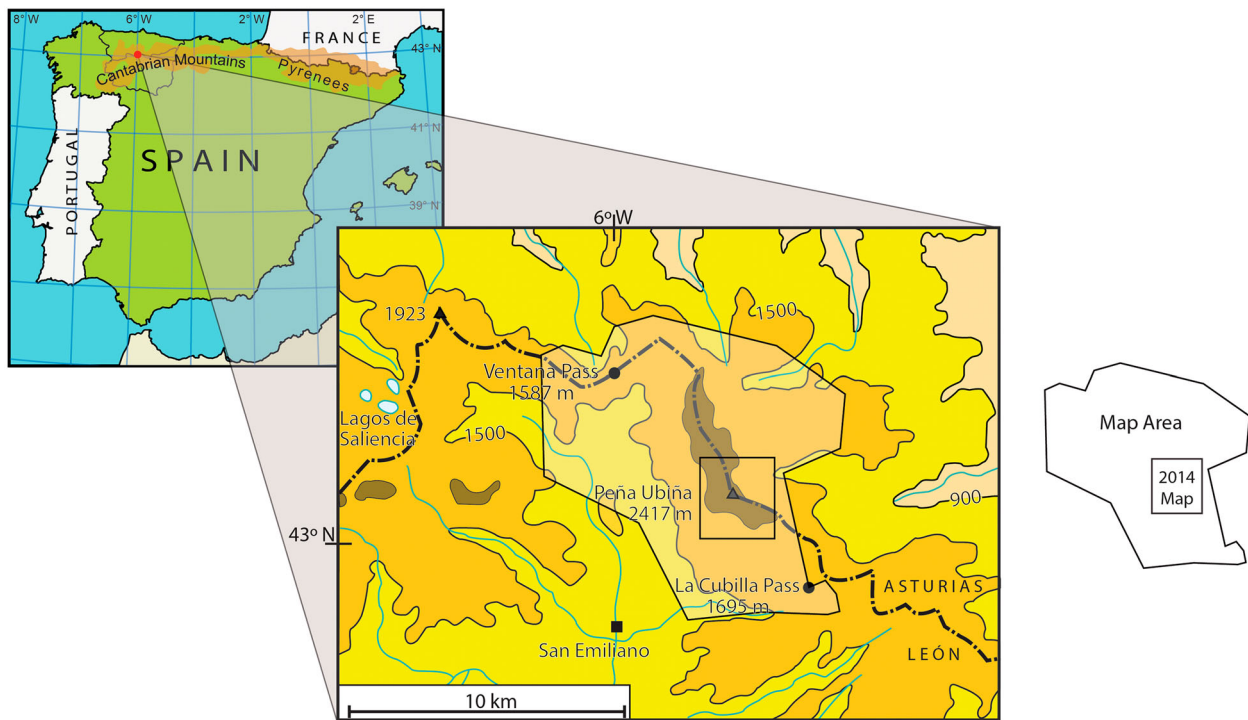


Figure 1. Schematic map showing the location of the Ubiñas Massif in the west of the Cantabrian Mountains. Outlined areas represent the extent of the present and of the 2014 maps.

<http://info.igme.es/visorweb/>; Merino-Tomé, Suárez Rodríguez, & Alonso Alonso, 2014) was consulted.

Outstanding values of the Natural Park of Las Ubiñas-La Mesa include high reliefs, lithological variety (siliciclastic and calcareous rocks) and a diversity of geomorphological features related to glacial, karst and fluvial processes. The Park has also a biological interest: mature woods, mainly beech forests, occupy lower zones and the area provides suitable habitat for representative fauna of the Cantabrian Mountains, as grouses, roe deers, chamois and, the most important, cantabrian brown bears, catalogued on the Spanish Red List of Endangered Species. The entire Park represents an outstanding zone for visitors with leisure mountain activities being carried out all the year round. Finally, it has an historical interest since a large number of structures from the Spanish Civil War are present in the whole area, demonstrating its strategic importance from august 1936 to October 1937 (Gallinar & Duarte, 2015).

