**Paleoenvironments and human adaptations during the Last Glacial Maximum in the Iberian Peninsula: a review**

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**Abstract**

The Iberian Peninsula is considered one of the most well-suited regions in Europe to develop studies on the relationship between environmental changes and human adaptations across the Late Pleistocene. Due to its southwesternmost *cul-de-sac* position and eco-geographical diversity, Paleolithic Iberia was the stage of cyclical cultural/technological changes, linked to fluctuations in climate and environments, human demographics, and the size, extension, and type of social exchange networks.

Such dynamics are particularly evident during the Last Glacial Maximum (LGM) timeframe, with a series of innovations emerging in the archaeological record, marking the transition between the traditionally defined Gravettian, Proto-Solutrean, Solutrean, and Magdalenian technocomplexes.

Stemming from a workshop organized in Erlangen in 2019 on “The Last Glacial Maximum in Europe - state of knowledge in Geosciences and Archaeology”, this paper presents, in the first part, an updated review on the paleoenvironments and human adaptations across four macro-regions (Northern, Inland, Mediterranean, and Western Atlantic Façade) in Iberia during the LGM; and, in a second part, a discussion on the pronounced inter-regional variability, unresolved research questions, and the most promising research topics for future studies.

**Keywords**

Last Glacial Maximum; Iberian Peninsula; Paleoenvironments; Human ecodynamics

**1. Introduction**

More than 40 years have passed since the first publications of the CLIMAP project (CLIMAP, 1976), where the term Last Glacial Maximum (LGM) is coined for the first time as a definition of a period in which, during the last glacial cycle, polar ice sheets globally reach their maximum extent. The results reported at that time on the global impact of this event are, even today, an absolute reference for characterizing the climatic patterns during the LGM: (1) displacement of the polar front to ca. 40º N of latitude; (2) relatively sharp drop in surface water temperature (on average -2.3ºC); (3) descent from the average sea level to, depending on the geographical area, at least -85 meters; (4) widespread proliferation of steppe and desert landscapes, to the detriment of forests, in most of the European continent.

Naturally, as research methods progressed, several shortcomings of the CLIMAP project became apparent. Other projects, such as MARGO (Kucera et al., 2005), EPILOG (Mix et al., 2001), or GLAMAP (Pflaumann et al., 2003), brought new perspectives to the generic characterization of the LGM. The current definition of the term remains, however, under debate, without achieving a coherent stratigraphic status (Hughes et al., 2013). In fact, although Mix et al. (2001) have proposed the definitive conversion of the former central age of ca. 18 ka BP to the calibrated value of ca. 21 ka cal BP, the exact chronology of the maximum ice extension interval in the various regions does not seem to be exactly in agreement (Gillespie and Molnar, 1995). Nevertheless, it is generally accepted that almost all ice fronts of the most important mountain ranges in the world would be in their LGM positions between 26.5 ka and 19-20 ka (Clark et al., 2009).

Some of the major advances in the characterization of the LGM were, however, those concerning the reconstruction of the effects of the event at a regional scale. The proliferation of analyzes of the sequences of isotopic stages derived from the observation of fluctuations in δ18O of fossilized planktonic foraminifera, high-precision pollen studies from deep-sea and terrestrial records, fauna and microfauna analysis from archaeological and paleontological sites, have allowed characterizing in greater detail regional and local environmental changes (Figure 1).



Figure 1 – Global and regional Iberian climatic/environmental proxies from ca. 40 to 10 ka cal BP. A - δ18O record of the NGRIP ice core, with numbers and grey bars referring to Greenland Stadials (Rasmussen et al., 2014), and indication of the LGM chronology used in this paper (Clark et al., 2009); B – Sea Surface Temperature reconstructions of marine drilling core MD95-2043 (Alborán Sea) (Cacho et al., 2001), and Heinrich Events detected in the same core; C – Percentage of temperate forest pollen in core MD95-2043 (Fletcher and Sánchez Goñi, 2008); D - Sea Surface Temperature reconstructions of marine cores MD95-2042 and SU81-18 (Atlantic) (Sánchez Goñi et al., 2008), and Heinrich Events detected in the same cores; E - Percentage of temperate forest pollen in cores MD95-2042 and SU81-18.

For the Iberian Peninsula, a relatively large number of these studies have been published in recent years, mostly based on the series of marine sedimentary columns collected off the Mediterranean and Atlantic coasts (de Abreu et al., 2003; Lebreiro et al., 1996; Naughton et al., 2009, 2007; Roucoux et al., 2001; Sánchez Goñi et al., 2008, 2000; Thouveny et al., 2000; Turon et al., 2003). The patterns found within most of these works indicate some apparent inconsistencies with the classic interpretations of the LGM environmental conditions. As Roucoux and colleagues point out: “the traditional LGM, while doubtless marking the largest extent of the great ice sheets, did not necessarily see the most severe climatic conditions everywhere” (Roucoux et al., 2005, p. 1646).

In this context, the identification of short-lived anomalous events within the LGM time span, such as the Heinrich Event 2 (HE2) (Heinrich, 1988; Sanchez Goñi and Harrison, 2010) (Figure 1), marked by an abrupt decrease in temperature and moisture, added weight to the notion that, for long periods, the LGM climate might have been warmer and moister in several regions in Iberia than during many of the stadial events of the Late Pleistocene.

These new perspectives had, in turn, a significant impact on the interpretation of human adaptations to the LGM, particularly by allowing to contextualize human ecodynamics in more restricted environmental scenarios than the ones provided by the long diachrony of the LGM.

Still valid, however, is the perspective that most of the LGM timeframe (*sensu stricto* between 23 and 19 ka cal BP – Mix et al. (2001)) corresponds, in Western Europe, with the significant technological changes of the Solutrean technocomplex, influenced mainly by major geographical shifts in the human range, within which Iberia played a crucial role as a long-term refugium (Straus, 2016, 2015, 2013). This broad one-to-one relationship led, over the years, to the publication of several syntheses and article compilations on the LGM/Solutrean human adaptations (e.g., Ripoll Lopez et al., 2012; Schmidt et al., 2019; SERAP Vallee de la Claise, 2013; Straus, 2016, 2015, 2013, 1991), and on general patterns for each region within Iberia (e.g., Aura et al., 2009; Aura and Jordá Pardo, 2012; Cascalheira, 2013; Corchón and Cardoso, 2005; de la Rasilla, 1989; de la Rasilla and Straus, 2004; Straus, 2000; Zilhão, 2013, 1994, 1987).

Solutrean weaponry, due to its singularity, received considerable attention over time, with its techno-typological characterization underpinning some of the most debated Solutrean topics. Among these are the question of external vs. indigenous origins of the technocomplex (see e.g., Alcaraz-Castaño, 2007; Otte and Noiret, 2002; Renard, 2010; Tiffagom, 2006), or the debate on the internal chronological organization (see reviews by e.g., Aubry and Almeida, 2013; Cascalheira and Bicho, 2015; Straus, 1986). The abundance and rarity of certain point types along the stratigraphic records of so-called key sites across Iberia have justified the broad application of Smith’s (1966) classical subdivision of the techno-complex into Lower, Middle and Upper stages (despite the use of different terms for each one of the phases, depending on the authors, regions and sites used – e.g., Inferior (Pericot, 1942; Ripoll Lopez, 1988; Villaverde and Peña, 1981), Inicial (Fortea and Jordá, 1976), Solutreanizante (Fullola, 1979), Etapa de Formación (Muñoz Ibañez, 2000), and Fase I (Jordá, 1955) were all used to describe the first stage in southern Iberia). In western and southern Iberia, Proto-Solutrean (Zilhão, 1997; Zilhão and Aubry, 1995) and Solutreo-Gravettian (Fullola, 1979) phases have been also recognized and associated to, respectively, the beginning and end moments of the Solutrean phenomenon (see below).

Following the extensive list of previous publications, this paper presents an updated review of the paleoenvironmental and archaeological data available for the LGM in Iberia, aiming to (1) evaluate the utility of the LGM concept to frame human ecodynamics in westernmost Europe; (2) identify what questions remain unsolved and which ones present more potential for future research within the timeframe considered; (3) contribute to the environmental and archaeological variability transept proposed to be represented by the special issue that this paper integrates.

The following sections present an overview of the current knowledge on the LGM in Iberia, organized across four macro-regions: Northern, Mediterranean, Inland, and the Western Atlantic Façade. Each section presents summaries on regional paleoenvironmental data, the chronology of human occupations, cultural phasing, techno-typological trends, and the artistic and symbolic manifestations.

For a better contextualization of the data presented below, a few methodological choices need further clarification.

First, although there is a general agreement that ice regression has started ca. 19.0 ka cal BP, the onset dates for the LGM are more problematic, ranging from ca. 30 to 23 ka cal BP (e.g., Hughes and Gibbard, 2015; Lambeck et al., 2002; Mix et al., 2001; Peltier and Fairbanks, 2006). Here, we followed one of the most recent studies based on a global multi-proxy (ice volume and sea level) approach by Clark et al. (2009), which sets the beginning of the LGM to ca. 26.5 ka cal BP (Figure 1).

Second, geographical organization into the four macro-regions presented in the following sections was based on several arbitrary factors, that included eco-geography and traditional subdivisions of the territory based on LGM-related (mostly Solutrean) cultural materials (see e.g., Tiffagom, 2006). This organization is purposefully different from recent approaches to the Upper Paleolithic of Iberia (e.g., Schmidt et al., 2012; Weniger et al., 2019), aiming to provide a more detailed set of environmental and archaeological information.

Finally, even though all currently available absolute dates for the defined time span are presented in our online compendium (available at <http://www.doi.org/10.17605/OSF.IO/NY8MX>), for comparative purposes in the discussion section, an inclusive approach (following e.g., Collard et al., 2010; Shennan et al., 2013) for radiocarbon results selection was undertaken. Thus, only dates regarded as invalid by the laboratory, and those that were clearly coming from reworked levels or lacking stratigraphical context were discarded.

**2. Regional frameworks**

**2.1. Northern Iberia (AA, MI-C, NI-G)**

Over the last few decades, the traditional notion of the northern Iberian corridor as a “cul-de-sac” during the Paleolithic has significantly evolved. At least in its eastern end (the Basque Crossroads), the region is now seen as an important hub of population movements between different natural regions: the Pyrenees, the Aquitaine, and the Ebro valley. The geology of the region divides it into two zones with a diffuse boundary between them, near the center of modern Cantabria. In the western areas, karst massifs are more circumscribed, and quartzite is the dominant lithic raw material. In the eastern areas, limestone and caves are more frequent, and due to the abundant outcrops of flint, quartzite was less used. If the region is viewed schematically as a strip of land 40 km wide and 500 km long, between the River Miño and Bidasoa, the westernmost site with LGM occupations is Valverde (Lugo), and the easternmost is the Aitzbitarte III and IV complex (Gipuzkoa) (Figure 2).



Figure 2 – Location of LGM sites from Northern Iberia (topographic data from the U.S. Geological, Survey Shuttle Radar Topography Mission - <https://earthexplorer.usgs.gov/>). Numbered black circles correspond to the sites referred to in the text: 1. Valverde; 2. Peña de Candamo; 3. Las Caldas; 4. El Buxu; 5. Cueto de la Mina; 6. La Riera; 7. Chufín; 8. Altamira; 9. Hornos de la Peña; 10. El Pendo; 11. El Ruso; 12. Cueva Morín; 13. La Garma; 14. Cobrante; 15. El Mirón; 16. Antoliñako Koba; 17. Bolinkoba; 18. Lezetxiki; 19. Kiputz; 20. Ekain; 21. Koskobilo; 22. Aitzbitarte III; 23. Aitzbitarte IV.

Upper Paleolithic scientific research in northern Iberia counts with over a century of history, although not all the information gathered during this time span is of the same resolution. Some of the first works by French researchers in the region contributed to a general systematization of the Upper Paleolithic occupations, the chrono-cultural sequence of parietal art, and the first paleoenvironmental observations. However, apart from some notes on the presence of large cold-adapted vertebrates in the region, which are abundant in the studies of Aranzadi, the Count of La Vega del Sella, and Hernández Pacheco, among others, modern sampling and laboratory protocols did not begin to be introduced until the 1960s. Pioneers in this regard were J.M. Barandiarán in Lezetxiki (Gipuzkoa, 1956-1968) and González Echegaray and Leslie Freeman’s team in Cueva Morín (Cantabria, 1966-1967).

The currently available information on LGM paleoenvironments in northern Iberia comes both from archaeological sites and geological deposits (i.e., peat bogs, marshes, lake beds). The latter provides the most continuous sequences, frequently with better temporal resolution than those of highly anthropized caves with human occupations. A particular conditioning factor is the geographic dispersion of the records and the information ‘gaps’ that this produces. The biogeographic diversity of the region, which includes littoral to sub-littoral areas and mountain barriers (running parallel to the ocean, located at no more than 100 km, and culminating in the east Asturian sector of the Picos de Europa where the summits reach over 2500 m altitude), has a significant impact on the oceanic influence resulting in very different landscapes and habitats.

