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Neandertal extinction and the millennial scale climatic variability of OIS 3

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Abstract

Population models seeking climate as a triggering factor for the extinction of Neandertals and the colonisation of Europe by Anatomically Modern Humans are contradictory due to uncertainties in the dating methods, in the cultural attribution of archaeological layers and to the lack of terrestrial continuous and well-dated palaeoclimatic sequences. This is particularly the case for the Iberian Peninsula where Neandertal populations seem to have survived later than in other regions of Europe. A review of the available palaeoclimatic evidence for OIS3 of Iberia reveals that this mainly consists of low resolution, fragmentary, ill-dated and often ill-interpreted records. Correlation between palaeoenvironmental sequences from two IMAGES pollen-rich deep sea cores and archaeological data from western Europe (the electronic archive of the radiocarbon dates is available at QSR website http://www.elsevier.nl/locate/quascirev) indicates that Aurignacian moderns colonised France and the north of Iberia at the onset of the H4 event. During this cold episode a probable contraction of Neandertal populations is recorded in southern Iberia where no Aurignacian settlements are detected. Such a decline in population density is correlated with the particular desert-steppe-like environments, made up of *Artemisia*, Chenopodiaceae and *Ephedra*, characterising the H4 of this area. While reducing the size of Neandertal populations, this inhospitable environment may have favoured their persistence in this region. Mainly exploiting herds of herbivores adapted to Graminees-rich grasslands, the Aurignacian moderns were probably not interested in colonising these arid Mediterranean biotopes, and did that only after the H4 event.

1. Introduction

Did climate play a role in the extinction of the Neandertals? A number of scenarios for the Middle/Upper Palaeolithic transition considers the replacement of Neandertals by Anatomically Modern Humans as being climatically driven or, at least, that climatic changes conditioned to some extent Neandertal/Modern interactions and the timing of the Middle/Upper Palaeolithic transition. Leroyer and Leroi-Gourhan (Leroyer and Leroi-Gourhan, 1983; Leroyer, 1988) were the first to create a scenario involving climate as a factor in the replacement of Neandertals by Moderns. They proposed that Aurignacian Modern populations colonised the South of France and the Cantabrian region coming from the East during a temperate phase that they called the Hengelo-Les Cottés interstadial and placed between ca 34,000 and 32,500 years BC (36–34.5 kyr BP), a time when the remainder of the French territory would have been still occupied by Châtelperronian Neandertals. During the following cold phase Neandertals would have coexisted in the south-west of France with Moderns, as suggested by the interstratifications of Aurignacian and Châtelperronian layers at the Roc de Combe and Le Piage sites (Bordes and Labrot, 1967; Demars and Hublin, 1989; Demars, 1990). By the end of this period Neandertals gradually retreated to the North and eventually became extinct. This happened just before a warm phase called the "Arcy interstadial", dated in Leroi-Gourhan scheme between 29,500 and 28,000 years BC (32.5–30 kyr BP). This scenario and, in particular, the hypothesis it implies of a long coexistence between the two populations in the Franco-Cantabrian region, has been used by a number of authors to suggest a slightly different population model, which has represented for more than a decade

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the dominant paradigm of the Middle/Upper Palaeolithic transition. The Châtelperronian and, by extension, other more or less contemporary industries such as the Ulluzzian of Italy, the Early Upper Palaeolithic of England, the Szeletian and the Bohunician of Central Europe would have developed after the arrival of Aurignacian Moderns in Western Europe and should be interpreted as the outcome of an acculturation of local Neandertals in regions in which the two groups lived, for a long time, side by side (Allsworth-Jones, 1986; Otte, 1988; Demars and Hublin, 1989; Harrold, 1989; Hublin, 1990; Kozlowski, 1990; Farizy, 1994; Bar-Yosef, 1996; Hublin et al., 1996; Mellars, 1998, 1999; Raposo, 2000). This hypothesis is based on the assumption that the earliest Aurignacian of northern Spain dates to ca 40,000 years ago. It has been recently argued, however, that such an early dating of the Aurignacian is not supported by the evidence (Zilhão and d'Errico, 1999). The reappraisal of the stratigraphy of these sites suggest that such a chronology is based on samples of dubious cultural meaning, either because they were collected in palimpsests containing other archaeological components or because the definition of the artefact suites as Aurignacian is not warranted. Wherever sample context is archaeologically secure, the earliest occurrences of the Aurignacian in western Europe date, according to these authors, to no more than ca 36,500–37,000 BP and developed later than the Châtelperronian and equivalent technocomplexes of central and eastern Europe.

According to Mellars, the strongest opponent of the Zilhao and d'Errico view, climate must have had a role in the Neandertal extinction (Mellars, 1992, 1996, p. 418–419): the dispersal across Europe of temperate-adapted Modern populations was favoured by the milder phases which punctuated OIS 3. The mixed deciduous/coniferous woodland characterising the Mediterranean zone of Europe during these phases probably provided the ideal penetration route for these populations, only requiring a limited "adaptation" on their part. The colonisation of the Mediterranean zone might have been even more rapid if the same ecological changes would have tended to cause the inverse shifts among Neandertals, destabilizing their ecological and cultural adaptations. This could have left certain habitats, along the Mediterranean coast, partially or entirely free of demographic competition. In a more recent paper Mellars tentatively identifies this warming as the temperate phase "which immediately follows the sharp glacial episode known as 'Heinrich event 3' (sic) in the deep sea core isotope record" and to which he attributes an age of ca 38,000–41,000 BP (Mellars, 1998, p. 497). For him this warm event may be correlated with the 'Hengelo interstadial' found in the palaeobotanical records of northern Europe. While facilitating the colonisation of most of Europe by Moderns, this warming would not have engendered a complete demise of the Neandertals. The two populations would coexist in France during the following five–six millennia and only a new climatic episode, cold this time, together with an increasing competition between the two groups, would have dealt the final *coup de grâce* to our predecessors. Mellars identifies this cold phase with the Heinrich event 4 (sic) (Mellars, 1998, pp. 502–503), that he places at around 33,000–34,000 BP.

Djindjian (1993, p. 151) proposes a still different picture: the Châtelperronian, the Ulluzzian and the other so called transitional technocomplexes must be interpreted as Neandertal local adaptations to the temperate environments which characterised the "Würm interstadial", a warming that he places between 43 and 34 kyr BP. At the end of this long interstadial the Aurignacian, seen as a cold adapted Modern culture, would have replaced those late Neandertal populations located above the 50° parallel (Lincombian, Ranisian, Jermanowician, Sztreletian) while those of Middle and Southern latitudes (Châtelperronian, Ulluzzian, Bohunician) would have lasted during the following cold phase, that he places between 34 and 31.5 kyr BP. Gioia (1990, p. 249) applies the logic of a Northern–Southern gradient to the emergence of the Ulluzzian in the Italian peninsula. Building on the supposed similarity of the so called Châtelperronian "knifes" and the Ulluzzian backed pieces (but see Kuhn and Bietti, 2000) she proposes that the Italian Ulluzzian may be interpreted as the result of a displacement of French Châtelperronian Neandertals pushed to the South by Aurignacian moderns invading the French territory and by the Neandertal search for milder conditions during the cold phase—ca 33–31.5 kyr BP—which would follow the "Würmian interstadial".

Another scenario is suggested by Laville and Marambat (1993). Correlation of radiocarbon dates with sedimentological and palynological analyses of cave sequences from the South-West of France suggested to them that the Châtelperronian appeared in this region at ca 35 kyr BP, at the end of the last of the three episodes that, according to Laville et al. (1985) would characterise the "Würm interstadial", dated to 45–35 kyr BP. This culture would have persisted during the following cold episode, which sees the arrival of the Aurignacian, as well as during the "Arcy" interstadial" (3031 kyr BP).

Climatic and ecological reasons have also been put forward to account for the apparent late survival (Zilhão, 1993; Hublin et al., 1995; Raposo, 1995; Bocquet-Appel and Demars, 2000) of Neandertal populations in the South of the Iberian Peninsula. Zilhão suggests Moderns might have stopped at the Ebro because during the interstadial, the regions to the south were significantly more wooded. Moderns would have become interested in these regions only when colder conditions began to compress the human range southwards into Iberia (Zilhão, 1995, 2000a, b). Burjachs and Julià (1996) suggest, on the basis of the Abric Romani pollen sequence, that the end of the Mousterian in northeastern Spain would be due to the expansion of North Europe ice cover during OIS 3 and that the Middle/Upper Palaeolithic transition occurred in this region at the end of the Hengelo interstadial, to which they attribute an age of 44 cal kyr BP.