Little geomorphological maps exist for the area, although the glacial forms of the Ubiñas were already mentioned by Stickel (1929), who made a short reference to them, attributing the slight development of glacier cirques to the steep slopes of these calcareous mountains. Castañón (1983) made a sketch on ‘glacial morphology and nival forms during glaciation’ representing main glacier cirques and moraines, among other features. Later, Gallinar et al. (2014) distinguished three glacial phases for the northeast sector of the massif, named maximum, internal and in altitude, but they did not represent them on a map, which impedes to

determine the distribution of the glacial and periglacial forms described in the text. More recently, Santos-González et al. (2018) analysed the paraglacial processes in a sector of the Cantabrian Mountains, which includes the western part of the Ubiñas Massif, and presented a geomorphological map showing the ‘main glacial and paraglacial forms’ of the area.

A geomorphological map of the south sector of the Ubiñas Massif (Alonso, 2014) was specifically made to be included as complementary information in the ‘Inventory of Sites of Geological Interest’ promoted by the Spanish Geological Survey in 2014–2015 (<http://info.igme.es/ielig/documentacion/ca/ca065/documentos/d-ca065-01.pdf>). This map, originally digitized at a scale 1:1000 and covering 13.17 km², was focused in the south part of the massif and registered distribution of the main surficial forms. Although glacial and periglacial features were specially detailed, as it was initially made with a basic approach, it also included those related to karst, slope, fluvial and anthropic processes. This map has a continuation in the **Main Map** presented here, which is aimed at covering the whole massif, contributing to the knowledge of the recent processes and forms operating in this part of the Cantabrian Mountains and creating a base document for the Park management.

Present-day meteorological data from the San Emiliano Station (42° 58' S 6° 0' W), located at 1170 m a.s.l., provided by the Ministry of Agriculture (<https://sig.mapama.gob.es/geoport/>), yield values of a MAAT of 6.7°C and a precipitation of 1076 mm y⁻¹, for the 1961–1997 period, although snow is not differentiated

in the precipitation values (snow patches can last until midsummer in sheltered zones). The cold period is calculated to last 11.133 months a year, while the Mean Minimum Temperature for the coldest month is -4.20°C . However, these data from San Emiliano station, located in the southern slope of the main divide and at relatively low altitude, are not representative of the whole mapped area, characterized by marked climatic contrasts. Using data of the Leitariegos Meteorological Station (at 1535 m a.s.l.) located 34 km to the west, [Alonso and Trombotto Liaudat \(2009\)](#) estimated that permanently frozen ground should be present at 2600 m and that important cryogenic activity must take place above 2000 m.

2. Methods

This map has been made following similar criteria to those applied in the previous geomorphological map of the south part of the Ubiñas Massif. Geomorphological mapping, produced at 1:1000 scale, although the final layout is at 1:22,000 scale, was made integrating both detailed field surveying and remote sensing techniques. Vectorized topography was obtained from the website of the National Geographic Institute (IGN; <http://www.ign.es/ign/main/index.do>), as well as the PNOA orthophotos (National Plan of Aerial Orthophotos, 2006; <http://centrodedescargas.cnig.es/CentroDescargas/index.jsp>) with a pixel size of 25 cm. From the IGN topographic base, only one contour curve out of five was represented in the final geomorphological map, resulting an equidistance of 50 metres. Air photos, at a variety of scales and from different years, were used to delineate an initial map with a GIS-software (ArcGis) later completed by field mapping and field photo

analysis. This process was repeated in some areas before reaching the final map ([Figure 2](#)). Aerial photos correspond to the flight of 1956–57, made by the USAF at a scale 1:33,000, the flight of 1985 (from the IGN) at a 1:15,000 scale, both with black and white images, and the flight of 2003 (from the Principality of Asturias) at a scale 1:15,000, in colour. Not all the flights provide the same information, thus many war related features, which are hardly visible today, can be seen on historical photographs of the USAF flight, taken around 20 years after the end of the Spanish Civil War.