Although the maximum peak of glacial extension is the dominant feature for the definition of the LGM (Hughes and Gibbard, 2015), several studies now suggest that, in northern Iberia, the maximum extent of the glaciers occurred before the traditional LGM timeframe, at ca. 42 ka cal BP (Moreno et al., 2010; Rico, 2012; Serrano et al., 2013, 2012). Following a period of deglaciation, the glaciers advanced again during the LGM, but without reaching their previous size and without affecting the whole region equally (Serrano et al., 2013). Lakes formed with the start of the deglaciation, like Enol, Ercina and Comeya lakes (Picos de Europa, Asturias). Although palynological studies have been attempted for this period, in some of them methodological issues (Ruiz Zapata et al., 2001) limit our knowledge on landscape change between the two peaks of ice expansion.

In the chronological framework of this paper, the oldest paleoenvironmental studies are dated to the Greenland Stadial 3 (GS-3 – ca. 27.5 to 23.3 ka cal BP) (Rasmussen et al., 2014) (Figure 1). They are based on cave records in what are now sub-littoral valleys in the eastern sector of the region (oscillations in sea level must be considered - Jordá Pardo et al., 2018). In the area around Santimamiñe (Biscay), the vegetation was open as a response to the cold phases of the GS-3, although the composition of the herbaceous-shrub layer and the micro-vertebrate assemblages (mainly remains of *Sorex araneus-coronatus*) indicate a significant degree of humidity (Iriarte-Chiapusso, 2011; Rofes et al., 2014). The final Gravettian environmental records appear to have developed in certain amelioration of the climate, which allowed tree cover to expand slightly (usually dominated by pine) but with an increase in deciduous species (Ekain, Gipuzkoa) (Sánchez Goñi, 1989) (Figure 3). The comparison of data from areas with a more significant oceanic influence, on the one hand, and high altitude environments, on the other hand, is difficult because of the few mountainous deposits with contemporary levels. However, how the vegetation was conditioned by lesser oceanic influence and the altitudinal gradient can be detected by steppe taxa (*Artemisia* and/or *Ephedra*) dynamics. In the coldest periods these species do not appear or appear only sporadically in valleys near the coast, whereas in the highlands they become the main herbaceous taxa. This is seen, for instance, at the base of the sequence of Puerto de Tarna (Asturias) (Ruiz Zapata et al., 2000).



Figure 3 - Pollen diagram from the open-air Gravettian flint workshop of Mugarduia south (904 meters a.c.s.l.), corresponding to an interstadial phase (after Iriarte-Chiapusso, 2013).

By the end of the GS-3 and immediately before the Greenland Interstadial GI-2.2, environmental conditions seem to deteriorate considerably. After that, a lack of continuous paleoenvironmental sequences makes it impossible to predict the conditions operating during the GI-2.2 and GI-2.1 phases (between ca. 23.3 and 23 ka cal BP). The sequence of Las Caldas (Levels 15 to 12) is perhaps the only dated example (Paquereau, 1981) for this timeframe, although overlapping radiocarbon dates hinder a precise chronological ascription. The same type of problem does not allow to picture a clear paleoclimatic association of the cold and dry period (Cuenca-Bescós et al., 2008; Straus et al., 2013) detected in the Solutrean levels (Level 127 and basal Level 126) at El Mirón (Cantabria). These might correspond to the stadial event that occurred between the two interstadials (GS-2.2 – ca. 23.2 ka cal BP) or to the start of GS-2.1 (ca. 22.9 ka cal BP) (Figure 1).

Open vegetation continues to predominate during the next stadial event, GS-2.1 (mostly in GS-2.1c), due to severe climatic conditions. The situation is the same as in preceding stadials. The degree of humidity varies, even among levels at the same site, like through Level 37 to 34 at Kiputz (Gipuzkoa) (Garcia-Ibaibarriaga et al., 2012) or Level 4 and 3 at Cobrante (San Miguel de Aras, Cantabria) (Ruiz Zapata and Gil-García, 2009). Humidity levels are also dependent on the geographical location of the sites, as shown by the distribution of the percentages of *Artemisia*. For example, at Area Longa (peat level III) in Galicia at one-meter above current seal level (a.c.s.l.), the herbaceous-shrub layer is dominated by Poaceae and heaths, accompanied by a low presence of *Artemisia*. In contrast, the percentage of *Artemisia* at Lagoa de Lucenza (pollen zone LPAZ-1), also in Galicia but at 1375 m a.c.s.l., reaches over 40%, reflecting the influence of the altitudinal gradient on environmental humidity and the effect of the mountain barriers (Muñoz-Sobrino et al., 2001).

Late Solutrean, Badegoulian, and early Magdalenian records are available corresponding to the GS-2.1b timeframe (starting at ca. 20.9 ka cal BP) (Figure 1). There are numerous deposits, most of them located in the coastal area or coastal mountains, with records dated to the GS-2.1b, although none of them covers the whole sub-event. Both small mammal and pollen data confirm a progressive improvement, from a situation of a very rigorous climate, as in the Lower-Middle Magdalenian levels at El Mirón, Level 17 Cabin area and Level 1110 Corral (Iriarte-Chiapusso et al., 2015) to a landscape with a more significant presence of woodland (Level 108 Corral at El Mirón - Iriarte-Chiapusso et al. (2015)). The increasing percentages of tree pollen are also identified in pollen zone 3 at Lagoa de Lucenza (ca. 18.8–18.3 ka cal BP) with a significant increase of burch, while *Artemisia* seems to retreat.

The number of non-anthropic paleoenvironmental records increases from this time onwards and up to the Late Glacial period. They allow corroboration of what is intuited with less resolution for the rest of the Upper Pleistocene. The environmental response of plant and animal communities to the same global climate events varies considerably, even in proximate areas, depending on their local geographic characteristics, such as landforms, orientation, altitude (Iriarte-Chiapusso et al., 2016).

Human subsistence strategies represent the area in which the paleoenvironmental record and human cultural behavior overlap. In the final stages of the Gravettian, but especially during the Solutrean, the general strategy implies a progressive specialization in the hunting of certain prey, sometimes in proportions higher than 80% of the hunted animals (Straus, 1992). These are the red deer in low-altitude areas and both ibex and chamois in the mountainous regions. Extreme examples of this are the sites of Bolinkoba (almost 80% of mountain goat in the Solutrean level) and levels 7 to 11 of La Riera (red deer is ca. 90% of the total remains in some of the levels) or Las Caldas (Corchón, 2017). As proof that the conditioning of the environment was not restrictive, at level 4 of La Riera, more than 60% of the remains correspond to *Capra pyrenaica* (Straus and Clark, 1986). The progressive specialization in the hunting of certain species of large mammals is combined with the diversification in the exploitation of other feeding niches, as evidenced by the quantities of marine mollusks (almost all of them, *Patella vulgata*) found in the oldest Solutrean layers of La Riera (Ortea, 1986). At exactly those same levels, frequent freshwater fishing of trout and salmon is also attested (Menéndez de la Hoz et al., 1986). Although the extent of this diversification of niches to fish species and other marine animals is not yet clear, the Amalda solutrean layer provided close to one hundred bird remains (Eastham, 1990), some of them with evident traces of having been consumed by humans. The diversification in the exploitation of all food resources available from different ecological niches is accompanied by an intensification in resource use, mostly visible in the systematic splitting of bones to extract marrow (see e.g., Altuna and Mariezkurrena, 2017 for Las Caldas). Thus, the Gravettian, but especially the Solutrean, must be understood in non-conflicting terms of specialization in certain large mammals but also intensification in the exploitation of diversified niches.

The 26.5 to 19.0 ka cal BP timeframe in northern Iberia does not match precisely the starting and ending dates of the traditionally defined technocomplexes. It covers the most recent phases of the Gravettian, the whole Solutrean (within which an Upper Solutrean phase is generically defined and, in a few cases, a Middle Solutrean is added), and the transition from the Solutrean to the Magdalenian. For some authors, this transition is seen as a Solutrean ‘in the process of desolutreanisation’, for others, it corresponds to the archaic or initial Magdalenian, while a third group defines it as Badegoulian (Álvarez-Alonso and Arrizabalaga, 2012; Corchón et al., 2015). Historiographically, however, the focus of LGM studies in Northern Iberia has been the Solutrean, how it has evolved from the Gravettian, and how it transforms in the transition to the Magdalenian *sensu lato*.

Although the series of dates is increasing, some effects distort the resolution of our analysis. For example, not all the technocomplexes seem to have been equally important in the different parts of the region. Gravettian assemblages seem to display an east-west gradient, beginning at an earlier time, with broader distribution and greater dynamism in the Basque Country and eastern Cantabria. At the start of LGM, the late Gravettian and the Solutrean are more vibrant towards the west, until the start of the Magdalenian when the geographic distribution of sites is more homogenous. Apart from some dates for Level III at Aitzbitarte III and dates that are hard to contextualize at Bolinkoba and Ekain, the other Gravettian sites corresponding to the early moments of the LGM are all located to the west. These are the cases of La Riera (Asturias), La Garma, Altamira, and Hornos de la Peña (Cantabria). After that, the date for Level 15 at Las Caldas (ca. 24.3 ka cal BP) represents the oldest Solutrean level in the region, while the Level I at Chufín (Cantabria), dated to ca. 21 ka cal BP, marks the last evidence for that technocomplex, although the last leaf-shaped points are dated to ca. 20.5 ka cal BP (de la Rasilla and Straus, 2004). Finally, during the following millennium, levels at El Mirón, Las Caldas, La Riera, and El Ruso (Cantabria), among other sites, have been classified in different ways, according to contrasting conceptions. This classification has been the cause of debate among specialists (Álvarez-Alonso and Arrizabalaga, 2012; Corchón et al., 2015).

As in other Iberian regions, research on the Solutrean lithic record is biased by the presence of characteristic bifacial artifacts (Figure 4). Although they can be regarded as evidently intrusive in the record (they appear without a clear origin and then disappear without any continuity with other techno-types), typological, traceological, and even morpho-technical studies of Solutrean lithic assemblages have seldom considered the rest of the toolkit (see as an exception, Corchón et al., 2013). In this sense, despite the vital maturity of lithic studies, very little can be said in terms of patterns of change or continuity for the Solutrean regarding either the previous technocomplex (Gravettian) or the following one (the Badegoulian or Magdalenian). One of the elements showing significant continuity, particularly in the Basque Region, is the so-called Noailles burin, which has been identified in Gravettian and Solutrean levels at the site of Antoliñako Koba (Aguirre, 2013).



Figure 4 – Bifacial and unifacial Solutrean implements from level 9 of Las Caldas (Asturias, Northern Iberia). Adapted from (Corchón et al., 2013, fig. 5).

Leaving aside the “intrusion” of flat retouch and leaf-shaped points (with some regional varieties, such as the so-called Cantabrian points with concave base), the rest of the lithic record seems to display significant continuity throughout the LGM. The *chaînes opératoires* designed to produce increasingly standardized bladelets become dominant for the manufacturing of backed elements that usually form the most substantial part of assemblages. At the same time, other reduction patterns were employed for larger blanks and domestic-type tools. As recent studies of lithic raw materials are showing, the type of available raw material (frequently quartzite and quartz towards the west of the region and predominantly flint in the east) is a critical conditioning factor in the typological composition and technological sequences of each area. In any case, the production of backed elements (and burins to a lesser extent), while requiring raw material of better quality, needs smaller amounts of the material. Thus, this factor does not influence the composition of the assemblages as much as might be thought.

Concerning organic tool assemblages, the diversity of implements made with antler increases during the regional Solutrean. In addition to the generalization of sagaie points, which are still quite scarce, needles, perforated batons, and rods made from antler appear in the record. The batons and rods almost always appear with some kind of decoration.

During the LGM in Northern Iberia, symbolic behavior becomes more widespread and is reflected both in personal ornaments (Avezuela and Álvarez Fernández, 2012) and in portable (Corchón, 2004) and parietal art (González-Sainz, 2004). The age of the parietal art is perhaps the least clear, as the difficulty in directly dating the surfaces and most pigments means that most of the representations in this period have to be classified under the label of ‘pre-Magdalenian’. Few absolute dates are available, mainly for archaeological contexts (and direct dates at Peña de Candamo - Fortea et al., 2004), and these allow particular subjects, techniques, and artistic conventions to be ascribed to the LGM. These attributions, however, are still far from certain. Portable art also becomes more common, with such distinctive elements as ribs with side notches, pairs of incisions, batons as the one of Cueto de la Mina (Asturias), El Pendo (Cantabria), the rod from Aitzbitarte IV with a snake-like engraving, and the figurine of a bird, shaped from a bear’s canine tooth at Buxu (Asturias).