According to Finlayson et al. (2000a, b), Finlayson and Giles Pacheco (2000), Finlayson et al. (2001) the entire question of the Neandertal extinction may be addressed from an ecological and palaeoclimatic perspective. As many other mammals, Neandertals were a mid-latitude species spreading northwards into the Great European Plain only during warm events, and, as a consequence of their adaptation, they were seriously affected by the climate deterioration of the OIS 4 and by the "moderately severe but highly variable conditions" at the end of OIS 3. Contrary to Neandertals, Moderns were able to exploit the high herbivore productivity of the open Eurasian environments through behavioural, rather than biological adaptation. The southern coastal areas of the Iberian Peninsula would have permitted an extended Neandertal survival for at least two reasons. The topographic heterogeneity of these areas offered a varied range of resources on which the opportunistic small range Neandertal subsistence strategies were based. And secondly because, as suggested by the anthracological and archaeozoological record from Gorham's and Vanguard caves (Barton et al., 1999; Finlayson and Giles Pacheco, 2000), these ecosystems were less or not affected by the rapid climatic oscillations of OIS 3. During much of this isotopic stage Neandertals would have lived, around Gibraltar, in open wooded savanna environments with a rich grass cover and a patchy shrub layer, the dominant components of the vegetation being typically thermo-mediterranean. With the colder conditions of the end of OIS 3 this open woodland would have been replaced by dense forests of Mediterranean mountain pine on the coast, and arid steppe vegetation in the inland. This climatic change would have deeply perturbated the Neandertal seasonal activities cycle at the point of producing the extinction of Southern Iberian Neandertals, an event which might have taken place even before the arrival of Modern competitors in these Southern regions.

How does the use of broadly similar and widely available evidence may lead to the creation of such a disparate variety of population models? Both Neandertals and Anatomically Moderns are seen, according to the chosen scenario, as basically cold or warm adapted populations and both warming or cooling events are invoked to account for the stasis, local development or expansion of the two human types. In fact, the reasons for which many of these scenarios look, at best, as viable hypotheses or, at worst, as post hoc accommodative arguments are not difficult to find. The chronological, palaeoclimatic, and archaeological record for the transition—not to speak of the anthropological record, which is not the main focus here—is ambiguous, and this for three main reasons: the limit of radiocarbon dating and calibration methods, the uncertainty in the cultural attribution of many archaeological layers, and the lack of continuous and well-dated, high-resolution palaeoclimatic sequences. One may also add to these reasons an uncritical use of the available evidence. Although putting some order in this heterogeneous "cloud of data" is since 1997 the main goal of the OIS 3 project (Davies et al., 2000; van Andel, 2002) only general syntheses of already available climatic data have been published so far by the members of this research group.

The general aim of the present paper is to evaluate the possible role of climate on the extinction of Neandertals and the timing of the colonisation of Western Europe by Anatomically Modern Humans. We will focus our attention on Iberia because this region seems to record the late survival of Neandertal populations and because this is the area which is providing, throughout the study of pollen rich deep sea cores, the best palaeoenvironemental data for the OIS 3.

2. Chronology

The potentiality but also the limitations, of radiometric dating for modelling Neandertal–Modern interaction during the OIS 3 have been the focus of several recent studies (Schwarcz, 1993; d'Errico et al., 1998; Djindjian, 1999; Hedges and Pettitt, 1999; Pettitt, 1999, 2000; Zilhão and d'Errico, 1999; Pettitt and Bailey, 2000; Zilhão, 2000a; Pettitt and Pike, 2001). These studies have cautioned that radiometric dating and in particular ^{14}C are not very effective methods to create reliable historical scenarios for the transition, and this for a number of reasons: (1) the large standard error which affects ^{14}C dates older than 30,000 BP, (2) the even larger standard error of ESR, TL and U–Th dates, making it difficult to compare these determinations with ^{14}C dates, (3) the large and not clearly identified fluctuations in the proportion of ^{14}C in the atmosphere during this period with the consequent absence—in spite of the valuable efforts made recently (Bard et al., 1998; Jöris and Weninger, 1998; Beck et al., 2001), of a reliable and unanimously accepted calibration method for ^{14}C dates older than 24,000 BP; (4) the potential large errors introduced in AMS ^{14}C dates by tiny proportion of modern contaminant, (5) the difference, more and more evident, between recently obtained AMS ^{14}C and old conventional ^{14}C dates, and between dates obtained on charcoal and on bone (Zilhão and d'Errico, 1999; Jöris et al., 2001; Sánchez Goñi et al., 2001). One may add to these problems the fluctuating criteria used to filter the datasets and to infer human palaeodemographics from ^{14}C dates. Bocquet-Appel and Demars (2000, p. 545), for example, regard as contaminated and eliminate a date when it is younger than one obtained from an overlying layer of the same site. They do not consider, however, that seeking the reason of such inversion might lead them to conclude that the age determination they have discarded was the only reliable date the site has provided. In a similar way, the members of the OIS 3 project have chosen, when more than one date is available for an archaeological layer (W. Davies pers. comm.), to use a mean of these dates. The danger of this option is, of course, to underestimate the time span during which the site was occupied or, worst, attribute this occupation to a period during which the site was in fact deserted. Another potential problem is the use of the amount of dates available for a given period to infer density of population. Davies (2001) discards Zilhão and d'Errico (1999) reappraisal of the chronology of putative old Aurignacian arguing that, since no less than 60 dates older than 36,500 BP are recorded for the Aurignacian, this demonstrates an early colonisation of Europe by Moderns. These dates, however, come from very few sites of controversial cultural attribution. The number of dates in itself is meaningless or misleading. An example of this misuse of dates is provided by Davies himself. This author uses frequency distributions of the Aurignacian dates to support the hypothesis of a two-phase dispersal model ("Pioneer" and "Developed" facies) of this technocomplex. However, the distributions of these dates is heavily influenced by the fact that some sites are overdated in comparison with others.

In sum, biased views on the chronology of the Middle/Upper Palaeolithic transition may be reached when population models, as is the case in most of the above mentioned scenarios, are built on few selected dates and by mixing up ages obtained with different dating methods (see Mellars (1999) for a good example of this procedure), or accepting all the available dates and cultural attribution at face value (Bocquet-Appel and Demars, 2000; Davies, 2001).

2.1. The "classical" chronoclimatic framework

Most of the above scenarios correlate cultural and climatic events by relying on a chronoclimatic framework based on the palynological and sedimentological analysis of cave deposits (e.g., Leroi-Gourhan and Leroi-Gourhan, 1964; Bastin et al., 1976; Leroi-Gourhan, 1989; Leroyer, 1990). While extracting environmental information from the very layers which keep a record of past human activities may be seen as the ideal approach to establish how climate affected cultural and biological changes, it has now become clear that archaeological sites are among the worst places where to identify climatic changes (Van Campo, 1976, Côuteaux, 1977; Bryant and Holloway, 1983; Turner, 1985; Turner and Hannon, 1988; Reille, 1990; Bryant and Hall, 1993; Sánchez Goñi, 1994a, 1996). It has also been shown that most of the interpretations leading to the creation of the "classical" chronoclimatic framework are questionable (de Beaulieu and Reille, 1984; Turner and Hannon, 1988; Sánchez Goñi, 1991, 1994a, 1996). Studies related to the transportation and taphonomy of pollen in archaeological sediment have shown (Bottema, 1975; Van Campo, 1976; Côuteaux, 1977; Hall, 1981; Bryant and Holloway, 1983; Turner, 1985; Coles et al., 1989; Sánchez Goñi, 1993, 1994a; Navarro Camacho et al., 2000) that pollen spectra from these sites must be submitted to critical analysis before they can be used to reconstruct the vegetation and, by extension, the climate of the past. The use of sedimentology for climatic reconstruction (e.g., Laville and Miskovsky, 1977; Fumanal and Dupré, 1983; Areso et al., 1990; Hoyos Gómez, 1994), a pillar of the classical chronoclimatic framework, has also been severely criticised (Colcutt, 1979; Farrand, 1982; Campy, 1990; Texier, 1990; Maroto, 1992; Campy and Chaline, 1993; Van Steijn et al., 1995) and will not be taken into account in the present study.