Sigpac orthophotos (<http://sigpac.mapa.es/feqa/visor/>), initially designed for agricultural purposes, were also consulted as they display a lower snow cover than PNOA. A 3D viewer online, with anaglyph glasses, provided by IGN (www.ign.es/iberpix2/visor) was used to complete the information obtained from the aerial photographs, orthophotos and from the topography.

Fieldwork was carried out over a four-year period (2014–2018). Field photographs of many of the features represented in the geomorphological map were included as attribute, to complete the information given by the cartography.

In order to standardize map symbols, the ‘Guía para la Elaboración del Mapa Geomorfológico de España’ (Guide for the Elaboration of the Geomorphological Map of Spain; [Martín-Serrano, Salazar, Nozal, & Suárez, 2004](#)) was followed, although some modifications were needed since not all symbols presented in this guide, originally created for a 1:50,000 scale, were adequate for a detailed map.

Except contour curves, imported from the IGN, all elements were manually digitized or modified, using orthophotos as a base map. [Table 1](#) shows features recorded in the map as polygons, polylines and points;

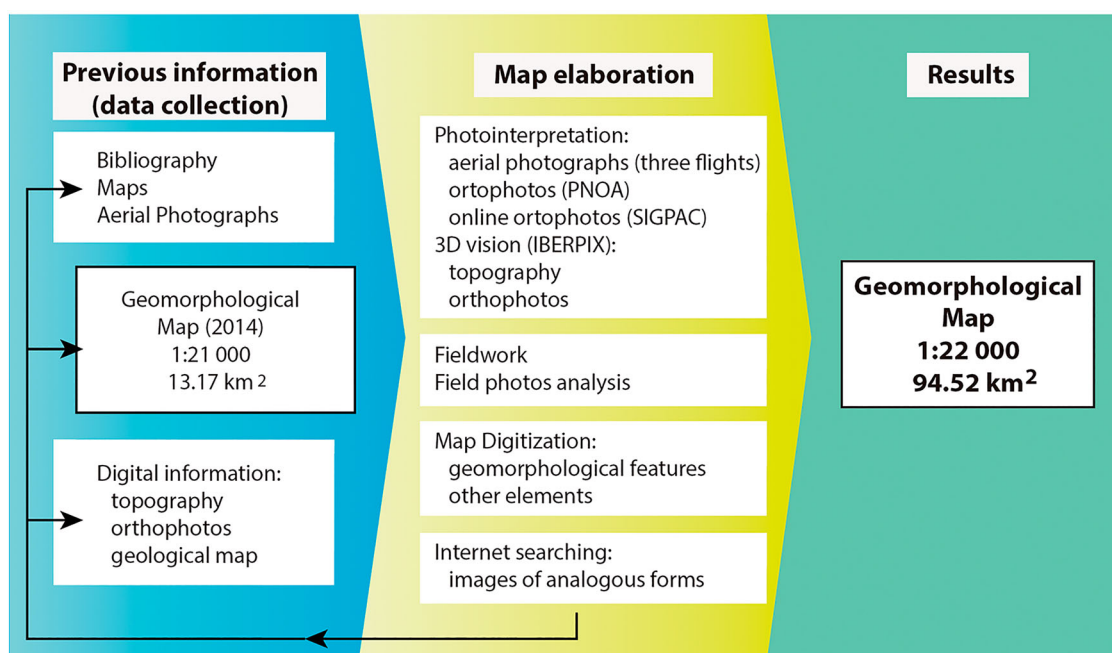


Figure 2. Diagram showing the steps followed to build the map.

Table 1. Elements represented in the map grouped by genetic criteria. Numbers in brackets correspond to the numeric key of the deposit.