**2.2. Inland Iberia (MA-C, JA-G)**

Inland Iberia, a vast territory composed of two plateaus (Northern and Southern Mesetas), separated by a mountain range (the Central System) (Figure 5), has traditionally shown scarce evidence for understanding cultural dynamics and paleoenvironments during the LGM. Thus, classic views on the Upper Paleolithic settlement of inland Iberia have depicted these lands as nearly or totally depopulated until the end of the LGM. Reasons behind this purported lack of cultural developments have revolved around the potentially harsh climatic and environmental conditions of these interior and upland regions as opposed to the more favored environments of the Iberian coastlines (see Alcaraz-Castaño, 2015).

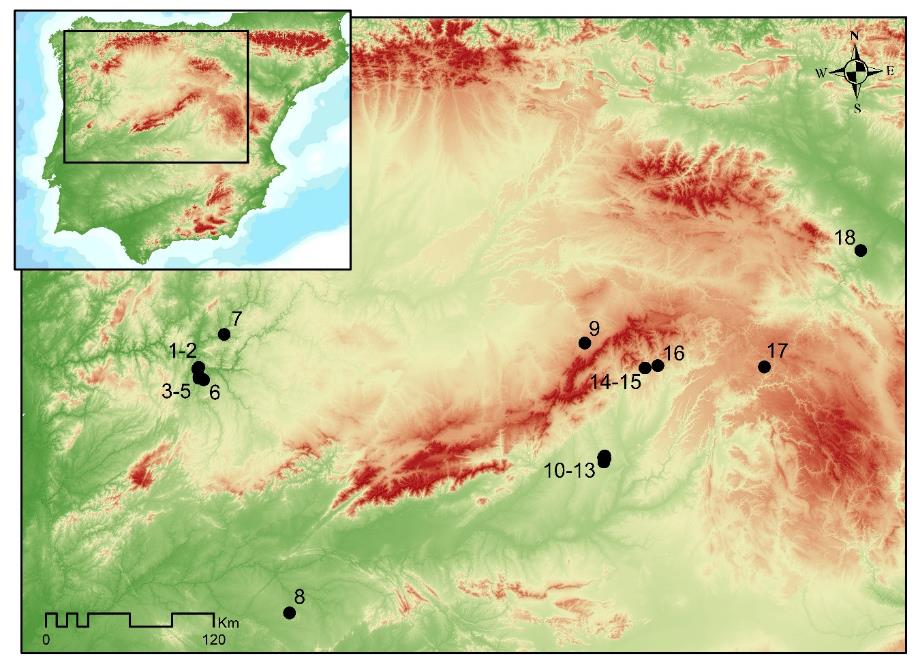


Figure 5 – Location of LGM sites from Inland Iberia (topographic data from the U.S. Geological, Survey Shuttle Radar Topography Mission - <https://earthexplorer.usgs.gov/>). 1. Fariseu; 2. Canada do Inferno; 3. Cardina I; 4. Penascosa; 5. Quinta da Barca; 6. Olga Grande; 7. Foz do Medal; 8. Maltravieso; 9. La Griega; 10. El Sotillo; 11. Nicasio Poyato; 12. Las Delicias; 13. Martínez; 14. El Cojo; 15. El Reno; 16. Peña Capón; 17. Los Casares; 18. Gato 2.

Recent reviews have roughly supported this picture, although the existence of short-term or sporadic incursions into central Iberia during temperate intervals within the LGM is currently generally acknowledged (Schmidt et al., 2012; Straus, 2015). Furthermore, habitat suitability models based mainly on paleoclimate simulations (Burke et al., 2017; Ludwig et al., 2018; Wren and Burke, 2019), have provided further support to this view. These works describe the Iberian interior as an ecologically risky area for human settlement during the LGM, mainly due to climate variability. However, besides that most of these models are centered on the LGM *sensu stricto* (i.e., 23-19 ka cal BP as defined by (Mix et al., 2001)), and thus previous phases, including the HE2, are barely considered, the high number of variables and methods involved in their building lead to some inconsistencies when comparing their results (see Burke et al., 2017, pp. 224–225; Harrison et al., 2016). Thus, other models (Banks et al., 2008; Maier et al., 2016; Tallavaara et al., 2015) have provided different pictures concerning inland Iberia, including the depiction of the Tagus River basin as a suitable area for human occupation during the Solutrean (Maier et al., 2016: Fig. 6).

In any case, during the last years a growing number of researchers has claimed that the scarcity of archaeological and paleoecological evidence in the Iberian interior is probably biased (Alcaraz-Castaño et al., 2013; Alcolea-González and Balbín-Behrmann, 2012; Aubry et al., 2016, 2015; Cacho et al., 2010; Zilhão et al., 2010). The few research projects focused on these territories compared to the coastal regions of the Peninsula – where most research efforts have been traditionally developed – and the difficulties of locating open-air sites – potentially much more common than cave archives in the Mesetas – may be behind this potential bias. A relevant number of new field evidence has recently triggered a new historiographic stage of this controversy. Nowadays, the idea of inland Iberia as a mere crossing-area where human groups based elsewhere entered only sporadically during the LGM is under attack (Alcaraz-Castaño, 2015). The main evidence supporting a new model on population dynamics and settlement patterns come from the southeastern foothills of the Central System range and the Madrid basin, but also from the Northern, Eastern, and Western peripheries of the Mesetas, and especially from the Portuguese territories around the Middle Douro basin. Growing chronometric, paleoenvironmental and archaeological data is making increasingly clear that hunter-gatherers occupied several regions of inland Iberia at least during some phases of the LGM. And, more interestingly, these occupations included episodes of harsh ecological conditions.

Unfortunately, paleoenvironmental evidence is still few and sparse in inland Iberia and does not suffice to provide a sound ecological framework for the LGM. However, an increasing number of data coming from a diversified set of contexts allows for preliminary environmental reconstructions. These contexts include pollen sequences, paleoglaciers, loessic deposits, micromammals assemblages, and isotopic analyses from faunal remains.

Pollen data is the most abundant thus far: in the southern Meseta, the Fuentillejo maar lacustrine record and the TD core at Tablas de Daimiel National Park show climatic variability within the LGM. These sequences recorded two cold periods dated to ca. 25-23 (matching part of the HE2) and 19-18 ka cal BP, characterized by *Juniperus* and xeric vegetation dominance, and a warmer one at ca. 23-19 ka cal BP, where mesophilous and temperate trees are present (Ruiz-Zapata et al., 2010; Valdeolmillos et al., 2003; Vegas et al., 2010). Also in the southern Meseta, the Solutrean open-air site of Las Delicias showed an archaeological layer dated by OSL to 18.2 ± 1.3 ka BP where pollen data pointed to an open landscape composed of herbaceous taxa, both steppe (Asteraceae liguliflorae, Asteraceae tubuliflorae and Poaceae) and xeric (Chenopodiaceae, *Artemisia,* and *Ephedra*), thus suggesting a generally dry and cold period dominated by open landscapes and steppe environments (Alcaraz-Castaño et al., 2017). These data could match the last stages of the LGM, although the large standard deviation of the OSL result deserves some caution. Closer to the Central System range, the sequence of human occupation recorded at the Peña Capón rock shelter has shown paleoecological evidence coming from isotopic, pollen, micromammal, and anthracological analyses. Although available data on stable isotopes obtained from herbivore teeth has pointed to warm climate and temperate environments around ca. 24 ka cal BP at this site (Yravedra et al., 2016), ongoing studies will soon complement these results (Alcaraz-Castaño et al. in prep.). Finally, in the Northern Plateau, the Cueva Mayor (Atapuerca) karst pollen record, combined with analyses of speleothem crystal fabrics, points to a landscape dominated by pines, junipers and xerophytic elements at ca. 20 ka cal BP, although mesophillus trees are also sporadically present (Martínez-Pillado et al., 2014).

Another proxy for paleoenvironmental reconstruction in inland Iberia comes from paleoglaciers in the Central System range. Combined with speleothem isotopic analyses, these studies have shown that the time of the regional maximum extent of paleoglaciers, occurred here at around 26 ka cal BP, was related to a high precipitation rate, being another stage of large extent at ca. 21 ka cal BP related to colder temperatures (Domínguez-Villar et al., 2013). Finally, sedimentological, geochemical and stable isotope analyses applied to several loess records in the Tagus basin has demonstrated the existence of arid and cold conditions between ca. 26 and 23 ka BP, thus closely matching the HE2 (Wolf et al., 2018) (Figure 1).

Overall, available paleoecological evidence shows harsh climatic and environmental conditions in the Iberian interior during the LGM, with potential intervals of climate amelioration between ca. 24 and 19 ka cal BP, the oldest of which could match GI 2.1 and GI 2.2 (Rasmussen et al., 2014).

Concerning archaeological sites, a total number of 20 locations related to the LGM can be currently identified in inland Iberia, either based on chronometric data, lithic assemblages, rock art style, or a combination of them. The first sites to be discovered were those of the Manzanares River valley in the Madrid Basin. Here, a large number of Solutrean-like assemblages bearing bifacial foliate points and other Upper Paleolithic artifacts were excavated in the river terraces during the early 20th century. Although they were considered part of the Upper Paleolithic settlement of central Iberia until the 1960s (Almagro Basch, 1960; Jordá, 1955), later on, these assemblages were largely dismissed, mainly because they were collected without stratigraphic control and their cultural attributions were confusing (Alcaraz-Castaño et al., 2012). However, after the re-study of some of them, such as El Sotillo, Nicasio Poyato, Martínez or El Cojo (Baena and Carrión, 2002), and especially after the re-excavation of Las Delicias site, where a minimum OSL age of 18.2 ± 1.3 ka BP was obtained for a layer containing Solutrean assemblages (Figure 6.15-16) (Alcaraz-Castaño et al., 2017), the middle and lower Manzanares valley has been demonstrated to be a focus of human settlement during the LGM. In an area of around 5.5 square km at least eight Solutrean open-air sites can be currently recognized here (Alcaraz-Castaño, 2015). Most of these sites are focused on flint procurement, and knapping activities and hence can be considered to have been lithic workshops. However, in some of them, such as El Sotillo, Nicasio Poyato, Martínez, and El Cojo, the significant number of retouched artifacts, including domestic tools (Figure 6.7-14), reveals that foraging and consumption activities were also developed (Alcaraz-Castaño, 2015; Baena and Carrión, 2002). Altogether, these data suggest that the Manzanares valley functioned as an organized territory for human activity during the Solutrean (Alcaraz-Castaño et al., 2017).



Figure 6 - Lithic assemblages from the LGM in Inland Iberia. Peña Capón (after Alcaraz-Castaño et al., 2019, fig. 4, 2013, figs. 6 and 7; Alcolea-González et al., 1997, fig. 8) - 1. Vale Comprido point; 2. endscraper with inverse flat retouch (layer III, Proto-Solutrean); 3-4. Laurel leaf points (layer 2b and layer II, Middle/Upper Solutrean); 5-6. Mediterranean-type shouldered point & Cantabrian-type shouldered point (layer I, Upper Solutrean). El Sotillo (after Martínez de Merlo, 1984, figs. 9 and 11) - 7, 8, 11. endscrapers; 9-10. backed bladelets; 12. laurel leaf point (layer c, Middle Solutrean). Nicasio Poyato (after Baena and Carrión, 2002, fig. 4.21 and 4.32) - 13. laurel leaf point; 14. endscraper (Solutrean). Las Delicias (after Alcaraz-Castaño et al., 2017, fig. 10) - 15. small foliate point; 16. laurel leaf point (layer IIc, Middle/Upper Solutrean). Olga Grande 4 (after Aubry, 2009, fig. 5.1.2–1 and 5.1.2-31) - 17-25. backed bladelets (layer 3, Gravettian); 26-32. shouldered points (layer 2, Upper Solutrean).

Another relevant area, where an increasing amount of evidence has been shown in the last years, is located close to the southeastern foothills of the Central System range, in the area around the Sorbe and Upper Jarama River valleys (Guadalajara). Here, the Peña Capón rock shelter has shown a recurrent sequence of human occupations between at least ca. 25.5 and 24 ka cal BP, where Upper and Middle Solutrean, Proto-Solutrean, and potentially Gravettian assemblages have been recorded (Figure 6.1-6) (Alcaraz-Castaño et al., 2019, 2013). The fact that the oldest human occupations at this site most probably occurred during the HE2 suggests that they were developed regardless of potentially harsh climate conditions. Although available isotopic data obtained on faunal remains from the Solutrean layers of Peña Capón points to warm temperatures (Yravedra et al., 2016), pollen and micromammal evidence demonstrate that some episodes of human occupation occurred instead during harsh environmental conditions (Alcaraz-Castaño et al. in prep.). Moreover, far from being an isolated point within a deserted landscape, Peña Capón stands as the main known location within a probably organized territory during the LGM: the presence of pre-Solutrean rock art depictions at El Reno cave in the neighboring Jarama valley (see below) and unprecedented evidence to be published in the fluvial platform between the Sorbe and Jarama basins (Sala et al. in prep.), depict a walkable territory exploited by humans during, at least, Solutrean times. This area could be extended to the western foothills of the Iberian range, where pre-Magdalenian rock art expressions are also found at Los Casares cave (see below).