A re-examination of the pollen diagrams used to establish the so called Upper Palaeolithic Interstadials (Les Cottés, Arcy, Tursac, Laugerie, Lascaux, Angles-sur-l'Anglin, Pre-Bölling) in the light of taphonomic and actualistic criteria, has demonstrated that there is no ground to accept such warming episodes (Sánchez Goñi, 1991, 1993, 1994a, 1996). Pollen spectra from these diagrams lack the number of pollen grains and the floristic diversity necessary for ecological reconstruction and even when these conditions are fulfilled the interpretation of these spectra is not based on commonly accepted criteria from present day pollen rain studies. A good example of these biases is given by the "interstadials" which punctuate the Middle/Upper Palaeolithic transition.

The identification of the Les Cottés interstadial (Bastin et al., 1976) is based on two pollen spectra from an archaeologically sterile layer sandwiched between the Châtelperronian and Quina levels. By their high content and diversity of arboreal pollen, these two spectra reflect a forest formation developed during an interglacial rather than an interstadial. Therefore, they cannot be attributed to the last glacial period (OIS 4–2, 70–10 kyr ago). No radiocarbon dates come from this layer and those from the underlying Mousterian layer, regarded by Bastin and collaborators as reliable, are instead considered as minimum ages by the dating laboratory due to detected recent contaminations (Vogel and Waterbolk, 1967). Since these ages do not contradict the attribution of the pollen spectra to a warm phase within an interglacial complex, probably OIS 5, there is no ground to claim the existence of an interstadial from this evidence.

The Arcy interstadial (Leroi-Gourhan and Leroi-Gourhan, 1964; Leroi-Gourhan, 1989) was identified at the Grotte du Renne (Arcy-sur-Cure, Yonne) on the basis of three pollen spectra characterised by low arboreal pollen percentages (3–18%) dominated by *Pinus* (3–10%). Apart from *Fraxinus* (5% in one spectrum), none of the other arboreal taxa recorded (*Tilia, Carpinus, Quercus, Corylus)* attains 1%, the pollen of Poaceae (50%), Compositae (30%) being largely dominant. Studies on pollen rain (e.g., Ritchie et al., 1987) show that such spectra correspond to open vegetation formations related, during the Pleistocene, to cold and/or dry periods. The spectra attributed to the Arcy interstadial, moreover, do not represent a progressive succession of colonising species (*Juniperus*/*Betula*/*Pinus*) as is to be expected during a climatic amelioration in western Europe. In sum, there is no reason to accept the reality of this interstadial.

The Hengelo interstadial represents a special case. This warming episode was identified by Van der Hammen and collaborators (1967) in a peat layer from Netherlands, on the basis of several coherent pollen spectra dated to ca 37–40 kyr BP. These spectra clearly reflect the gradual afforestation—succession of *Juniperus*/*Betula*/*Pinus*—typical of northern European latitudes after a cold phase. This warming and its age seem well established. It is the identification of this episode in a number of palaeolithic sites (e.g., Leroi-Gourhan, 1971; Burjachs and Renault-Miskovsky, 1992) which is problematic for the same reasons discussed above for Arcy and Les Cottés. An additional problem is that the "archaeological version" of the Hengelo interstadial has been in some cases assimilated to the Les Cottés warming and called the "Hengelo-Les Cottés interstadial" (e.g., Renault-Miskovsky and Leroi-Gourhan, 1981; Dupré, 1988), while in other cases is considered by the same authors (e.g., Leroi-Gourhan, 1989) as an independent climatic event that would have preceded Les Cottés. Moreover, when treated as a single phase this warming is given an age of 36–35 kyr BP (Leroi-Gourhan, 1989), i.e., significantly younger than that obtained for the true Hengelo episode.

Does the rejection of these interstadials affect the above-described scenarios? Yes and no. Yes, in the sense that these climatic events cannot be used anymore as factors triggering cultural changes, migrations etc. No, since in most of these scenarios radiometric dating rather than climatic evidence has been used to correlate sites. Of course the rejection of the classical palaeoclimatic framework does not imply that climatic oscillations did not occur during this period and played a role in the transition. In order to check this we will first reappraise available palaeoenvironmental evidence from the Iberian Peninsula, the region which is the object of our attention here, and secondly will show the potential of data from deep sea cores collected off the Iberian margin to elaborate a new scenario for the transition.

3. Palynological evidence from the Iberian Peninsula during the OIS 3

Information on past plant communities for this time period (Fig. 1) is limited to pollen analysis from 10 archaeological sites (Lezetxiki, Otero, Morin, Valiña, Labeko, Romani, Arbreda, Carihuela, Beneito, Perneras) and two non-anthropic pollen sequences, one from the Banyoles lake and the other from the Padul peat-bog.

The level IIIa from Lezetxiki, containing a lithic assemblage attributed to the Aurignacian (Esparza, 1985), or to an admixture of Aurignacian and Mousterian (Baldeon, 1987), and with a ^{14}C date of 19,340 ± 780 BP (I-6114) only provides large amounts of fern spores and pollen of *Asteraceae* interpreted as the result of taphonomic processes (Sánchez Goñi, 1993).

Two warming phases were identified at Otero (Leroi-Gourhan, 1966) on the basis of pollen spectra from the Aurignacian and Mousterian levels 4–9. This is difficult to accept considering the very low percentages of arboreal pollen (1–8%) all over this sequence.

Two interstadials were also identified at Morin in the layers covering OIS 3 (Leroi-Gourhan, 1971). The spectra interpreted as suggesting the older warming, which come from layers with Mousterian, Châtelperronian and Aurignacian assemblages (levels 12–8), have a too low pollen content (a mean of 50 grains per sample) and idiosyncratic arboreal taxa (e.g., *Abies*, *Fagus*, *Tilia*) to support such an identification. Those representing the more recent interstadial, correlated to an Aurignacian I assemblage, might well reflect a temperate phase (40% of arboreal pollen with *Juniperus*, *Betula*, *Corylus*, *Quercus*). However, no ^{14}C date is available for this level.

At Valiña, Galicia, a lithic assemblage attributed by the excavators to the Châtelperronian and dated between 34,800 + 1900–1500 BP (GrN-17729) and 31,600 ± 250 BP (GrA-3014), but bearing no diagnostic tools, is associated to a single pollen spectrum dominated by arboreal pollen (*Pinus*, *Betula*, *Quercus*, *Corylus*, *Abies*) (Fernández Rodríguez et al., 1993). The presence of several *Abies* pollen grains is suspect since ongoing pollen analysis of marine core MD99-2331 (Sanchez Goñi, unpublished data), collected off Galician coast, only records this taxon during the Last Interglacial complex (130–70 kyr BP).