	Polygons	Polylines	Points
Glacial	Till (1) Supraglacial till (2) Obturation deposit (3) Abraded surface	Glacier cirque Glacier threshold Moraine crest Slope break Transfluence	Block
Periglacial and Nival	Rock glacier (4) Protalus rampart (5) Periglacially reworked till (6) Sorted stripes (7) Wind erosion terracetes (8) Solifluction (9) Nivo-torrential carbonate fan (10)	Avalanche channel	Ploughing block
Fluvial and Lacustrine	Nivo-torrential mixed fan (11) Fluvio-torrential deposit (12) Lake Wetland	Watershed divide Stream Ephemeral stream Erosional scarp Gully	
Slope	Mixed landslide (13) Rock fall/Rock avalanche (14) Talus slope (15) Debris cone (16) Cemented debris (17)	Scarp Slide scar Sliding direction Crest Furrow	
Karst	Karst deposit (18)	Karst depression	Ponor Spring
Structural forms	Old erosive surface		
Anthropic	Anthropic terraces (19) Anthropic (20)		War remain
Topographic symbols		Level curve Road Mountain trail	Peak Locality/Refuge

data were genetically grouped in glacial, periglacial and nival, fluvial and lacustrine, slope, karst, structural forms, anthropic and topographic symbols.

To facilitate description, a grid with an approximate 2 km square cell size was superimposed to the final map, resulting a total of six rows (A to F) and six columns (1–6) labelled in the left and upper borders.

2.1. Map features

As this type of maps can be a complex document when used for applied purposes (Griffiths & Abraham, 2008), the following comments are intended to ease its interpretation.

2.1.1. Glacial

Diamictons with clasts of different lithologies, in some cases including abraded and striated blocks, were identified as till. Not always forming moraines and often containing only limestone clasts, in some areas tills were recognized in small outcrops on slopes formed by stream incisions or even in slide scarps (as in B4 and B5).

Coarse diamictons, mainly formed by very large blocks and placed at a certain distance of steep calcareous walls, were interpreted as supraglacial till (e.g. south B4; Figure 3). These deposits have been distinguished from till because they probably constitute a vestige of old avalanches on glacier ice, similar to the rock avalanche on Bucksink Glacier (Alean, 2011) a process also reported in other glacier environments (e.g. Delaney & Evans, 2014).

Glacial obturation deposit were only recognized in B2 and in northeast C5.

Glacially abraded surfaces on limestone are clearly preserved in areas close to glacier cirques (good examples in C4), although no striae were found.

Some large glacially transported blocks were recorded as reference for field photographs.

2.1.2. Periglacial and Nival

Limestone slopes in Ubiña Massif do not display rock glaciers. Only one well-developed rock glacier was identified in the NW part of the map on cambro-ordovician sandstones (B1; Figure 4).

Protalus ramparts developed at the toe of talus slopes (as in east C4) were identified following Washburn (1973) criteria.

Sorted stripes on limestones are located to the north of the map (A3 and B3). A slope deposit to the east of Colines, in C3, (reworked till by periglacial and slope processes) shows a crude classification in bands and was mapped as a solifluction deposit.

Wind erosion terracetes, formed by eolian deflation in frost loosening soils, were only found close to water divides in siliciclastic areas (east B1). They are probably similar to the *Rasenguirlanden* cited by Troll (1973), at altitudes over 1560 m, in Sierra de Guadarrama and Somosierra.

Nivo-torrential carbonate fans were distinguished based on their size, clast composition and location at the lower end of avalanche channels (as in north E3-E4). They are usually found on steep slopes, being