Further west, at the western edge of the northern Meseta, it is found the largest concentration of LGM sites in inland Iberia, which is also associated with a large rock art cluster (see below). In the Côa River valley (Douro basin, Portugal), two Gravettian layers have provided TL dates in the range of ca. 31 - 26.5 ka at the sites of Olga Grande 4 (Figure 6.17-25) and Cardina 1 (Aubry et al., 2012; Valladas et al., 2003), and Proto-Solutrean have been described at the sites of Olga Grande 14 and Cardina 1 (associated to a TL date of 23.4 ± 1.5 ka BP) (Aubry, 2009). Cardina 1 also contains a Solutrean component which has been related by Aubry et al. (2015, 2012) to a TL date of 20.7 ± 1.3 BP, although this comes from layer 4.10, a palimpsest containing the mentioned Proto-Solutrean, as well as Gravettian assemblages (see Aubry et al., 2010). At the site of Fariseu, layer 9 showed Upper Solutrean assemblages that were radiocarbon dated by associated charcoal to 22.6–23.2 ka cal BP (Aubry, 2009). Other sites containing undated Upper Solutrean assemblages in the Côa valley are Olga Grande 4 (Figure 6.26-32) and Olga Grande 14 (Aubry, 2009). Furthermore, the study of lithic raw materials sourcing at these sites have suggested the probable existence of yet-to-be-discovered human presence at different points of the Duero and Tagus basin in central Spain during Gravettian and Solutrean times (Aubry et al., 2016, 2015, 2012). Also, in inland Portugal, in a northern area of the Douro basin, the site of Foz do Medal (Alto Sabor valley) has shown stratigraphic layers containing both Gravettian (right bank) and Solutrean (left bank) assemblages (Gaspar et al., 2016, 2015). Chronometric dates (AMS and TL) have only been obtained for the Gravettian, although they have shown contradictory results and thus cannot yet be considered useful (Gaspar et al., 2016).

Other peripheral areas of the Mesetas have shown archaeological evidence in the range of the LGM, although they present uncertainties in some cases. Thus, at Maltravieso Cave level A (Cáceres, Lower Tagus basin), two radiocarbon measurements have dated a scarce and undiagnostic lithic assemblage between ca. 22 and 20.3 ka cal BP (Canals et al., 2010). In the Atapuerca area (Burgos), the open-air site of Valle de las Orquídeas showed two TL dates of 27.5 ± 2.3 ka and 29.9 ± 2.3 ka BP for a terra rossa layer below a level containing undiagnostic lithics assemblages (Mosquera et al. 2007). Also at Atapuerca, in the site of Cueva Mayor, a sequence bearing few lithic and faunal remains (including some blades) was radiocarbon dated to between ca. 34 and 20 ka cal BP (Carretero et al., 2008). Finally, more robust evidence has been gathered at the Gato 2 rock shelter (Zaragoza, Middle Ebro basin), where layer 2, assigned to the Archaic Magdalenian, has shown four radiocarbon dates between ca. 22.8 and 21.0 ka cal BP (Utrilla et al., 2012).

Concerning symbolic graphic expressions, the number and variability of Paleolithic rock art sites in the Iberian interior account for one of the most relevant territories in southwest Europe (Alcolea-González and Balbín Berhmann, 2006; Aubry and Sampaio, 2008; Baptista, 2009). This can be divided into three main geographic clusters, covering a large portion of both the northern and southern Mesetas (Alcolea-González and Balbín-Behrmann, 2012): (1) The Castilian central cluster, located in the corridor connecting the Ebro valley and the Southern Meseta between the Central System and the Iberian System mountain ranges, where up to eight decorated caves have been described to date; (2) the Western cluster, where close to fifty decorated sites are found in the surroundings of the western border of the northern Meseta; and (3) the Southern cluster, where up to three sites are found along the Guadiana basin.

Despite significant advances in recent times, research on the Paleolithic graphic expressions in inland Iberia still faces two main shortcomings: the scarcity of portable art (but see Aubry and Sampaio, 2008; García-Díez et al., 2012 for non-figurative objects of several sites at the Côa valley and Maltravieso) and the absence of chronometric dating. Although the latter issue undoubtedly hampers our attempts for establishing sound chronological frameworks, in the last years, research has experienced significant advances based on stylistic arguments combined with stratigraphic evidence gathered at the site of Fariseu (Côa valley). Here, graphic motifs (Fig 7.1) directly associated to archeological deposits demonstrated the existence of two large decorative phases, one Magdalenian and another pre-Magdalenian, the latter corresponding to the so-called Côa “Old Sanctuary” (Aubry and Sampaio, 2008, p. 171; Baptista, 2009, pp. 217–220). Although this two-phase model, which is accepted by many as the basic chronological framework for the whole Paleolithic rock graphic phenomenon of Western Europe (González-Sainz, 1999), has been reasonably extrapolated to the rest of the Iberian interior (Alcolea-González and Balbín-Behrmann, 2012), the absence of radiometric dates does not yet allow for accurate chrono-cultural phasing within the pre-Magdalenian rock art of these territories. Thus, we should expect that some (most probably few) of their motifs could fall out of the LGM time range, either in Gravettian or Aurignacian (or even earlier?) times.

The largest concentration of pre-Magdalenian rock art is found in the Western cluster, and especially in the Middle and Lower Côa valleys and, to a lesser extent, in the Sabor River valley. The most relevant sites are found in the Lower Côa, including Penascosa, Quinta da Barca, Fariseu, and part of Canada do Inferno. A chronology starting in the Gravettian is widely accepted for these sites (Aubry, 2009; Baptista, 2009; Zilhão, 2003). Most of their motifs are produced by deep pecked engraving, in most cases later regularized by abrasion, although contour red paintings are also found (Baptista, 2009, p. 71). Themes include mostly animals, among which aurochs, horses, caprines, and cervids are largely represented, while very few. Association and composition of images are often articulated by means of intensive synchronic superimpositions (Figure 7.1). Style of figures is based on a very simple canon with motifs often limited to outlines, bearing details only in their main areas and lacking conventions and quartering besides the simplest, such as stepped manes (Figure 7.1). The perspective of figures is often unrealistic, and they usually have large sizes. In these cases, the existence of paint cannot be ruled out as a means to perceive the images from considerable distances.

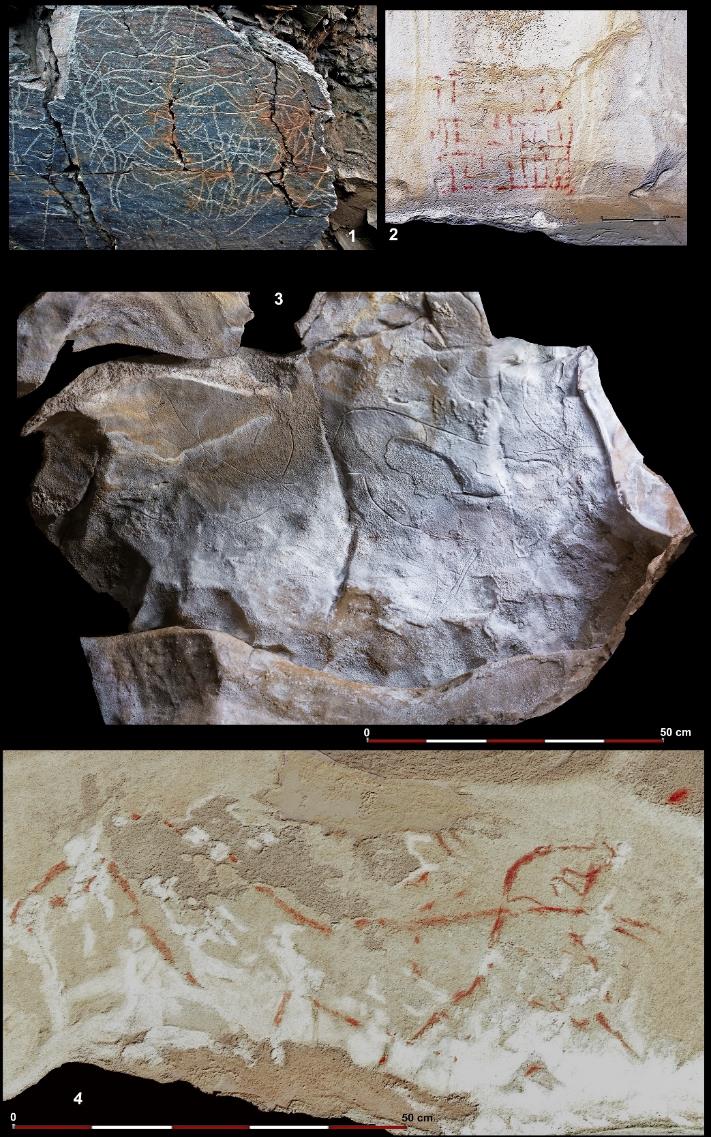


Figure 7 – 1. View of the right side of Fariseu rock panel 1 (Côa valley) (Photo: A. Martinho Baptista); 2. Rectangular sign found at El Reno Cave (Guadalajara) (Tracing: J.J. Alcolea-González); 3. Panel of the final chamber of El Reno cave, showing two deers, one horse and one reindeer (Orthomosaic: J.J. Alcolea-González); 4. Red painted horses found at the terminal gallery of El Reno Cave (Tracing: J.J. Alcolea-González).

The pre-Magdalenian phase documented at the Castilian caves shares some traits with that of the Western cluster, although it bears a relatively specific iconographic model (Alcolea-González and Balbín-Behrmann, 2012, pp. 190–191). Here, the variability of figures is sparse: there is a large dominance of horses, and male deers and caprines are the main complementary animals. Other motifs considered rare and marginal in the Paleolithic art of Western Europe, such as anthropomorphic figures and felines, are relatively abundant. Associations of figures are also singular in the Central cluster, being deers often depicted as the central figures within panels (Figure 7.3), a practice which is rare in other European regions but will be maintained here as a usual trait (Alcolea-González and Balbín-Behrmann, 2012, p. 190). Themes also include the occasional appearance of complex signs, mostly composed of reticulated rectangular forms (Figure 7.2). Animal figures are barely detailed, showing very simple conventions, and they are usually limited to outlines, either in absolute profile or straight bi-angular perspective. Techniques are also straightforward, being most images engraved by simple and deep incisions, and lacking complex features such as quartering or modelling. However, an exception is found at El Reno cave (Guadalajara), where engravings are found together with paintings, which are, in fact, predominant (Figure 7.4).

The described pre-Magdalenian traits are found in virtually all caves of this cluster, being especially notable in the engravings of La Griega (Segovia) (Corchón, 1997) and most of the paintings and engravings of El Reno (Alcolea-González et al., 1997). This is also supported by the existence of superimpositions in sites such as Los Casares and El Reno, where figures showing strong Magdalenian traits are found above others pointing to old conventions (Balbín-Behrmann and Alcolea-González, 1992).

Finally, in the Southern cluster, only the rock art found at Maltravieso cave (Cáceres) (Ripoll et al., 1999) can be possibly related to the LGM, as decorations recorded at the caves of El Niño (Albacete) (Garate Maidagan and García Moreno, 2011) and La Mina de Ibor (Cáceres) (Ripoll and Collado, 1997) strongly points to an exclusively Magdalenian age. The main motifs found at Maltravieso are hand stencils, followed by sparse animal paintings and engravings, and some painted geometric signs. Given that the traditional interpretation of hand stencils as markers of an early Upper Paleolithic age has been demonstrated by direct chronometric dating at several sites (García-Díez et al., 2015), those found at Maltravieso could plausibly point to an LGM chronology. This hypothesis finds support in the two radiocarbon dates obtained in layer A as discussed above (see also García-Díez et al., 2012). However, recent indirect dating of one of these stencils by the U-series technique (Hoffmann et al., 2018), strongly suggests that at least part of the Maltravieso rock art could be much older.

**2.3. Mediterranean Iberia (JEAT)**

Central and southern areas of the Iberian Mediterranean region currently form one of Europe’s warmest and most arid regions. This would also have been the case in the past and have been related to the HE and D-O events described in the Alborán Sea MD95-2043 core (Cacho et al., 2001; Fletcher and Sánchez Goñi, 2008) (Figure 1). Significant drops in temperature and precipitation, together with oscillations in sea level, account for many of the paleoenvironmental changes that occurred. Extensive coastal territories provided a large number of resources and served as a great communication corridor for human groups. The uneven impact that these changes had on the terrestrial and marine environment, due to cold waters entering the Alborán Sea from the Atlantic, is a feature that had paleoenvironmental and paleoeconomic effects (Aura et al., 2016).