Two pollen analyses are available for the Labeko Koba (Sánchez Goñi, 1993, 1994b; Iriarte, 2000), a Basque site with a Châtelperronian level dated to 34,215 ± 1265 BP (Ua-3324) and four Aurignacian levels (VII–IV) dated to 31,455 ± 915 BP (Ua-3321, level VI), and 30,615 ± 820 BP (Ua-3322, level V). The first analysis (Sánchez Goñi, 1993) associated the level VII to a cold phase. The more recent study (Iriarte, 2000), attributes a single spectrum from the bottom of the

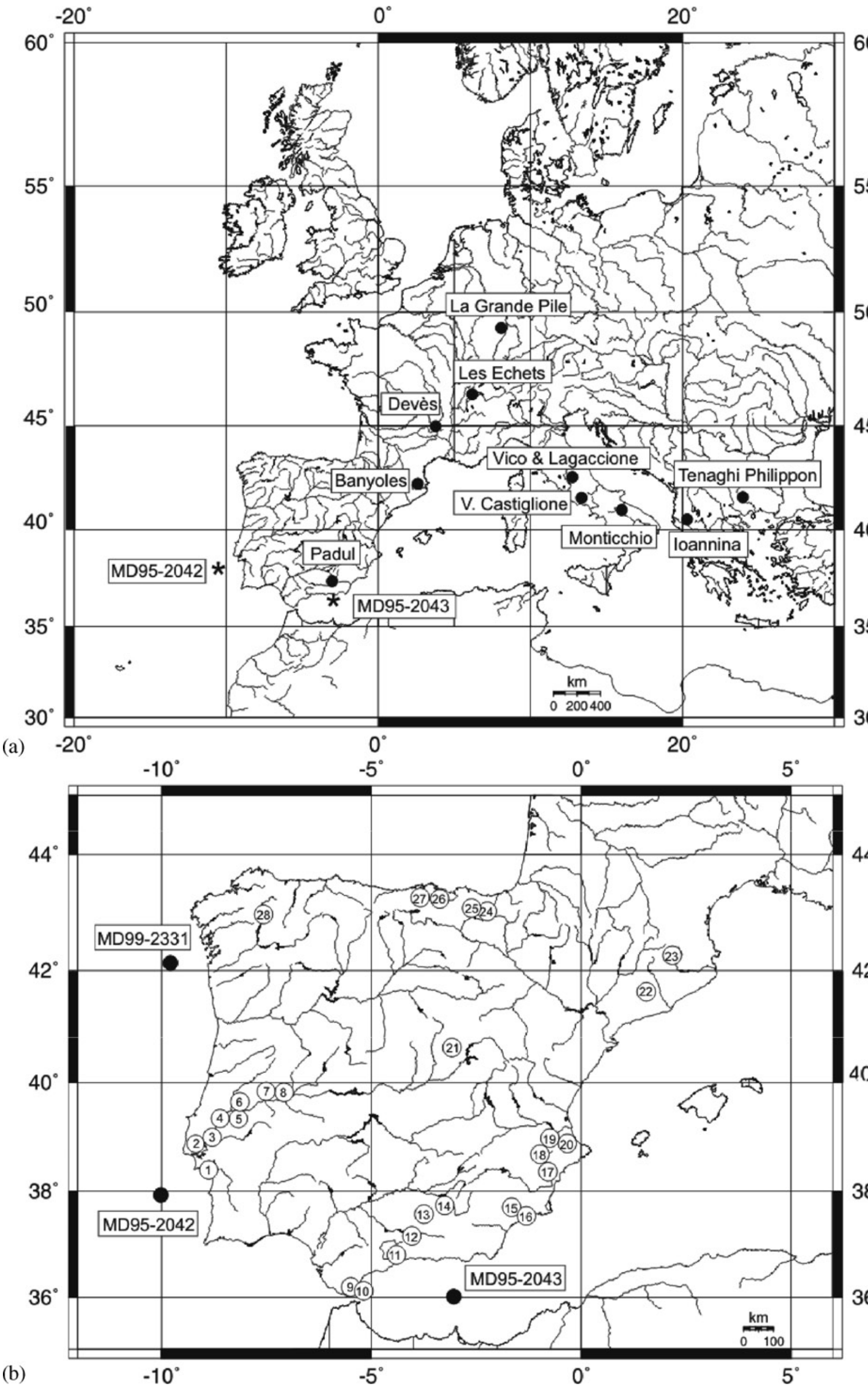

Fig. 1. (a) Location of the main European pollen sequences covering the OIS 3 and of the pollen rich deep sea cores mentioned in the text; (b) Mousterian and Aurignacian sites from the South of the Iberian Peninsula which have provided ^{14}C dates and Iberian sites with palynological analyses (*). 1: Gruta da Figueira Brava, 2: Pedreria do Salemas, 3: Pego do Diabo, 4: Gruta da Oliveira (Almonda), 5: Gruta do Caldeirão, 6: Lapa dos Furos, 7: Vila Ruivas, 8: Foz do Enxarrique, 9: Devil's Tower, 10: Gorham's Cave, 11: Bajondillo, 12: Zafarraya, 13: Cueva Horá, 14- Carihuela *, 15: Perneras *, 16: Palomarico, 17: El Salt, 18: Mallaetes, 19: Cova Negra, 20: Cova Beneito *, 21: Jarama VI, 22: Romaní *, 23: Arbreda *, 24: Labeko *, 25: Lezetxiki *, 26: Otero *, 27: Morín *, 28: Valiña *.

Châtelperronian level to a warming and two spectra at the top of this level to a cold phase while the scattered spectra available for the Aurignacian levels VII to V would reflect cold followed by milder conditions. In fact the single spectrum used to support the warming during the Châtelperronian is composed by 52 pollen grains with 4 from mesothermophyllous taxa, which is insufficient for making such a claim. The pollen spectra associated to the early Aurignacian confirms the Sánchez Goñi identification of a cold phase, those from the more recent Aurignacian may well indicate a relative warming, as suggested by Iriarte.

Three pollen zones are identified at the top of the Romaní pollen record (Burjachs and Julià, 1994), which covers the first part of OIS 3 (ca 60–40 kyr cal BP). The lower zone (60–50 kyr cal BP) is interpreted as a cold period ponctuated by short warm phases. The following zone (50–46 kyr cal BP), with a very low arboreal pollen content, reflects cold and dry conditions while the upper one (46–40 kyr cal BP) records a clear warming. Within this last phase the first Aurignacian appears, in levels dated by U–Th to 43.8 cal kyr BP and by AMS ^{14}C to between 23.16 and 37.9 kyr BP (but see warning in Zilhão and d'Errico 1999, p. 22).

At L'Arbreda, the first third of the sequence contains assemblages attributed to the Mousterian and the Aurignacian. They are dated to between 41,400 ± 1600 and 34,100 ± 750 BP, and between 39,900 ± 1300 and 22,590 ± 290 BP, respectively. According to the pollen analysts (Burjachs and Renault-Miskovsky, 1992) the Mousterian would correspond to a cold period, the ancient Aurignacian to a warming, and the evolved Aurignacian first to a cold phase and subsequently to a new warming. However, the pollen spectra do not significantly differ from each other, all being dominated by herbaceous plants (> 80%) such as *Artemisia*, Poaceae and Asteraceae. And the sporadic occurrence of mesophillous trees equally concern the phases the authors interpret as warmings and those described as coolings (see discussion in Sánchez Goñi, 1999). We favour a more parsimonious interpretation for these spectra which consider them as the reflexion of a unique cold episode.

The pollen diagram from Perneras (Carrión et al., 1999) reveals temperate conditions associated to an undated Quina Mousterian followed by a possible climatic deterioration associated to an equally undated and probably late Aurignacian.

According to Carrion and others (1999) the Carihuela sequence provides, in spite of some hiatuses, an almost continuous record of the vegetational changes occurring in South-eastern Iberia during the last climatic cycle. The synthetic pollen diagram from this Mousterian site would register interglacial conditions in layers dated by U–Th to ca 117,000 BP followed by a "pre-Würmian" phase characterised by episodic forest regressions and two "Pleniglacial maxima" interrupted by an "inter-Pleniglacial" episode, beginning at ca 45,200 yr BP. The upper part of the diagram, correlated to the Lateglacial, would record several short stages of *Quercus* colonisation, one of them at ca. 12,320 BP, and the Younger Dryas. We believe that this interpretation does not take into due account the uncertainties inherent to the stratigraphy and the chronology of this site. The synthetic diagram on which the authors rely to build their climatic reconstruction is in fact a juxtaposition of spectra obtained from seven independent sections located in three different chambers of the cave. The stratigraphic correlation is based on a presumed lithological similarity between layers from these sections and on the faunal content of the layers (Vega Toscano, 1988). However, there is no straightforward resemblance between these sections (Carrión 1992, p. 40) and their faunal content cannot be used as unambiguous stratigraphic marker as the same species re-occur all along the different sections. The available radiometric dating consists of 20 TL dates coming from three sections and ranging between 13,400 ± 600 and 82,500 ± 4900. Unfortunately these dates, obtained in the early 1970s, do not help the chronological attribution of the layers as the stratigraphic provenance of the dated burnt flints is lost (Carrión et al., 1998). The unreliability of the stratigraphic correlation is further demonstrated by the fact that the position of the pollen diagrams in the sequence changes from one publication to another migrating up and down according to new radiometric datings. This is the case for the spectra from CIII AE-section 3. Inserted by Carrión (1992) in the middle of the sequence and interpreted as indicating the "Würmian interstadial of 40,000 and 34,000 BP" these spectra have been moved to the base of the sequence to indicate interglacial conditions once a U–Th date of 117,000 ± 41,000 BP for the top of this section was obtained. The two new ^{14}C AMS dates of 45,200 ± 1270 and 12,300 ± 60 BP, each coming from a different section, are clearly insufficient to establish a reliable correlation between the sections making up this 7 m long composite sequence. Carrión's claim that the pollen spectra associated with the former date identify an "inter-Pleniglacial episode beginning at ca 45,200 yr BP", should also be taken with caution. The spectra presented in the synthetic diagram (Carrión et al., 1999, p. 1063) as contemporaneous of this date do not come from the section where the dated sample was collected, and those associated to this sample, omitted in the diagram, reflect, in clear contradiction with the authors interpretation, cold and dry conditions rather than a warming. The authors justify the discarding of these cold spectra by interpreting them as the result of a percolation. One can wonder, however, why this taphonomic process should only be at work in this particular layer. And even if one accepts as correct the stratigraphic correlation between sections and the resulting last published synthetic pollen diagram, it is hard to accept the alternation of warm and cold phases proposed by the authors for the Pleniglacial. In particular, no significant differences exist between the putative cold phase that the authors situate before 45,000 and the two "warmings" which precede and follow it.