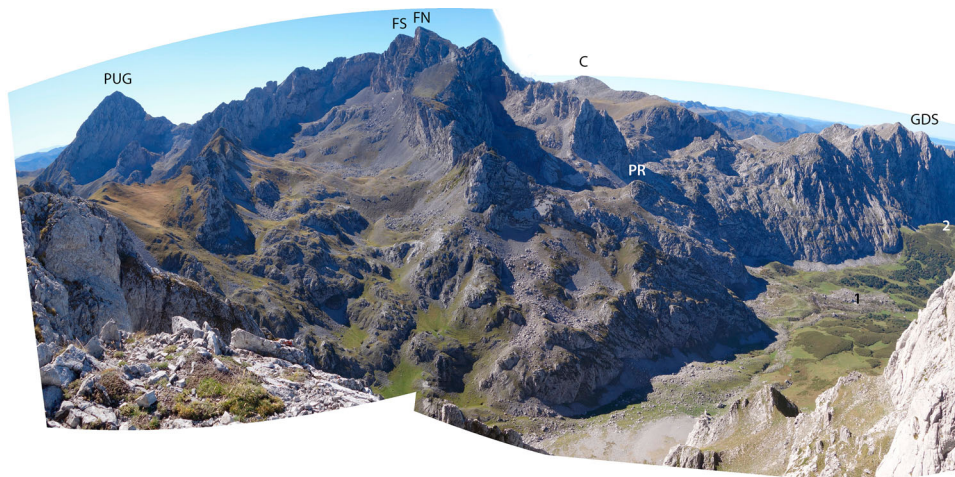


Figure 3. View of C4 and B4 from south to north. Supraglacial till (1), interpreted as supraglacial avalanche rock deposits, lies to the north of a set of moraines at the front of Peña Redonda (PR). 2 marks a transfluence zone (in northwest B4), where glacier ice crossed a low pass moving to the north. Note the coalescent debris cones at the toe of the limestone steep slopes. Main peaks are, from south to north, Peña Ubiña La Grande (PUG, 2411 m), Fontán Sur (FS, 2414 m), Fontán Norte (FN, 2408 m), Colines (C, 2205 m), Peña Redonda (PR, 1882 m) and Güerto del Diablo Sur (GDS, 2133 m).

much smaller than mixed fans included in the fluvial group, and are mainly feed by snow avalanches.

Avalanche channels are often controlled by faults, not represented in this map, or by stratification.

Large ploughing blocks, in solifluction areas, were considered of interest to be represented in the map.

2.1.3. Fluvial and lacustrine

Nivo-torrential mixed fans are larger than nivo-torrential carbonate fans. They reach valley bottoms (C1 and north D4-D5), and are included in this group because their formation is mainly controlled by fluvio-torrential processes with a lesser nival influence.

Antropized sloping valley bottoms, other than fluvio-torrential deposits, have not been represented.

Rivers were partially modified from those acquired, with other data, from the IGN, while streams,

ephemeral currents and lakes (including ponds) were manually digitized.

2.1.4. Slope

In this map, rock avalanche and rock fall deposits are represented by a unique symbol as they were distinguished by clast size, not attending transport mechanisms revised by [Hungre, Leroueil, and Picarelli \(2014\)](#). Similarly, landslides include different types of deposits related to slope instabilities in a wide sense.

Debris accumulations with a fan shape, at the toe of steep slopes and connected with avalanche channels, have been represented as debris cones. They are distinguished from talus slopes, which represent a more laterally continuous debris cover on slopes, and from the previously mentioned nivo-torrential carbonate fans, in whose formation water plays a more important role.



Figure 4. View of B1 to the northwest. La Ferreirúa (F, 1976 m), with siliciclastic bedrock, contains the only tongue shaped rock glacier (1) recorded in this map, several glacial moraines (2) and probably lobate rock glaciers (3) in positions close to cirque wall.



Figure 5. Areas A4-A5-B5-B6, view to the north. During summer, Puertos de Güeria is an important grazing zone for cattle and horses. Partially covered with till, it presents numerous lateral and frontal moraines. (1) Supraglacial till. (2) Outcrop of cemented calcareous clasts (in dark colour) among till, interpreted as preglacial talus slope deposits. Peña Rueda (PR, 2152 m) was a strategic location with several war structures.

Cemented debris contain a wide range of carbonate cemented deposits, from a single block, probably glacially transported (marked as a block, in north B4 or in east F3) to large outcrops of *in situ* breccias (as in south B5, east C5 or in F4; Figure 5).