A recent review of the data from Padul wetland shows a regression of Mediterranean forest taxa (*Quercus*, *Olea*, *Phillyrea,* and *Pistacia*) in Zone 2a (~24.5 -15 ka cal BP), parallel to an expansion of sclerophyllous taxa (*Artemisia*, Amaranthaceae, and *Ephedra*) and pines (Camuera et al., 2019). Data from Padul coincide with the anthracological general trends obtained from archaeological sites (Badal et al., 2013; Badal and Carrión, 2001). During the Pleniglacial, open landscapes would have prevailed, formed by cryophilous pines, junipers, and several genera of shrubs. Charred plant remains indicate cold, dry conditions during HE2 and increasingly arid conditions in the LGM *stricto sensu*. In the central sector, the most complete sequence is observed at Cendres (Villaverde et al., 2019). Anthracological phases CC.1E to CC1.C describe a combination of *Pinus nigra-sylvestris*, *Juniperus sabina*, *J. thurifera,* and *J. communis*. These data show that the mean annual temperature would have been around 8-10ºC, with an average precipitation of 500-600 mm. The recovery and study of paleobotanical remains at Cendres has shed light on an important list of species used by humans (Martínez Varea and Badal García, 2018), which are added to the known data from Nerja (Figure 8).



Figure 8 - Location of LGM sites from Mediterranean Iberia (topographic data from the U.S. Geological, Survey Shuttle Radar Topography Mission - <https://earthexplorer.usgs.gov/>). Numbered black circles correspond to the sites referred to in the text. 1. Montlleó; 2. Hortet de Cortés–Volcán del Faro; 3. Malladetes; 4. Parpallo; 5. Beneito; 6. Santa Maira; 7. Cendres; 8. Comte; 9. Ratlla del Bubo; 10. La Boja; 11. Cueva Ambrosio; 12. Nerja; 13. Bajondillo; 14. Ardales.

Anthracological data from Nerja also show open vegetation. *Pinus nigra-sylvestris* is the most abundant taxon (10-45%), followed by *Pinus pinea* (8-22%), from which pine cones were collected for eating the pine kernels, but their wood was not used for firewood (Badal, 2001). Based on the combination of these two species of *Pinus*, an average annual temperature of 8-15°C has been proposed for the HE2, which would have been somewhat higher for the end of LGM (13-17ºC) (Badal et al., 2013). Open vegetation, with less than 20% of tree species, has been described at Ardales for a level dated to the end of the LGM (Ramos-Muñoz et al., 2019).

The pollen samples from Malladetes (Dupré Ollivier, 1988) and Beneito (Iturbe et al., 1993) indicate open landscapes under dry conditions. In the southernmost region, Bajondillo shows percentages of herbaceous plants above 70%, while tree taxa account for 10-15%; only in the most recent Solutrean stratum (Bj6) do these taxa reach 40% (López Sáez et al., 2007).

In inland areas, at altitudes above 300 m, the situation was different. *Juniperus* sp. is the most important taxon, representing 70-97% of the anthracological remains (Badal et al., 2013; Barton et al., 2013). These are sites located between Cabo de la Nao and the Gulf of Almería, at a distance of more than 40 km from the Pleniglacial coastline, namely La Ratlla del Bubo (Soler et al., 1990, p. 199), La Boja (Zilhão et al., 2017) and Cueva Ambrosio (Rodriguez Ariza, 2005), possibly representing the aridest landscapes of the LGM, with a rainfall of around 300-600 mm.

The terrain to the south of 40ºN consisted of open landscapes formed by cold and sclerophyllous taxa. However, some thermophilous taxa (evergreen *Quercus*, *Pinus pinea*, *Rosmarinus officinalis*, *Pistacia* sp.) would have been found on the coastal plains, possibly because they would have been sheltered in coastal areas and would have enjoyed a higher rainfall. These data indicate that there was a drop in the bioclimatic zones during the last Pleniglacial, and those currently situated at an altitude of 1000 m would have been on the coastal plain itself (Badal and Carrión, 2001; Barton et al., 2013; Camuera et al., 2019; Carrión et al., 2010).

Sedimentary studies also showed climatic degradation. Gelifraction processes have been identified at Malladetes (Fumanal, 1986), Beneito (Iturbe et al., 1993), and Ambrosio (Jordá Pardo et al., 2012). Similarly, micromammal remains indicate cooler ecological conditions than today, with variable humidity. *Microtus arvalis*, a species that currently takes refuge in mountainous and inland areas, has been identified at Cendres, Comte, Beneito, and Nerja (Guillem Calatayud, 2001; Tormo, 2010). At Cueva Ambrosio, colder, drier conditions have also been established based on the identification of *Microtus nivalis* (Sesé and Soto, 1988).

There do not appear to be any significant diachronic changes in terrestrial mammals, and they should be carefully used as bioindicators due to their adaptive capacity (Aura et al., 2002; Pérez Ripoll and Martínez, 2001). The two most common species (*Capra pyrenaica* and *Cervus elaphus*) are predominantly related to the surroundings of the sites. Larger mammals (*Bos* sp. and *Equus* sp.) are present to some extent, although less so from the Late Glacial period onwards. Occasional remains of *Equus hydruntinus*, *Sus scrofa*, *Rupicapra rupicapra,* and *Capreolus capreolus* have been identified, but they do not show any clear correlation with paleoclimatic oscillations.

Lynx, wolf, cat, and fox are the most commonly identified carnivores. Their use as an economic resource has been described (Real et al., 2017). The recent identification of *Cuon alpinus* has been related to alternating occupations of the caves at the beginning of the Upper Paleolithic. However, there is also evidence of the processing of this species. A dhole skull found at Santa Maira presents cut marks (Pérez Ripoll et al., 2010).

Fragmentary data are available on the Pleniglacial avifauna of the Iberian Mediterranean region. At Nerja, the remains of Columbidae, Corvidae, and Anatidae have been identified, with the occasional reference in the Gravettian and Solutrean to *Melanitta nigra/fusca*, species that currently have a more northern, even boreal, distribution (Morales Pérez et al., 2020). Species typical of arid/semi-arid and high mountain environments (Sánchez Marco, 1988) are mentioned at Cueva Ambrosio, and *Otis tarda* has been identified at Santa Maira (Sánchez Marco, 1988).

The presence of Atlantic marine fauna in the Solutrean levels of Nerja coincides with the low SSTs reported in the MD95-2043 core (Cacho et al., 2001) (Figure 1 – A and B). Some of the species of mollusks and fish identified from the end of LGM, currently have a boreal distribution (Jordá Pardo et al., 2018; Serrano et al., 1997). This is the case of Gadidae (Rodrigo García, 1991) and *Salmo salar* (Kettle et al., 2011), which have been dated to 24.7-21.7 ka cal BP (Aura et al., 2019). Finally, one seal has been identified among the Gravettian remains from Cendres, while at Nerja one *Monachus monachus* and two *Phoca vitulina* remains have been classified, all from Solutrean levels (Aura et al., 2016).

Archaeologically, the period between 26 and 19 ka cal BP, corresponds, in this area of Iberia, to the end of the Gravettian, the Solutrean, the Badegoulian, and the beginning of the Magdalenian. The data available for each area of the Mediterranean Iberia and technocomplex vary considerably. The patterns described below are mostly concerned with the southern sectors, as the northernmost regions (e.g., Catalonia) offer many features that are common to Pyrenean sites (Fullola, 1979; Fullola et al., 2019; Mangado, 2005).

Radiocarbon data come from 25 multi-stratified sites, with a total of 91 radiocarbon dates, only 58 present reliable results for the southern sectors. Amongst the non-reliable results are the ones obtained by standard C14 methods in Parpalló and Malladetes, although their contribution to the Iberian Mediterranean region sequence continues to be a useful reference.

The distribution of dates by phases and archaeological units also varies. Most sites are associated with Solutrean contexts, with 47 of these accounting for 83.4% of the total known sites. These are assemblages with highly diagnostic stone points, while contexts corresponding to the limits of this period are poorly documented or have suffered erosive processes (Aura, 2007, 1995; Aura et al., 2012b).

The relationship between the Solutrean and both the Gravettian and the Badegoulian is poorly understood. One of the effects of this situation is that the chronological duration of the Solutrean is longer than the other phases (Aura and Jordá Pardo, 2012). Another question is the small number of samples, both for the end of the Gravettian and the transition between the Solutrean and the Badegoulian. For the millennium ca. 25.7-24.8 ka cal BP four dates are associated with assemblages from the Gravettian (Cendres), Lower Solutrean (La Boja), Vale Comprido elements (Nerja), and Middle Solutrean (Ambrosio). This situation is repeated at the end of the sequence, with the addition of regional taphonomic processes that have been described at various sites. For the millennium ca. 21-19.5 ka cal BP, six dates are available that come from contexts in which erosive processes are identified (Cendres XIII) or that are formed by limited archaeological assemblages (La Boja OH6 and OH5), with Badegoulian (Beneito II-ext) or Magdalenian (3 dates) techno-typological features.

During the second half of the HE2, assemblages have been described from the Final Gravettian (Cendres XV), the Lower Solutrean with unifacial points (La Boja OH11 and OH10) and assemblages showing technological and typological continuity with the Gravettian (Nerja: NV 10 and NV 9).

The work carried out at Cendres has made it possible to characterize the Mediterranean Gravettian. Its variability is related to the availability of raw materials and sites’ function, so its evolution is not linked to the Noailles model of the Cantabrian-Pyrenean region. However, its final moments are not well documented.

At La Boja, the radiocarbon age for a Lower Solutrean assemblage coincides with that of the “classic” evolutionary model based on the replacement of stone points that places some of the oldest assemblages of the Lower Solutrean in the region (Fortea and Jordá, 1976; Jordá, 1955; Pericot, 1942; Villaverde, 2001).

At Nerja (NV10 and NV9), a blade production system related to the Gravettian tradition has been identified, lacking backed microlaminar tools, but with unifacial points, Vale Comprido-style blanks and core-scrapers (Zilhão and Aubry, 1995) (Figure 9). Its position between productions belonging to the Gravettian and “true” Solutrean tradition led to its comparison with Parpalló, and it was proposed that there would have been an intermediate phase that has not yet been established (Tiffagom et al., 2007).



Figure 9 - Lithic tools and osseous weaponry from the Mediterranean Iberia. 1. antler point; 2 and 4 Vale Comprido-style points; 3,6,7. unifacial points. 5: scraper carinated-core; 8-9. Mediterranean shouldered points; 10-11. tanged and winged point, Parpalló type; 12. pedunculated point; 13. single beveled point with Le Placard decoration; 14-16. single beveled points; 17. burin-core; 18. discoid-facial core; 19-22. raclettes. Cueva de Nerja (1, 2, 5 and 6); Parpalló (3, 4, 7, 8-18 and 22); Hort de Cortés–Volcán del Faro (19-21). (Photos: M. Tiffagom, J.Ll. Pascual, V. Villaverde, M. Borao and J.E. Aura).

The limited data on raw materials and technology indicate local and regional procurement. At Cendres, local flint accounts for 39-49% of the total and regional for 30-50%, coming from a distance of between 40 and 60 km (Villaverde et al., 2019). At Nerja, the identification of non-rounded cortex and the size of the blanks indicates a good quality flint supply at a distance of more than 25 km (Aura et al., 2001).

The osseous industry is manufactured with bone and consists of points and awls. Most are simple or double points; only two single beveled points have been identified. The first needle is documented at Parpalló (Pericot, 1942, p. 35). Domestic tools (chisels, spatulas) have also been described, but they are very scarce.

Solutrean typical tools became generalized from ca. 24.7. Between this date and 23.7 ka cal BP heat treatment of flint to produce foliate points with flat retouch is also evident (Tiffagom, 2006). The diagnostic morphotypes are different foliates (laurel leaf, asymmetric Montaut points, and early pedunculated tools). It is equivalent to the Middle Solutrean, but the use of Full Solutrean is used to emphasize that unifacial and bifacial foliate points, the first tanged and winged points and Mediterranean shouldered points occur (Fortea and Jordá, 1976; Fullola, 1979; Pericot, 1942; Tiffagom, 2006) (Figure 9). The initial chronology of this horizon has been traced at La Boja, ca. 24.9- 24.2 ka cal BP (Zilhão et al., 2017).

Data on the Solutrean bone industry are conditioned by the number of pieces found at Parpalló in relation to other sites. The characteristics of this phase are similar to those of the previous phase. Bone appears to be the dominant raw material, and the majority of the finds are simple and double points, with some single beveled points and awls (Figure 8). The first points with a polygonal base are described at Parpalló, and perforated needles are not documented at any site.

The period between 24 and 23.5 ka cal BP is characterized by the presence of tanged and winged points typical of Parpalló and identified as Upper or Evolved Solutrean. Their dating at various sites seems to define this time frame. There are few specimens in the previous phase, and after 22.5 ka cal BP their presence is also very limited. Something similar occurs with bifacial foliate points, which are more numerous than tanged points but which follow a similar trajectory in time. From 23 ka cal BP there is an increase in tools manufactured by abrupt retouching (Mediterranean shouldered points and backed bladelets) (Figure 9).