The pollen analysis from Beneito (Carrión, 1992; Iturbe et al., 1993; Carrión and Munuera, 1997) gives rise to similar criticisms. This cave site has yielded two

Mousterian layers overlied by three Aurignacian, one Gravettian and two Solutrean layers. AMS provides a date of 38,800 ± 190 BP (AA 1387) for the top of the Mousterian (level X) and of 33,900 ± 110 BP (AA 1388) for the first Aurignacian (level IX) while conventional ^{14}C gives for the same layers dates of 30,160 ± 680 BP and 26,040 ± 890 BP (Gif 7650), respectively. Pollen spectra from the lower Mousterian indicate an open *Pinus* forest replaced in the Upper Mousterian by a *Quercus* forest with Mediterranean shrubs. In contrast, the pollen content of the Aurignacian and the remaining Upper Palaeolithic levels reflects a steppe-like vegetation. The authors consider the *Quercus* forest as the vegetational outcome of the "inter-Pleniglacial" warming and concludes that the identification of this temperate phase, that he situates just before 38,000 BP, confirms the finding of the same phase at Carihuela. The main problem with this interpretation is that the ^{14}C date of 38,000 BP comes in fact from the middle of a 50 cm thick layer—level X, corresponding to the top of the Mousterian—which contains no pollen. This means that there is no ground, as with Carihuela before obtaining the U–Th date, to attribute this warming to a period at around 40,000 BP and, as a consequence, the *Quercus* forest and the associated Mousterian might well be of Interglacial age. This inconsistency is difficult to realise from the published evidence because, unlike the other pollen hiatus found in the sequence (level VIIb), that of level X is curiously omitted in the pollen diagrams (Iturbe et al., 1993, p. 33; Carrión and Munuera, 1997, p. 293) and the position of the dated sample, which comes in fact from the middle of level X (Iturbe et al., 1993, p. 82), is omitted in the diagrams and located by the pollen analyst at the interface between level IX and X in one stratigraphic sketch (Carrión and Munuera, 1997, p. 290) and at the bottom of level IX (Carrión and Munuera, 1997, p. 294) in another.

The non-anthropic pollen sequences of Banyoles (Pérez-Obiol and Julià, 1994) and Padul (Pons and Reille, 1988) only give vague palaeoclimatic information for the period at hand. Banyoles only spans from the very end of OIS 3 (28,000 BP) to the present. OIS 3 is represented at Padul by 2.6 m of sediment, 15 spectra, and two ^{14}C dates of 31,600 ± 1300 BP (Gif 5400) and $> 38,400$ BP (Gif 5387). Characterised by low percentages of arboreal pollen with *Juniperus* as the more represented species, these spectra reflect cold conditions. However, the low resolution of this analysis and the uncertain chronology of these spectra make it difficult, as the authors of the analysis admit, to use them to identify particular climatic changes.

The above review clearly shows that the available palaeoclimatic evidence for OIS 3 of Iberia consists of few, low resolution, fragmentary, ill-dated, and often ill-interpreted sequences. It would be of little help to try and overcome this situation by relying on syntheses of palaeoenvironmental data for Europe (van Andel and Tzedakis, 1996; Davies et al., 2000). Since almost all continental sequences from other regions show most of the drawbacks described above for Iberia, the pictures provided by these syntheses appear as too general and speculative to model climate—human interaction during OIS 3. Therefore, we need to abandon land sequences and look elsewhere for a more reliable climatic record before we try and correlate climatic succession and archaeological evidence.

3.1. The millennial-scale climatic varibility

Three climatic archives: deep-sea deposits, ice caps and continuous terrestrial sediments, have been searched in the last three decades to produce a detailed reconstruction of the past climatic variability. Analysis of climatic proxies from ice and marine cores has recently shown that OIS 3 (60–25 kyr BP) includes 30 climatic phases resulting in temperature changes over Greenland and in the ocean surface waters (Dansgaard et al., 1993). These studies indicate that each of these climatic phases lasted for between 500–2000 years and that the shift between cold and warm phases was more rapid than previously thought, probably less than 100 years, and produced a change of around 10°C temperature in the atmosphere above Greenland (Johnsen et al., 1992). Cold and warm phases are called Dansgaard-Oeschger stadials and interstadials, respectively. Some of the cold stadials, contemporaneous with the arrival of armada of icebergs in the North Atlantic ocean (Heinrich, 1988), are called Heinrich events (Bond et al., 1993). Until very recently, there was very limited information on the possible impact of these climatic changes on the European continent.

Few climatic oscillations are recorded over the OIS 3 at Padul, Lac de Bouchet, Les Echets and La Grande Pile (de Beaulieu and Reille, 1984; Pons and Reille, 1988; Pons et al., 1992).

More recently, correlation of palynological analyses from Valle di Castiglione, Lagaccione, Vico and Stracciacappa sequences, Lazio region, identified (Follieri et al., 1998; Magri, 1999; Magri and Sadori, 1999) seven main fluctuations of trees during the Pleniglacial (ca 74–14 kyr BP). In turn, twelve climatic phases are recognised between 60 and 26 cal kyr by Allen (Allen et al., 1999) at Lago di Monticchio, Southern Italy. In Greece, pollen records from Ioannina (I-284), Kopais and Lesvos, Greece (Tzedakis, 1999; Tzedakis et al., 2002) show distinct shifts between open vegetation and forest periods, and reveals the presence of high-frequency, probably millennial, climatic oscillations. However, while it appears from this evidence that Southern Europe was submitted during the OIS 3 to an alternation of climatic fluctuations, it remains difficult to correlate specific fluctuations as identified in each of these terrestrial sequences with particular Dansgaard-Oeschger climatic oscillations such as Heinrich events 3–6. The uncertainty of this matching makes also difficult to establish whether Dansgaard-Oeschger stadials were in phase with terrestrial cooling. Paterne et al. (1999) have for example proposed that the cooling in the sea surface temperatures during the Heinrich events was associated with warm and wet conditions in the Mediterranean region.

The problem of the correlation between marine and terrestrial records is now circumvented by pollen analyses from deep-sea cores. Pollen changes in these records can be compared directly and in situ with marine proxies, a luxury unknown to terrestrial sequences.

We know now from these analyses (Sánchez Goñi et al., 2000, 2002) that each of the Dansgaard-Oeschger climatic phases did have an impact on the continent, and that the cold marine and Greenland oscillations were in phase with dry and cold conditions in south-western Europe. Marine pollen assemblages reflect an integrated image of the regional vegetation (Turon, 1984). They mask local vegetation changes, enhancing the changes that are significant at a regional scale and likely represent the direct outcome of climatic shifts.

The new data from these records have obvious implications for models seeking climate as a possible factor in the replacement of Neandertals by Anatomically Modern Humans and particularly on the last phase of this process which, on the basis of the available evidence, took place in Southern Iberia.