Polyline crest and furrow have no genetic meaning. They can mark the crest of a protalus rampart as well as the ridges and furrows in avalanche deposits or in supraglacial till. In other cases, as in south C4, crests are not ascribed to a specific process, as it is not clear whether they represent small moraine crests or are related to karst evolution

2.1.5. Karst

Deposits related to karst evolution were included in a unique symbol as karst deposits.

Karst depression boundaries were easily digitized as most of them are located in sparsely vegetated zones (e.g. E5). As pointed out by Ford and Williams (2007), most karst depressions in glaciated terrains are polygenetic forms with a complex history and, for this reason, in this map dolines and glaciokarstic depressions were included in the same group.

Ponors, from small sinkholes to stream sinkpoints with vertical walls, are well represented in some areas, as D5-E5.

2.1.6. Structural forms

Pre-Cenozoic surfaces, located in high zones (C4-5 and D4) and not destroyed or modified by younger processes, are represented as old erosive surfaces. Some of them display a thin debris cover affected by solifluction.

2.1.7. Anthropogenic

This group comprises mainly war structures, mining remains and small aggregate quarries. War structures,

represented as polygons or as points depending on their surface, include shell scrapes, trenches, stone fences, cave refuges, machine gun nests and casemates. In the case of polygons, to be distinguished from other anthropic features, they are combined with a specific point symbol. Open coal mining, in A2-B2, although now abandoned is quite noticeable, as neither exploitation fronts nor waste dumps have been rehabilitated.

Anthropic terraces refer to modified slopes for agriculture purposes; at present, they are no longer cultivated but used as cutting or grazing meadows (Figure 6).

2.1.8. Topographic symbols

Locality/refuge symbol includes villages, mountain refuges and mountain passes.

Other data, not shown in the final layout, as field-photo locations not ascribed to a single feature and mountain paths, were also recorded forming part of the hidden data, available for future projects.

Deposits were coded originally by colours and later completed with a numeric key (see Table 1) to facilitate their identification.

3. Discussion and conclusions

Several questions arise from the examination of this geomorphological map, where higher zones correspond to a glaciokarst landscape (Figure 3) with a long nival history after deglaciation.

Cirques are in general not well developed, as already observed by Stickel in 1929, and some glaciers were formed by accumulation of snow avalanches at the toe of oversteepened slopes: east of D3 shows a group of moraines at the toe of a calcareous wall with no glacier cirques (Figure 6). A similar situation is found in



Figure 6. View to the east of the western part of the massif (D1-D2-C3-D3-D4). Low lands are strongly modified by agricultural activities, most of them abandoned at present. Note the level achieved by these anthropic terraces (1); former cropping fields (where potatoes and pulse were cultivated) are now transformed into cutting or grazing meadows. Asterisk on the left marks an abraded limestone surface (in D1) with a discontinuous till cover and some glacially abraded siliceous clasts. Colines (C, 2205 m) and Peña Ubiña La Grande (PUG, 2411 m), among other peaks, form the main water divide in this area.

the east A3, although in this case, there is a small accumulation zone, over 300 m above the till deposit, hanged on a calcareous wall.

Position and characteristics of supraglacial till (Figure 3), considered as rock avalanches on glacier ice, indicates that these failures probably took place when glacier fronts were close to the cirques in a retreating phase, similarly to what happens in present glaciated areas, where Evans and Clague (1994) relate debutressing of rock slopes adjacent to glacier surfaces with glacier retreating. Lobate front and flow lines (south B4) would support the hypothesis that transport was not able to obliterate avalanche characteristics; Delaney and Evans (2014) point out that original avalanche features seem not to be modified by glacier motion. To the south of El Meicín Refuge (D4), a very large block interpreted as supraglacial till displays jigsaw-puzzle cracks with its northeast and southwest ends showing a more accentuated dismembering. In Alps, Ostermann et al. (2012) post-date most rock avalanches to the Last Glacial Maximum; in Ubiñas, these deposits probably correspond to the phase III, defined in the eastern part of the Cantabrian Mountains by Jiménez Sánchez (1996), when glacier fronts were stabilized at altitudes between 1500 and 1700 m. Postglacial slope evolution, which presumably began during deglaciation, starting at 21–20 ka in the Central Cantabrian Mountains (Rodríguez-Rodríguez et al., 2018), continues at present. Some areas have experienced many changes since glaciers retreat. For instance, the area located behind the frontal moraine in south E3 does not preserve signs of having been once glaciated. Also, some of the surficial deposits on the slopes to the west of Peña Ubiña Pequeña, which were originally till, have been modified

by slides of variable magnitude depending on bedrock characteristics (San Emiliano Fm.).