In this phase, there is evidence for some diversification in the osseous industry. Most of the pieces are probably made from bone, but no up-to-date data are available for Parpalló. In addition to single and double points, we also have those with a polygonal base, single beveled, grooved, and long points. Needles are referenced at Ambrosio, Parpalló, and Cendres.

In the sequence from Parpalló, Mediterranean shouldered points are more numerous than foliate points from the 4.75-4.50 m section. This process served to define an Evolved Solutrean II (Fortea and Jordá, 1976), for which the denomination Solutreo-Gravettian has now become more widely used (Fullola, 1979; Villaverde and Peña, 1981).

The earliest Mediterranean shouldered points are dated to 23.5 ka cal BP (at Parpalló and Ambrosio) and are the predominant lithic projectile before 23 ka cal BP. Based on this reference, the processes of technical “hybridization” described by Tiffagom (2006), which would be the end of Solutrean typical assemblages and the generalization of laminar-microlaminar production systems, would dominate between 23 and 22 ka cal BP. A trait that is repeatedly observed at different sites is the reappearance of unifacial points at the end of the Solutreo–Gravettian. Although always found in small numbers, there are even more of these than bifacial foliate points.

The osseous industry of Beneito (B2-B1), Cendres XIII, Ambrosio (II), and Nerja (NB8s) follows the dynamics described for the previous phase; in fact, some of these contexts could have been included in the previous phase. The most important features are the predominance of single points and the presence of single beveled points and needles. Most of the objects are manufactured from bone.

The period between ca. 21-19.5 ka cal BP is hard to classify as an archaeological inter-phase since its archeo-stratigraphic bases are yet to be defined and its chronological range adjusted. Layers 11-6 of the Talud sector of Parpalló contain materials that have been described as Badegoulian (Aura, 2007, 1995). For layers 12 and 11, several radiocarbon dates attest a chronology of ca. 22.7-22.1 ka cal BP, therefore clearly overlapping with the Evolved Solutrean regional dates (Aura and Jordá Pardo, 2012).

In a previous work, it was proposed the co-existence of various traits may indicate the presence of a “formative” Badegoulain phase with Evolved Solutrean and Badegoulian elements that in turn would suggest a transition rather than a simple substitution process (Aura et al., 2012a: Fig. 6). No analysis of possible inter- and intra-stratigraphic refitting has been carried out to evaluate this hypothesis.

These “transitional” or “mixed” assemblages tend to be classified as Evolved Solutrean based on the most easily identifiable morphotypes of shouldered points (Aura et al., 2012a) (Figure 8). This situation is the result of erosive processes that have resulted in an aggregation of Solutrean and Badegoulian materials (Aura, 1995).

The hypothesis formulated in other works presents a shorter chronology for the Solutrean, which would be consistent with a more extensive Badegoulian than the period considered so far. These arguments are consistent with the situation recently described at Montlleó, in a context dated to 22.7 – 22.4 ka cal BP with some shouldered points and Badegoulian tools such as raclettes (Fullola et al., 2019) (Figure 9). We are currently obtaining chronostratigraphic data from the site of Hortet de Cortés–Volcán del Faro, where we have identified Badegoulian materials (Aura, 1995).

The osseous industry found in these layers of Parpalló shows significant changes. Antler now accounts for at least 40%, in addition to single beveled points. In fact, Pericot states that “…they all (beveled antler points) appeared in contact with the first Magdalenian section, to which culture they should belong” (Pericot, 1942: Fig. 36). Single, double, and polygonal base points are still present.

The first assemblages from the classic Lower Magdalenian are dated to ca. 19.6-19.2 ka cal BP. These are assemblages of laminar production, with highly standardized productions aimed at obtaining blades, and a differentiated microlaminar production, which was used to manufacture an important assemblage of armatures by simple, and abrupt retouch.

Their identification is limited to a small number of sites, including Cendres XII (Villaverde et al., 2012) and La Boja OH4 (Zilhão et al., 2017). The assemblage from Ardales Zone 2 (Ramos-Muñoz et al., 2019) is also believed to correspond to this phase, which is at the chronological limit of this work. These are assemblages with a small number of pieces. At sites with Solutreo-Gravettian occupations and without Badegoulian levels or materials, Lower Magdalenian occupations have gone unnoticed among Solutreo-Gravettian microlaminar tools. Based on their identification south of Parpalló, it is not possible to maintain that the evolved Solutrean in the southernmost sectors of Iberia lasted well until the Magdalenian (Ripoll Lopez, 1988).

In this context, the Magdalenian is a technocomplex that must be differentiated from the Badegoulian, meaning that the designation Old Magdalenian of Badegoulian facies, the name we initially proposed for Parpalló (Aura, 1995, 1988), should no longer be used. The Badegoulian has its own techno-economic features in terms of both lithic and osseous equipment (Ducasse, 2010; Pétillon and Ducasse, 2012), which have also recently been identified at Parpalló (Borao Álvarez et al., 2016). Another question is the relationship between these two technocomplexes, about which little is known.

In the southern sectors of the Mediterranean, Solutrean ornaments consist of scaphopods (20‰), gastropods (55%), and marine bivalves (10%). Terrestrial gastropods, basically *Theodoxus fluviatilis*, account for less than 5%. Special findings include the 65 remains of Serpulidae-Vermetidae and the two squalus teeth described in the Solutrean level of Parpalló (Soler, 2015). Mammal teeth (*Cervus elaphus*, *Capra* sp., *Vulpes vulpes*, *Lynx pardina*) represent less than 2% (Avezuela and Álvarez Fernández, 2012; Martínez Martínez, 2015; Soler, 2015; Soler et al., 2013).

The combination of *Littorina obtusata*, *Nucella lapillus,* and *Nassarius* sp. accounts for about 30% of all the Solutrean ornaments. These are common species on the Atlantic coast of Iberia, and they could have inhabited the Mediterranean coasts thanks to the drop in SSTs in the Alborán Sea during the timeframe under consideration. Badegoulian ornaments are only documented at Hortet de Cortés–Volcán del Faro and Parpalló.

A review has recently been published on the pre-Magdalenian art of the Mediterranean (Villaverde, 2018), highlighting the importance of Solutrean art. Based on the engraved slabs found at Parpalló and parietal sites in the south of the area, pre-Magdalenian art is organized into two broad phases, with significant conceptual, formal, and stylistic variations. The first again highlights the link between Gravettian art and the unifacial point phase, up to early moments of the full Solutrean. The second phase is associated with bifacial and tanged points, which characterizes the entire upper Solutrean and Solutreo-Gravettian period.

The transition from Style III to IV (Leroi-Gourhan et al., 1983) coincides with the end of this second phase. However, it should not be forgotten that Parpalló contains the largest assemblage of Badegoulian art if we consider recent inventories (Clottes et al., 2012). Certain features are found in its Badegoulian A phase that should serve as a focus for this discussion. We are referring to the decrease in the number of engraved slabs, certain archaic traits affecting stylistic conventions, the abandonment of painting to represent zoomorphic figures, or changes in the species represented and in signs (Villaverde, 1994). As can be noted, Badegoulian A phase shows differences when compared to both Evolved Solutrean art and later Magdalenian art. However, their identification is hidden within the Magdalenian cycle. Badegoulian art is yet to be discussed.

**2.4. Western Atlantic Façade (JC)**

The first attempts to reconstruct what would have been the westernmost edge of Iberia environment in a glacial period were those by Jean Roche (1977, 1971). Based on data obtained from the faunal assemblages of caves such as Salemas, Casa da Moura and Lapa do Suão, all located in the Portuguese Estremadura (Figure 10), the author characterized the regional climate as stable, with humid periglacial conditions, during the whole Würm glaciation. This model was based on the constant presence, from the Mousterian to the Magdalenian, of hyena, wolf, horse, aurochs, and red deer, as well as sporadic occurrences of rabbit, chamois, ibex and wild boar (Roche, 1977, 1971). Along with these observations, Roche argued, however, that in the mountain massifs of central Portugal, the action of ice would have been felt, at least during the most rigorous periods, such as the LGM. This latter idea was corroborated by Ferreira (1985) and Daveau (1980, 1973). They attribute the maximum duration of this glaciation to a period of around 5000 years (between 24.0 and 18.3 ka cal BP), precisely during the development of glacial phenomena in the mountains of Estrela, Cabreira, Gerês, and Peneda. These conditions would, on the other hand, be the basis for the creation of cryoclastic and solifluction deposits, not only at the high altitudes of the referred mountain ranges but also in several other areas of Central and Northern Portugal, located at much lower altitudes (around 100 meters a.s.l) (Daveau et al., 1985). These conditions would result in deserted landscapes at altitudes above 700 meters and with extensive pine and alder forests below this elevation (Daveau, 1980).



Figure 9 – Location of LGM sites from Atlantic Iberia. Numbered black circles correspond to the sites referred to in the text (topographic data from the U.S. Geological, Survey Shuttle Radar Topography Mission - <https://earthexplorer.usgs.gov/>). 1. Ourão; 2. Buraca Escura; 3. Buraca Grande; 4. Lagar Velho; 5. Caldeirão; 6. Lapa do Anecrial; 7. Lapa do Picareiro; 8. Almonda; 9. Casal do Cepo; 10. Cabeço do Porto Marinho; 11. Olival da Carneira; 12. Olival do Passal; 13. Furninha; 14. Casa da Moura; 15. Lapa do Suão; 16. Lapa da Rainha; 17. Baío; 18. Salemas; 19. Correio-Mor; 20. Poço Velho; 21. Monte da Fainha; 22. Escoural; 23. Vala; 24. Vale Boi.

Later, Zilhão (1987) added several details to this scenario, suggesting that the LGM of the Portuguese Estremadura would have been composed of three distinct climatic/biotic zones: (1) the highlands of the limestone massif, with an environment practically analogous to the current periglacial areas, where, depending on the local soils, semi-arid surfaces with little vegetation were present; (2) the coastal plains and the northwestern areas around the Tagus River, covered by a very dense forest, particularly in the more confined valleys, and the areas with high elevations (above 100 meters) with more sparse vegetation and the presence of species typically found in boreal, temperate and Mediterranean forests; (3) and the plains located at lower altitudes, characterized by large deposits of dunes, formed by strong winds from the North and West. More recent studies of archaeological sequences in Central Portugal (namely in Gruta do Caldeirão and Lapa do Anecrial), with particular emphasis on the observation of plant macro-remains, of micro and macro-fauna, and in the geochemical analyzes of cave sediments (Cruz, 1993, 1990) consolidated the paleoclimatic reconstruction proposed by Zilhão (1987).

Despite the arguments offered by faunal and sedimentological studies in the caves of Estremadura, it should be noted their contradiction with some of the pollen analyzes published in recent years, based on the assessment of deep-sea cores off the western coast of Iberia.

Roucoux et al. (2005) demonstrate, in fact, that the climate seems to have been hotter and more humid in the western areas of Iberia during the LGM than during many of the stadial events of the MIS 3. This pattern corresponds, on the other hand, to relatively warm conditions in the open sea (De Abreu, 2000; Pailler and Bard, 2002) and in Greenland (Dansgaard et al., 1993), adding weight to the notion that the traditional LGM does not necessarily indicate more severe climatic conditions in all geographical areas.

Reconstructions of sea surface temperatures off the coast of Portugal (Cayre et al., 1999; de Abreu et al., 2003; Pailler and Bard, 2002) reveal winter values of between 12º C and 15º C during the LGM. Compared to the current temperature record, these are only about 5º C colder, but 5º C to 10º C higher than during the so-called Heinrich events (Pailler and Bard, 2002). Salgueiro et al. (2010) estimate sea surface temperatures of 16.5-18.4ºC off Portugal with a spike to modern sea surface temperatures at ca. 20 ka cal BP (Figure 1).

Terrestrial records for Late Pleistocene paleoenvironmental reconstructions are still very scarce in Portugal. Macro-remains of quaternary forests are present at numerous places on the northwestern Iberian coastal areas. At the Maceda Beach Formation, the presence of *Pinus sylvestris*, *Quercus robur*, and *Fraxinus* sp. dated between ca. 34 and 24 ka cal BP, indicate the continued presence of a Scots pine forest across the formation of the deposits. According to Haws (2012), although there are some breaks identifiable in the sequence, there is no apparent reason (*contra* Zilhão and Almeida, 2002) for a forest decline beginning with GI-2 and continuing during the LGM *stricto sensu*, when sea surface temperatures were similar to today, and arboreal pollen increased relative to the earlier layers.

Paleoenvironmental proxies from archaeological sites are also limited in westernmost Iberia, and mostly coming from fauna and anthracological studies. Macro-charcoal assemblages from the archaeological site of Lagar Velho, point for a dominant presence of Scots pine, *Erica* and Leguminosae (*Cytisus, Ulex, Ononis, Medicago*). The same seems to hold true for the short-term occupation at Lapa do Anecrial (ca. 27.8-24.7 ka cal BP) (Almeida et al., 2007), for early-LGM Layer 2 of Buraca Escura (ca. 26.8-25.5 ka cal BP) (Aubry et al., 2001), and for Cabeço do Porto Marinho (Queiroz et al., 2002).