3.2. Pollen sequences from deep-sea cores

Two new high-resolution palaeoclimatic records, one from a core collected in the Alboran sea (MD95-2043, 36°8′N, 2°37′W) and another from a core retrieved off Lisbon (MD95-2042, 37°48′N, 10°10′W) cover the last climatic cycle (Cacho et al., 1999; Sánchez Goñi et al., 1999; Shackleton et al., 2000; Thouveny et al., 2000; Pailler and Bard, 2002) (Fig. 1). The chronology of the first core is based on 21 ^{14}C AMS dates and the identification of three isotopic events (Cacho et al., 1999). The age model of the second core, confirmed by ongoing AMS dating (N. Shackleton, pers. com.), is based on the wiggle-matching of the plancktonic isotopic curve with that of GRIP-GISP2 (Shackleton et al., 2000). The study of the marine climatic proxies (foraminifera, ice rafted detritus, alkenons, dinocysts, and isotopes), preserved in these cores, perfectly identifies the millennial scale climatic variability of OIS3 (i.e., Dansgaard-Oeschger oscillations). The Heinrich events 5, 4 and 3 are identified in the Atlantic core by the ice rafted detritus and the peaks of polar foraminifera. In the Mediterranean core these three events are detected by the polar foraminifera and dated at between 46.5–45.4, 40–38.5, and 31–29 cal kyr BP, respectively.

Pollen analysis of these two sequences (Sánchez Goñi et al., 2000, 2002) provides a detailed picture of the climatic and vegetational changes of Southern Iberia for the period between 48 and 26 kyr BP (Fig. 2). The direct correlation of land and marine environmental changes allows measuring the impact of each Dansgaard-Oeschger oscillation and Heinrich event on the Iberian landscape.

Both pollen sequences identify on land 19–20 climatic phases which remarkably parallel the Dansgaard-Oeschger stadials and interstadials. We know now that the continental response to global climatic changes was rapid ($\sim$150 years) and synchronous with sea surface temperature fluctuations. The cold/dry phases result in the development of desert-steppe vegetation dominated by *Artemisia*, Chenopodiacae and *Ephedra* with a minor contribution of Poaceae while the mild/wet periods are related with an open *Pinus*- deciduous *Quercus* forest with Mediterranean trees and shrubs such as evergreen *Quercus*, *Olea* and *Pistacia*.

Poaceae are detected in both marine sequences at lower percentages (ca 10%) than at Padul (ca 50%). It is probable that the abundance of grasses in this terrestrial sequence reflects the edaphic dominant local vegetation rather than the importance of grasslands at a regional scale. At present Poaceae, and in particular *Nardo-Festucetum* communities, colonise the surroundings of lakes, lakelets, streams and glacial depressions of the Sierra Nevada mountains (Martinez-Parras and Peinado Lorca, 1987). Now located between 2000 and 2900 m, these grasslands certainly developed at lower altitude during the last glacial period colonising the surroundings of Padul depression, located at 800 m a.s.l.

During the cold phases atmospheric and marine influence inhibited the development of woodlands and drastically reduced plant and animal resources typical of the Mediterranean regions. Small pockets of trees certainly survived in the middle and low altitudes of inner valleys as suggested by the continuous record of tree species. While producing a rapid spread of the meso-thermophillous taxa confined in these refugia the successive warmings were not of enough amplitude to develop the dense Mediterranean forest recorded in this area at the onset of the Holocene (Pons and Reille, 1988; Lézine and Denèfle, 1997). During the Heinrich events, annual precipitation, as reconstructed by transfer function technique based on modern analogues (Guiot and Goeury, 1996; Peyron et al., 1998), are estimated 400 mm below present values, and winter temperature ranges between 6° and 13° below present figures. Summer temperature of the sea was around 10°C, that is 10°C less than today (Cacho et al., 1999). During these cold events, Iberia was certainly subject to strong winds from north–north west and south as suggested by grain-size sediment study and geochemical analysis of the Mediterranean core (Moreno et al., 2002). In contrast, temperate phases show annual precipitations

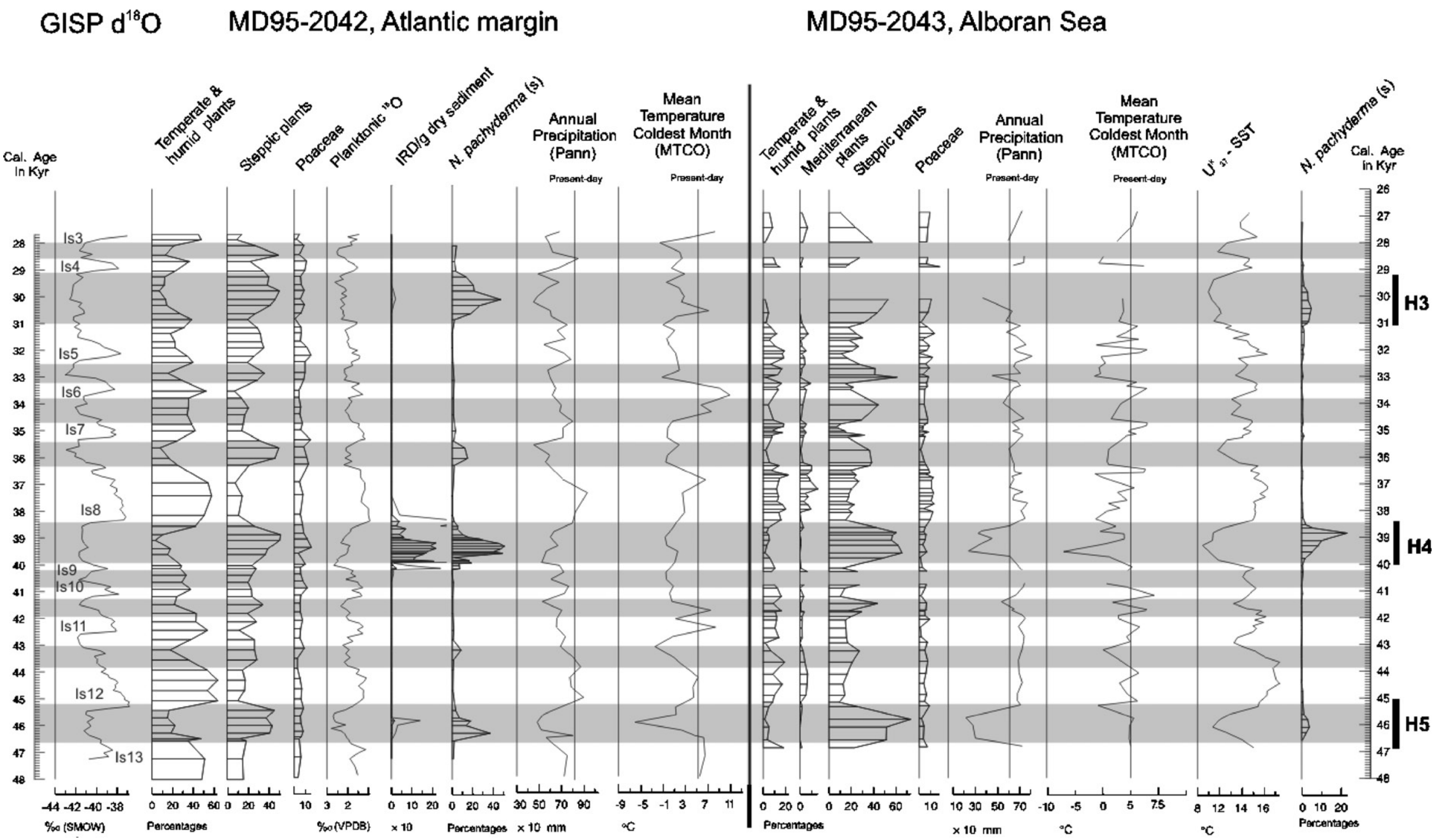

Fig. 2. Palaeoclimatic records from the Iberian margin cores MD95-2042 and MD95-2043 and their comparison with the GISP2 δ^{18}O curve. The curves of the Ice Rafted Detritus (IRD) and of the polar foraminifera *N. pachyderma* (s) of core MD95-2042 are established on the basis of the new high-resolution analysis of these proxies and differ for this reason from those published in (Sánchez Goñi et al., 2000) and (Sánchez Goñi et al., 2002). Gray intervals indicate Heinrich events (H5, H4 and H3) and the other Dansgaard-Oeschger stadials.