Some disagreement on the moraine distribution to the west of the Ubiñas Massif exists between Santos-González et al. (2018, their Figure 3) and the map here published. Based on field data, one of their moraines is actually a San Emiliano Fm. outcrop, with a very and discontinuous till cover (D-3), while another one, to the southeast of Peña Ubiña Pequeña, is here interpreted as a crudely bedded cemented preglacial deposit (F-4).

Probably the most striking fact is that, in spite of the altitudes of this massif, no rock glaciers have been found except on cambro-ordovician sandstones, in the northwest. This absence of rock glaciers formed by Barcaliente and Valdeteja limestone clasts was noticed by Alonso (2014). Although there is a large tongue-shaped rock glacier on limestones not far to the west, with the front at 1740 m, most rock glaciers in the area are formed by sandstone clasts.

Thus, a tongue shaped rock glacier (Figure 4), the only one mapped in the area, on siliciclastic bedrock (B1) with the front at 1450 m and a NNE aspect, could correspond to a Tardiglacial cryomere, to which tongue shaped rock glaciers in low positions were ascribed by Alonso and Trombotto Liaudat (2009) in a zone located 45 km to the southwest. A set of ridges and furrows in the same mountain alignment, at higher altitudes and close to cirque bottoms, are interpreted as periglacially reworked till, as some of these crests point to the north, not to the northeast following main slope direction. Although they probably are lobate rock glaciers, corresponding to a more recent and less intense cryomere, they would need a more detailed

examination. A deposit formed by limestone blocks with a group of crests (in north E5) proposed as a possible rock glacier (Alonso, 2014) is now interpreted as two protalus ramparts. The absence of rock glaciers in the Ubiñas Massif requires a further analysis as it could be due not only to bedrock characteristics.

Cemented debris were carefully mapped as they could give information on preglacial dating. Figure 5 shows one of these outcrops partially covered by till; it is formed by crudely stratified angular calcareous clasts, indicating that it probably corresponds to a preglacial talus slope deposit. Other examples of cemented debris (east of C5) are interpreted as an old talus slope deposit.

Most anthropic terraces likely represent reworked till deposits, as they often contain glacially abraded, iron-flat and bullet shaped clasts, indicating a subglacial transport. Recently unburied limestone iron-flats maintain in some cases striated surfaces.

New mapping techniques, like GIS software, and availability of digital elevation data, high resolution orthophotos and increasing number of aerial photographs, among other remote sensed data, have improved and facilitated the mapping of landforms over the last decades. However, field work is still of paramount importance in geomorphological mapping as it has been in the present case. Information from the aerial photographs should be always field-checked to determine some details, as clast composition, shape and surface characteristics, sometimes key to interpret the deposit in which they are included.

The information provided by this map represents a basic source document for further maps focused on specific features that could be need in the future. It could be used in glacier reconstructions, or as a previous survey in generating a landslide risk map. Simplified or thematic maps, based on this one, could be also used with educational purposes to illustrate fundamental glacial and periglacial processes and forms, among other topics.

To sum up, the use of this basic geomorphological map will allow a better understanding of the Ubiñas terrain, of outstanding interest, for helping administrate the natural resources of the area or for regional planning by other administration managers.

Software

Esri ArcGis 9 was used for map production including data management, digitizing and final layout generation. Location map was created with Inkscape and later imported as a figure in the final layout. An A1 size is recommended for map printing.

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Disclosure statement

No potential conflict of interest was reported by the author.

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