In LGM levels (T and U) at Lapa do Picareiro, faunal assemblages show some remarkable similarities to the present-day (Haws et al., 2019; Haws, 2012). The composition of the assemblages suggests that relatively warm and humid conditions existed during most of the LGM. High percentages of rabbit and bird bones along with large mammals, especially red deer and ibex, but also horse and lynx are present. Birds show a high taxonomic diversity with at least 13 recognized species, but mostly partridges, crows, and pigeons. Amphibians include the common toad, *Bufo bufo*, and the Iberian spadefoot, *Pelobates cultripes*, both find currently in Portugal.

At Lagar Velho, faunal remains were recovered from both level TP06 in the Hanging Remnant dated to ca. 28-24.5 ka cal BP (GI3-HE2 interval), and level TP09 dated to ca. 24.6-23.5 ka cal BP (HE2-GI2 interval). Small differences were detected between both levels. For TP06 red deer and rabbit dominate, but there are several horse and hare remains that suggest more open environments. The presence of wild boar and hedgehog in this layer point to a mosaic ecosystem of open woodlands (Moreno-García and Pimenta, 2002). Several present-day species of birds were found, including chough (*Pyrrhocorax*), partridge (*Alectoris*), jackdaw (*Corvus monedula*), falcon (*Falco tinnunculus*) and starling (*Sturnus*). In TP09, roe deer replaces aurochs, and hare declines sharply. The very low frequency of wild boar in this level suggests an increase in forest conditions.

A total of 19 archaeological sites are currently identified in Portugal with absolute dates that fit in the 26.5-19 ka cal BP interval used in this paper. From 85 radiocarbon and luminescence results, only 57 present reliable results in terms of stratigraphic reliability. As in other areas of western Europe, a significant number of other sites are also attributed to the LGM due to the unique aspect of the Solutrean industries. These are the cases of Buraca Grande, Ourão, Casa da Moura, Almonda, Casal do Cepo, Olival da Carneira, Olival do Passal, Furninha, Lapa do Suão, Lapa da Rainha, Baío, Correio-Mor, Poço Velho, Monte da Fainha, Escoural, and Vala. In seven of these sites, recognizable Solutrean artifacts are limited to stone projectiles (Cascalheira, 2013).

Most of the LGM-related sites are located in the Portuguese Estremadura, and only four (Monte da Fainha, Escoural, Vala, and Vale Boi) are situated south of the Tagus basin. At least three techno-cultural entities are securely recognized for the LGM in these areas: the Terminal Gravettian, the Proto-Solutrean, and the Solutrean.

While, in chronological terms, the Solutrean has been clearly separated from the Proto-Solutrean, the temporal distinction between the Terminal Gravettian and the Proto-Solutrean has been harder to establish. In general terms, the Terminal Gravettian is characterized by intensive use of quartz (~30%), the presence of marginally retouched bladelets, rare back bladelets, and a high frequency of carinated/thick-nosed “scraper”-cores (Almeida, 2000). The Proto-Solutrean, on the other hand, shows three different reduction sequences: one for the production of the so-called Vale Comprido points (Figure 11), through the removal of elongated blanks with convergent profiles and thick platforms; another for the production of blades, of Gravettian tradition; and another for the production of bladelets, probably obtained through the exploitation of thick carinated elements (Zilhão, 1997).



Figure 11 – Proto-Solutrean and Solutrean lithic materials from the Western Atlantic Façade. 1-5. Lapa do Picareir - Proto-Solutrean/Early Solutrean blanks (photos by Jonathan Haws); 6-7. Vale Boi – Vale Comprido points and blanks (Photos by Joana Belmiro); 12-20. Vale Boi – stemmed and shouldered points (Photos by João Cascalheira).

Two alternative models are currently available that either see these two entities (Terminal Gravettian and Proto-Solutran) as contemporary, and thus representing functional facies of the same system, or as discrete chronological phases (Zilhão, 1997; Zilhão et al., 1999; Zilhão and Aubry, 1995). Recent data from Lapa do Picareiro (Haws et al., 2019) and Vale Boi (Belmiro, 2020) has, however, provided significant evidence for a chronological separation of the two entities. In any case, it seems somewhat secure to claim that significant technological changes occur in westernmost Iberia at the onset of the LGM, particularly during the HE2 (Figure 1), possibly representing an intensification and diversification of the techno-economic patterns as a response to climatic deterioration across the Heinrich Event (Belmiro et al., 2017; Cascalheira and Bicho, 2013).

A single site, Cabeço do Porto Marinho, presents an accepted radiocarbon date of ca. 19.5 ka cal BP, attributed to the Early Magdalenian (Bicho and Haws, 2012). The scarcity of radiocarbon dates for the later parts of the LGM (from ca. 21 ka cal BP onwards) is one of the main reasons for the current lack of knowledge on the Solutrean-Magdalenian transition in the region. The presence of a Solutreo‑Gravettian phase, as described for the Mediterranean region, is not securely attested in Portugal. Zilhão (1997) argued for the presence of such a phase, due to similarities between a small bone projectile from Buraca Grande and similar pieces recovered from sites in Mediterranean Spain, as well as by the presence of very small abruptly retouched shouldered points (also typical of the Spanish Solutreo-Gravettian) in Caldeirão. The author recognizes, however, that the phase is not preserved in the stratigraphic sequences, particularly in the caves of Buraca Grande and Caldeirão, in the latter due to the strong bioturbation recorded in the upper part of the Solutrean layers.

The chrono-stratigraphic model generally accepted for the Portuguese Solutrean is the one synthesized, based on data from Estremadura, by Zilhão (1994) and respective updates (Zilhão, 2013, 1997). The chrono-cultural subdivision follows the one provided by Smith (1966) for southwestern France that organizes the technocomplex in three distinct moments based on the successive appearance of the different index fossils: Lower, Middle and Upper Solutrean.

While no data is currently available for the Lower Solutrean phase, the Middle Solutrean lithic industries seem to be marked by the preferential production of blades from bidirectional cores carefully prepared by micro-faceting of platforms (Zilhão, 1997). Typologically, laurel leaves and points *a face plan* are predominant. For the Upper Solutrean, only the site of Olival da Carneira offers enough data for a detailed analysis of the technological standards of this phase, despite no radiocarbon results are available. Although the strategies are apparently the same as in the previous phase, there is a noticeable microlithization of the industries, whose goal is now the production of bladelets. In addition to the appearance of pedunculated points, small laurel leaves continue to be present at this stage. In southern Portugal, the site of Vale Boi provides the largest Solutrean assemblage of the western Atlantic façade, with more than 20.000 lithic artifacts recovered from several areas across the site, but mostly from the rock shelter (Cascalheira et al., 2012). Expedient reduction sequences to produce mostly flakes and bladelets are common at Vale Boi. Formal tools are dominated by end-scrapers, notches, splintered pieces, and unevenly retouched flakes. Differences between layers in the typological composition of the assemblages are mostly seen in the elements coming from the Solutrean tools group and backed shouldered points (Figure 11).

One of the main characteristics of the organization scheme of the Solutrean in Portugal is the existence of gaps, either in the transition between phases (i.e., Middle-Upper Solutrean) or covering a complete stage (i.e., Lower Solutrean). Together with other phenomena of redeposition and palimpsest formation, these discontinuities are given by Zilhão (2013) as expected, considering that LGM climatic oscillations must have had a marked impact on deposit preservation. However, as mentioned elsewhere (Cascalheira, 2013), the hypothetical character that covers part of the attributions, particularly the absence of chronological overlap between each of the phases and inherent evolutionary progression between the various index fossils, or the extrapolated existence of a Lower Solutrean stage, becomes even more evident if we pay attention to some particularities of the sites involved in the proposal. The Caldeirão cave, whose role in the construction of the model is central, presents some problems in the Solutrean sequence, such as the insecure stratigraphic position of the totality of the elements attributable to the Upper Solutrean (Zilhão, 1997, p. 513) or the inversion problems presented by the rejected dates at the top of layer Fa.

Additionally, a recent analysis by Cascalheira and Bicho (2015) of the available chronometric data from southern Iberia revealed the presence of tanged “Parpalló-type” points at a much earlier time (ca. 25 ka cal BP) than previously thought. This fact calls into doubt the status of the traditionally-defined type-fossils as precise temporal markers for each Solutrean phase across westernmost Iberia. This pattern is mostly visible at Vale Boi, a recently excavated site in southern Portugal (Bicho et al., 2012a; Cascalheira et al., 2012).

LGM artistic manifestations in the westernmost edge of Iberia are rare. At Escoural, the only cave in Portugal with paleolithic engravings and paintings, some of the representations have been attributed to the Solutrean, based on stylistic similarities with other artistic manifestations across Iberia (Lejeune, 1997).

Some examples of mobile art, in the form of small schist/graywacke engraved plaquettes, were recovered from the sites of Caldeirão and Vale Boi. In the case of Caldeirão, the schist piece is engraved in both faces: one dominated by a very stylized anthropomorphic figure, crossed by oblique lines; the other presents a striated pattern which could be interpreted as a pisciform representation, or as the representation of the hindquarters and back of an animal motif with the striated body (Zilhão, 1988).

At Vale Boi, four engraved slabs were, so far, identified in Solutrean levels dated to between ca. 24.5 and 20.5 ka cal BP. In three of these slabs, zoomorphic elements are visible (Bicho et al., 2012b; Simón Vallejo et al., 2019, 2012). The anatomical zoomorphic stylistic conventions used in Vale Boi have been compared with other regions of Iberia, attesting their similarities with other representations present in the late Gravettian/Solutrean of the Mediterranean art sequence, and in some of the Côa valley sites (Aubry and Sampaio, 2008).

Vale Boi also provided the largest LGM assemblage of body ornaments in westernmost Iberia. A total of 82 perforated shells were recovered from Proto-Solutrean and Solutrean levels at the site, contrasting with a total of seven pieces found in sites from Central Portugal (Bicho, 2009). The most present species in both regions and phases is *Littorina* sp. (Tátá et al., 2014). At Vale Boi specimens of *Antalis* sp., *Theodoxus* sp., *Trivia* sp. are also well represented (André et al., 2019).

**3. Discussion**

Climatic changes that occurred during the LGM had important repercussions in the geography, technology, and social behavior of human populations in Europe. Human range contraction into southern European peninsulas (Banks et al., 2008; Barton et al., 2013; Bocquet-Appel and Demars, 2000; Bradtmöller et al., 2012; Burke et al., 2014; Jochim, 1987; Straus, 1991), with subsequent (or even earlier – see Maier and Zimmermann, 2017) genetic bottlenecks (Barbujani et al., 1998; Fu et al., 2016; Keinan et al., 2007; Posth et al., 2016; Torroni et al., 2001), and the emergence of a distinct set of cultural materials (Jordá, 1955; Smith, 1966; Straus, 2016, 2015), are amongst the most significant implications.

However, the impact of the LGM and accompanying stadials (GS3-GS2.1), interstadials (GI2.2 to GI2.1) (Rasmussen et al., 2014), and rapid climate change events (HE2 - (Sanchez Goñi and Harrison, 2010) and D-O 2 - (Rahmstorf, 2003)), in the environments across the continent was, as expected, eco-geographically variable. Thus, while the broader paleoanthropological significance of the LGM is crucial, a better understanding of the particularities of how human groups responded to the millennial and centennial shifts in their habitats is of utter importance. This is particularly evident when the diversity of environments and human adaptations across Iberia from ca. 26 to 19 ka cal BP is considered, which is well mirrored in the currently available set of radiocarbon dates.

Figure 12 presents a comparison between the Summed Probability Distributions (SPDs) for the four different macro-regions described in the sections above. The extent to which each sub-region departs from the pan-regional trend is tested via permutation (following the methods in Crema (2016). Given the small sample available for the analysis (n = 266), statistical results should be viewed with caution, since there is a high chance for the occurrence of Type II errors. Additionally, because of the different caveats addressed below for each specific timeframe, the dates presented should not be regarded as direct indicators of fluctuations in human population numbers. Still, the shape of the regional SPD curves and their comparison with the general Iberian trend provide some interesting patterns when combined with the data described in the regional frameworks section.