(~600–800 mm) and winter temperatures (~5–10°C) which do not significantly differ from present values.

Heinrich events and Dansgaard-Oeschger stadials have similar impact on the Atlantic side of southern Iberia while on the Mediterranean side the former appear colder and much drier, resulting in even more widespread desert-steppe formations. The main difference detected in the pollen diagrams between the Atlantic and the Mediterranean sides of Iberia concerns the proportion of plants characteristic of different ecological groups. *Ericaceae* (heather) are better represented in the Atlantic side while desert-steppe and Mediterranean plants show higher percentages in the Mediterranean region. This is due to a precipitation gradient similar to that seen today between the wetter Atlantic coast and the more arid Mediterranean side.

It is now clear that the Dansgaard-Oeschger climatic variability is a global phenomenon (Voelker, and workshop participants, 2002) which produced, in this region, an alternation of semi-desert vegetation and open Mediterranean forest. Thus, evidence from pollen-rich deep-sea cores directly challenges the hypothesis that there were no, or very little changes in the Mediterranean region during the cold phases of OIS 3. These abrupt environmental shifts must have influenced settlement patterns, subsistence strategies and the demography both of the late Neandertal populations of the Southern Iberia and those of the first Modern groups colonising this region.

4. Last Glacial millennial-scale climatic variability and the Middle–Upper Palaeolithic transition

Did these rapid environmental changes play a role in the extinction of the Neandertals and the timing of the transition? In order to correlate archaeological and palaeoenvironment records, we have created an archaeological database including 5206 dates from 1169 sites which cover the Middle and the Upper Palaeolithic as well as the Mesolithic of Europe. This is based on the screening of the archaeological literature, the critical comparison of published and unpublished databanks available in the literature (e.g., Hedges et al., 1998; Evin et al., 1999; Zilhão and d'Errico, 1999) or communicated to us by colleagues (J. Zilhão; M. Street) and research institutions (University of Liège; ^{14}C laboratory of Lyon and Oxford; INQUA-University of Leuven, OIS 3 project-Cambridge, Monrepos-CALPAL). We have also integrated in this database a number of unpublished dates from Iberian sites (J. Baena, M. Cortes, pers. com.). A selected database including all the available ^{14}C dates from Mousterian, Châtelperronian and Aurignacian sites located in France and Iberia was created. This consists of 321 conventional ^{14}C and 118 AMS dates (Fig. 3). The electronic archive of the radiocarbon dates is available at QSR website (http://www.elsevier.nl/locate/quascirev).

To avoid possible errors due to the uncertainties inherent to available calibration methods, we created an uncalibrated age model for MD95-2042 based on the AMS ^{14}C dating of the upper and lower limits of the H3 and H4 events as established for a number of North Atlantic marine cores (Elliot et al., 1998, 2002) and the commonly accepted average age for the H5 (Auffret et al., 2002). According to this age model, the Heinrich 4 event took place between 35.3 and 33.9 kyr BP, the H3 between 28–26 kyr BP and the H5 events at ca 45.5 kyr BP.

In order to evaluate the time-span and, to some extent, the population density of each technocomplex involved the Middle–Upper Palaeolithic transition we elaborated histograms presenting the frequency distribution of dated sites per millennium. In these histograms each site with one or more dates from the layers attributed to a given technocomplex and falling within a given millennium counts for one unit. This eliminates the bias introduced by the use of a mean value, when several dates are available for one or several layers attributed to a technocomplex. Also, it partially overcomes the problem of the difference in the number of dates available per site.

We will focus first on the French record as the archaeological sites from this region do not present the problems of cultural attribution which characterise a number of Iberian assemblages.

The comparison between the ^{14}C conventional and AMS dates for the transition reveals a significant gap between the frequency distribution of the sites dated by the two techniques (Fig. 3). This is particularly evident in France, where AMS dates for the Mousterian are older than 35 kyr BP while those obtained by conventional ^{14}C cover a much wider time span. Similarly, the maxima of the Aurignacian sites dated by AMS (35–34 kyr BP) antedates by least 2000 years the maxima of those dated by conventional ^{14}C. Also the conventional ^{14}C dates for this culture go at least up to 20 kyr BP, i.e., 7000 years later than the more recent dates obtained by AMS. Stratigraphic evidence demonstrates that conventional ^{14}C dates underestimate the true ^{14}C age of the French Mousterian and Aurignacian, and that only AMS dates ought to be taken into account when it comes to attribute chronologically the sites of the Middle/Upper Palaeolithic transition. As observed by Zilhão and d'Errico (1999), conventional ^{14}C dates for the Mousterian would indicate a long contemporaneity with the Aurignacian, and we might then expect to find Mousterian levels overlying Aurignacian levels, which is never the case. Also, we know that the oldest securely dated Gravettian, which stratigraphically always follows the Aurignacian, is AMS dated to ca 28 kyr. This clearly contradicts the hypothesis that the Aurignacian sites to which conventional ^{14}C gives an age younger than

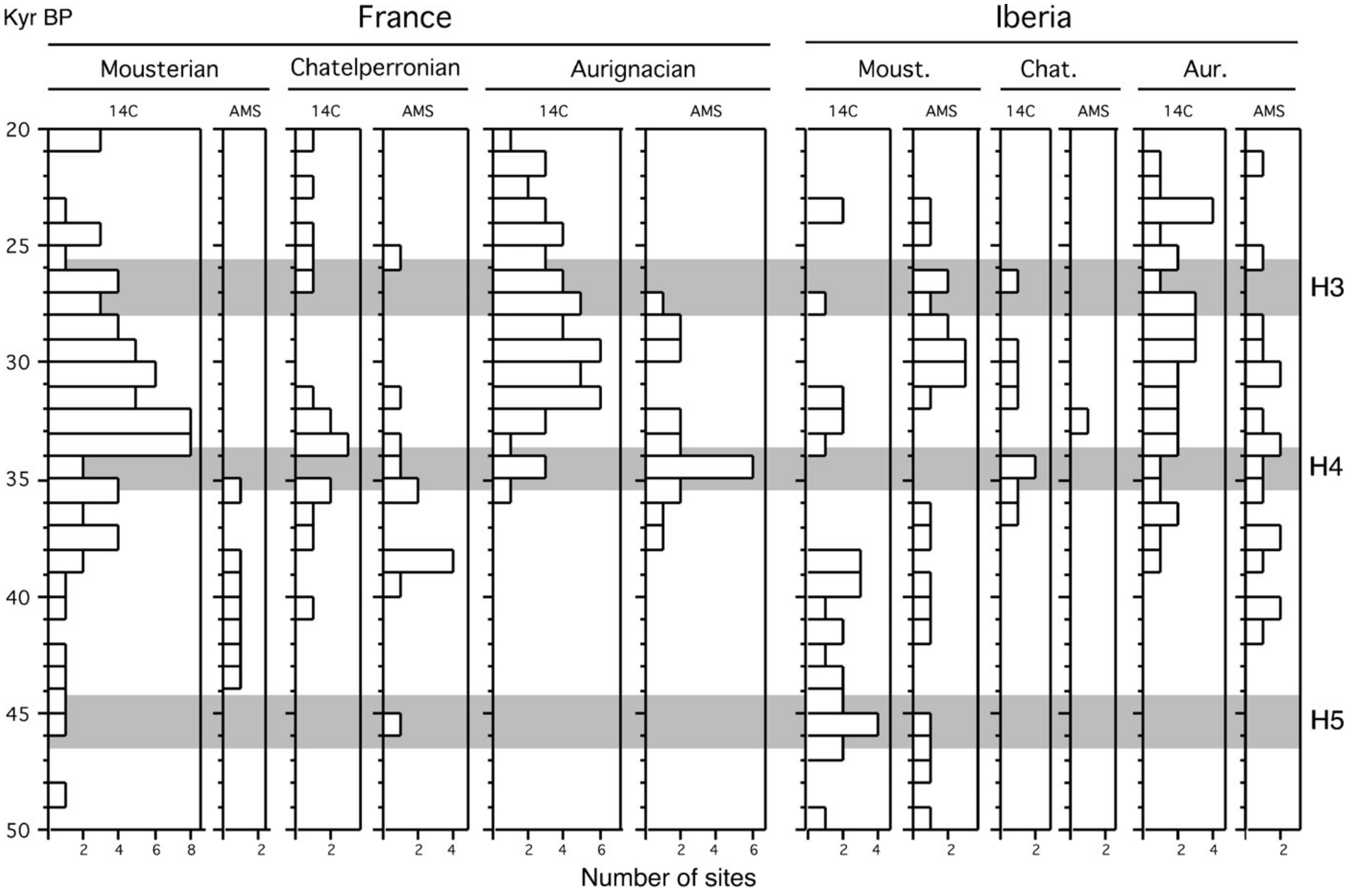

Fig. 3. Frequency distribution of Mousterian, Châtelperronian and Aurignacian dated sites per millennium from France and Iberia.