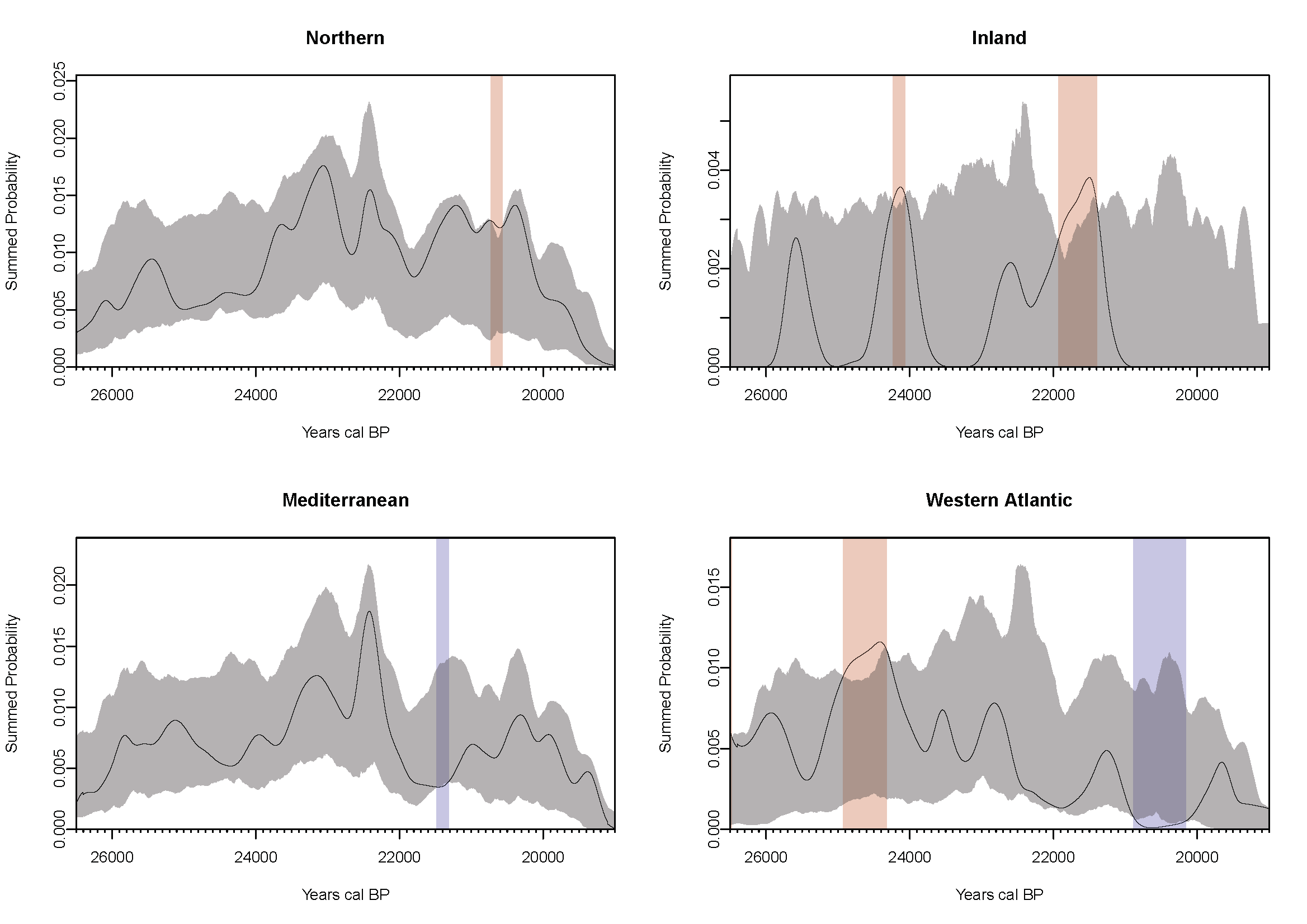


Figure 12 - Comparison between the Summed Probability Distributions (SPDs) and pan-regional trend for the four Iberian regions used in this review. The grey shaded region depicts the critical envelope that encompasses the middle 95% of the simulated SPDs based on the pan-regional data. Red and blue regions highlight portions of the regional SPDs where positive and negative deviations are detected. Calibration and analysis were performed using the RCarbon package for the R statistical environment. For more information on the methods used for SPD calculation and binning, please refer to Crema et al. (2016) and Roberts et al. (2018).

Confirming the patterns detected by Weniger et al. (2019), evidence in Northern Iberia seems quite weak from ca. 26 until 24 ka cal BP, roughly during the HE2 timeframe. In addition to what the authors mentioned, however, the high number of dates recorded in Southern Iberia is mostly related to a significant peak of results in the Atlantic façade between ca. 25 and 24.3 ka cal BP. Inland Iberia reveals two significant peaks (ca. 25.5 ka cal BP and ca. 24.2 ka cal BP) within this timeframe, which, similarly to the western edge, have been associated with the occurrence of Proto-Solutrean and Solutrean materials (Alcaraz-Castaño et al., 2013; Cascalheira and Bicho, 2013). The low number of results for southern and northern Iberia during the HE2, especially compared to the after 24 ka cal BP segment, partially explain the lack of good resolution in these regions for the Gravettian-Solutrean “transitional” moment presented above. Whether the low number of radiocarbon dates can be considered as a proxy for low population densities or preservation bias due to the harsh conditions of the HE2 has yet to be systematically explored. Nevertheless, as attested by the regional sections above, the occurrence of Proto-Solutrean assemblages (with Vale Comprido components) in westernmost Iberia (Zilhão and Aubry, 1995), central Iberia (Alcaraz-Castaño et al., 2013), southern Iberia (Aura et al., 2009), and southwestern France (Renard, 2011), roughly within the 26-24 ka cal BP timeframe, makes its presence predictable in the northern Iberian territories.

From the 24 ka cal BP mark onwards, significant differences in the number of dates between regions are especially evident. This timeframe marks the generalization of the Solutrean toolkit and amelioration of climate conditions in most regions. In the Mediterranean and Northern Iberia, radiocarbon results tend to progressively grow, reaching their highest numbers between 23 and 22 ka cal BP (see also Weniger et al., 2019). On the contrary, the number of dates for the westernmost Atlantic sector presents a broadly descending trend, reaching a low of dates right before ca. 20 ka cal BP. These differences are likely related to the fact that most sites attributable to the Solutrean based on typological grounds in the Atlantic façade are not radiometrically dated (Cascalheira, 2013; Zilhão, 1997).

From this interval onwards (< ca. 22 ka cal BP), two different scenarios seem to occur, separating the northern and southern parts of the peninsula: in Mediterranean Iberia, a very sharp drop occurs, followed by stability in the low number of dates until the end of the LGM; while in Northern Iberia evidence keeps rather strong until shortly before ca. 20 ka cal BP, when the number of available dates significantly decreases. Again, as in the Gravettian-Solutrean transition, the lack of a reliable set of dates echoes the abovementioned difficulties in the identification/isolation of a Solutreo-Gravettian phase in Portugal, and a possible Badegoulian/Early Magdalenian phase in eastern Iberia. These difficulties are magnified by the fact that assemblages occurring after and before the more stable core of Solutrean occupations tend to be more variable within and across regions.

Three different factors seem to be contributing to the apparent discrepancies between regions and the lack of a more robust understanding of LGM human ecodynamics across Iberia.

First, following the trends just presented, are the problems associated with absolute dating, and their impact on the establishment of more detailed correlations between paleoenvironmental proxies and human occupations, and inter-site/region comparisons in terms of cultural phasing. Dating problems are transversal to all Paleolithic archaeology (Talamo et al., 2012), and although significant methodological improvements have been accomplished over the last few years, some of the limitations are still insurmountable. For the LGM of Iberia, it is rather clear that much remains to be done in this context. While a vast majority of the radiocarbon dates were acquired by Accelerator Mass Spectrometry (AMS), not always the most recent protocols of sample selection (e.g., preference for anthropically modified bones) and pretreatment (e.g., ultrafiltration, ABOx-SC - (Higham, 2011)) were used. A future focus on the obtention of absolute dates using some of these protocols will, very likely, reveal severe underestimations at current gaps in the SPD curves, and show a considerably different scenario within and across regions.

Frequently, however, the problem is not the quality of the dates but the lack of reliable materials to be dated, or the inexistence of age-adequate, well-preserved, deposits. This is, in fact, the second shortcoming for a deeper understating of the LGM in Iberia: the difference across regions in what relates to the number and quality of the (potentially) available paleoenvironmental and archeological datasets. These differences result from several factors, ranging from research history to regional geomorphology and its influence on site preservation. The important series of paleoclimate proxies available for Northern Iberia, where several non-archeological deposits are known and well-characterized for the LGM, contrast markedly with the western Atlantic façade, for example, where very few terrestrial paleoenvironmental records are currently described for this timeframe (Granja et al., 2008). In contrast, the LGM environments of southern and western coastal regions of Iberia are well documented in the rich pollen sequences of deep-sea cores. A stronger reliance on these proxies might explain the identification and isolation of abrupt events (rather distinct in the marine sequences), such as the HE2, as possible triggers for cultural change in southern and western Iberia (Cascalheira and Bicho, 2013), but not in the northern sectors. In contrast, problems with the correlation of climatic conditions registered in deep-sea cores to more inland continental regions have been systematically denoted in other studies (Beghin et al., 2016; González-Sampériz et al., 2010; Jennerjahn et al., 2004; Wolf et al., 2018).

Lastly, it is noteworthy the deficiency of currently active field projects and the associated restriction of inferences taken from old excavations’ assemblages. Over the last two decades, data concerning the LGM human occupation of Iberia has had a steady but slower growth, particularly when compared with other topics such as the Middle-Upper Paleolithic transition. Approaches using published data and the re-analysis of available collections to explore a range of topics, from settlement patterns (Banks et al., 2009, 2008; Barton et al., 2013; Burke et al., 2017, 2014; Schmidt et al., 2012; Weniger et al., 2019) to lithic technology (Cascalheira, 2019; Schmidt, 2015; Tiffagom, 2006), have been prominent. Most of these valuable advances, however, tend to perpetuate inherent problems coming from a majority of time-averaged deposits (sometimes excavated before modern recording methods) representing the LGM archaeology of Iberia. In this context, further discussion on underdetermination in Iberian LGM archaeology is essential, particularly by focusing on the quality of the available dataset, its scope, sampling interval, resolution and dimensionality (Perreault, 2019).

In most cases, revisiting previously excavated sites is impossible, and the start of survey projects for the discovery of new sites is considered high-risk by most funding institutions. Still, only by targeting the acquisition of new empirical data will it be possible to solve long-standing debates on LGM human ecodynamics. A notable progress in this context is, for example, the recent archaeological and paleoenvironmental work in central Iberia reported above. Through the acquisition of new chronometric, paleoenvironmental, and archaeological evidence, former scenarios of a punctual human occupation in the Iberian hinterland during the LGM have been challenged (see e.g., Alcaraz-Castaño, 2015; Alcaraz-Castaño et al., 2019, 2017).

In this context, almost entirely unexplored regions in what concerns to LGM archaeology, such as the southwesternmost and northwesternmost areas (including southern Portugal, the westernmost sector of Andalusia, and Galicia), or the vast interior sectors of Iberia, are amongst the most promising ones for future research. In Galicia, the recent discovery of Solutrean implements at the open-air site of Valverde (Monforte de Lemos, Lugo) (de Lombera Hermida et al., 2013; Fábregas and de Lombera Hermida, 2010) opened up the possibility that future works would help to fill the gap between the Solutrean sites of Asturias and the Côa valley (Straus, 2016). Similarly, in southern Portugal, rich LGM occupations have been confirming the potential of the region as an important population hub during the LGM (see, e.g., the site of Vale Boi - (Bicho et al., 2012a; Cascalheira et al., 2012)).

**4. Conclusion**

This paper aimed to provide an updated review of the LGM archaeological and paleoenvironmental records of Iberia. By focusing on four different macro-regions with significantly different environmental backgrounds and research histories, the discrepancies found are notable and very important for future discussions on the topic. The following points are amongst the main outcomes:

* Despite being frequently considered as a viable unit of analysis, the LGM of Iberia encompasses a rather diverse set of cultural and environmental realities that should be considered beyond the simple division of South vs. North, or the one-size-fits-all cultural taxonomic attributions. For this reason, and based on the quality of the available datasets, it is still very risky to try any type of global synthesis comparing Iberian LGM adaptations.
* Work in new sites or the reappraisal of already known sites using new cutting-edge archaeological and paleoenvironmental methods will be essential to critically evaluate current models and resolve the debates surrounding: (1) the eco-cultural dynamics of less well-known moments, such as the Final Gravettian, the Proto-Solutrean, the Solutreo-Gravettian and the Badegoulian (2) the chronological structure of the Solutrean techno-complex; (3) and the correspondence of human cultural dynamics with regional and global paleoenvironmental variability.
* Investment in relatively unexplored areas and a focus on macro-regional studies will allow to fill the gaps in knowledge regarding settlement patterns and socio-cultural dynamics, about which many assumptions have accumulated over the years based on absence of evidence, not necessarily implying evidence of absence.

**Data Availability**

The complete dataset of sites’ coordinates and radiocarbon dates for the LGM of Iberia used for this paper are available at <http://www.doi.org/10.17605/OSF.IO/NY8MX>. The R code used for the analysis and visualizations presented in Figures 1 and 12 is also available in the same repository.

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