27 kyr BP may represent a "persistence" of this culture synchronous with the Gravettian and the late Mousterian. Since such long contemporaneities are untenable, the error must lie in the dating. In fact most of conventional ^{14}C dates indicating young ages were produced long ago, often from collagen extracted from several bones, and at a time when modern techniques of pre-treatment against contamination were not available. This is confirmed by recently obtained conventional ^{14}C dates which tend to match more closely the AMS results.

In the light of the above discussion, the comparison between the palaeoenvironmental record and the ^{14}C dates for the French Aurignacian reveals that the beginning of this culture coincides in this region with the onset of the H4 event. Apart from an unreliable date of 40 kyr for the Aurignacian of the Grotte du Renne, certainly the worst site to date the transition (d'Errico et al., 1998; Zilhão and d'Errico, 1999) and one from Caminade, which probably dates the top of the more recent Mousterian level of this site (Bordes, 1998), very few AMS dates for the French Aurignacian are older than 35.3 kyr BP and, considering their sigma, they may well indicate ages which fall within the time span of this climatic event. Due to the limits of the ^{14}C dating for both the archaeological and the palaeoclimatic records (large standard deviation, differences between dated samples, variation in the reservoir ages etc.) it is problematic to establish whether the arrival of the Aurignacian in France took place during the temperate phases (Is 9–10) immediately preceding the H4 or at the very beginning of this cooling. Whatever the case, the height of the Aurignacian certainly took place in Western Europe during this rigorous episode as indicated by the peak of Aurignacian sites AMS dated between 35 and 34 kyr BP. This culture also persisted during the following temperate (i.e., Is 5–8 *sensu* GRIP-GISP2) and cold/dry episodes preceding the H3 (Fig. 3) when is replaced by the Gravettian.

The widespread distribution of conventional and AMS ^{14}C dates for the Châtelperronian and the relatively low number of dates available make it difficult to propose a reliable chronology for this culture and to correlate it to one or more climatic phases of the OIS3. Moreover, the apparent overlapping of Châtelperronian and Aurignacian dates is partially due to the different nature of the dated material. The available dates for the Châtelperronian are exclusively made on bone while those for the Aurignacian on bone and charcoal, and we know (Zilhão and d'Errico, 1999; Jöris et al., 2001) that for the period at hand ^{14}C dates on bone are often younger than those on charcoal. This results in a probable underestimation of the age of the Châtelperronian. If we discard the few dates which are clearly too young, the ^{14}C dates for this culture are perfectly consistent with its precedence over the Aurignacian as indicated by the stratigraphy of the sites preserving remains of both technocomplexes (d'Errico et al., 1998; Zilhão and d'Errico, 1999) and the recent reappraisal of the instances of interstratification (Bordes, 2001). If a short overlap between the two technocomplexes did occur, which is difficult to affirm on the basis of the available evidence, it probably took place just before or within the first part of the H4 event. AMS dates also indicate that the Mousterian immediately precedes or slightly overlap the Châtelperronian. Although the available AMS dates situate the French Mousterian between the H4 and H5 events it is difficult to say whether these dates chronologically attribute the more recent Mousterian or should just be considered as minimum ages.

An uncritical analysis of the dates for the Aurignacian of the Iberian Peninsula (Figs. 3 and 4) would conclude that this culture was present in this region well before it was in France as few sites have provided a consistent number of AMS dates ranging between 41 and 37 kyr BP. All these dates, however, come from layers of controversial cultural attribution (Castillo, Arbreda, Reclau Viver) or in which the association between the dated samples and the Aurignacian material is uncertain (Zilhão and d'Errico, 1999). The presence of an old Aurignacian in the North of Iberia, where these sites are located, seems contradicted by the fact that, if one agrees with the commonly accepted hypothesis of an Eastern origin of the Aurignacian, no contemporaneous or older traces of the passage of this population are found in France and Italy, the regions that the Aurignacian must have crossed to reach Iberia. These old dates would best fit the hypothesis of an autonomous development of the Aurignacian in the North of Iberia. However, no evidence, apart from the unconvincing "Proto-Aurignacian" character of the Castillo Level 18 assemblage, supports this scenario either.

If we discard these controversial dates, as Zilhão and d'Errico (1999) propose, the oldest Aurignacian of the Iberia is found in the North of the peninsula and dated at no more than 36,500 BP, i.e., the same age of the oldest Aurignacian in France. Thus in the North of Spain the beginning of the Aurignacian also coincides with the onset of the H4 event. In contrast, and as already noticed by several authors (Vega Toscano, 1990; Zilhão, 1993) no Aurignacian older than 33.5 kyr BP, is found south of the so called "Ebro frontier".

The Iberian Mousterian in turn shows two concentrations of dates, the younger of which is absent in the French record, separated by a previously undetected hiatus (Fig. 5). Interestingly this hiatus coincides with the H4 event.

Two hypotheses may account for this pattern. The first is that it might just result from the relatively reduced number of ^{14}C dates available for the Mousterian and the Aurignacian of Southern Iberia. The second hypothesis is that this pattern reflects somehow the population density of this area during the H4 event. The first hypothesis is contradicted, as far as the Mousterian is concerned, by the fact that, all over Europe, no Mousterian sites are AMS dated to the H4 event (Sánchez Goñi et al., 2001). This suggests that this period corresponded, and not only in Iberia, to a significant reduction in the size if not to the final extinction of Neandertal populations. If, as suggested by available evidence, the Aurignacian did not colonise the South of Iberia before 33.5 kyr BP, this implies that during the H4, this area was characterised at once by a very low density of Neandertal populations and by the virtual absence of modern humans. More than a cultural barrier this frontier would, in this case, indicates a time span in which both Neandertal and Modern populations found difficult to develop subsistence strategies adapted to the Southern Iberia environments.

In fact a main difference existed between these Mediterranean environments and those of the Franco-Cantabrian region during the H4 event (Fig. 5). Work in progress in a core (MD99-2331) collected off the Galician coast (Fig. 1) indicates that a mixture of heath and grasslands communities (Ericaceae, *Calluna*, Poaceae, Asteraceae, *Helianthemum*, Cyperaceae, Plumbaginaceae) made up the vegetation of the Franco-Cantabrian region during the H4 event. In contrast, the formations colonising the south of the peninsula were mainly composed, as we saw above, by *Artemisia*, Chenopodiaceae, *Ephedra* and small refugia of Mediterranean trees and shrubs. It is known (Gauquelin et al., 1998) that each type of steppe formation is characterised by a different phytomass (Fig. 6). Steppes dominated by Poaceae such as *Stipa* and *Festuca* the dry grassland typical of Central European and Pannonic plains (Polunin and Walters, 1985), have a high above- and below ground carbon storage while those mainly composed by *Artemisia* and Chenopodiaeae store a very low amount of carbon. The amount of phytomass determines the biomass of a steppic region and, as far as prehistoric subsistence strategies are concerned, the type and amount of mammals available to the hunters (Ramade, 1984; Griggo, 1995; Delpech, 1999).

Our results suggest that during the cold phases of OIS 3 the northern Iberian grasslands were able to feed large mammals adapted to cold conditions while the southern Iberian desert-steppe were probably unable to fulfil this role. In other words, available evidence supports the scenario that the late arrival of the Aurignacian in the

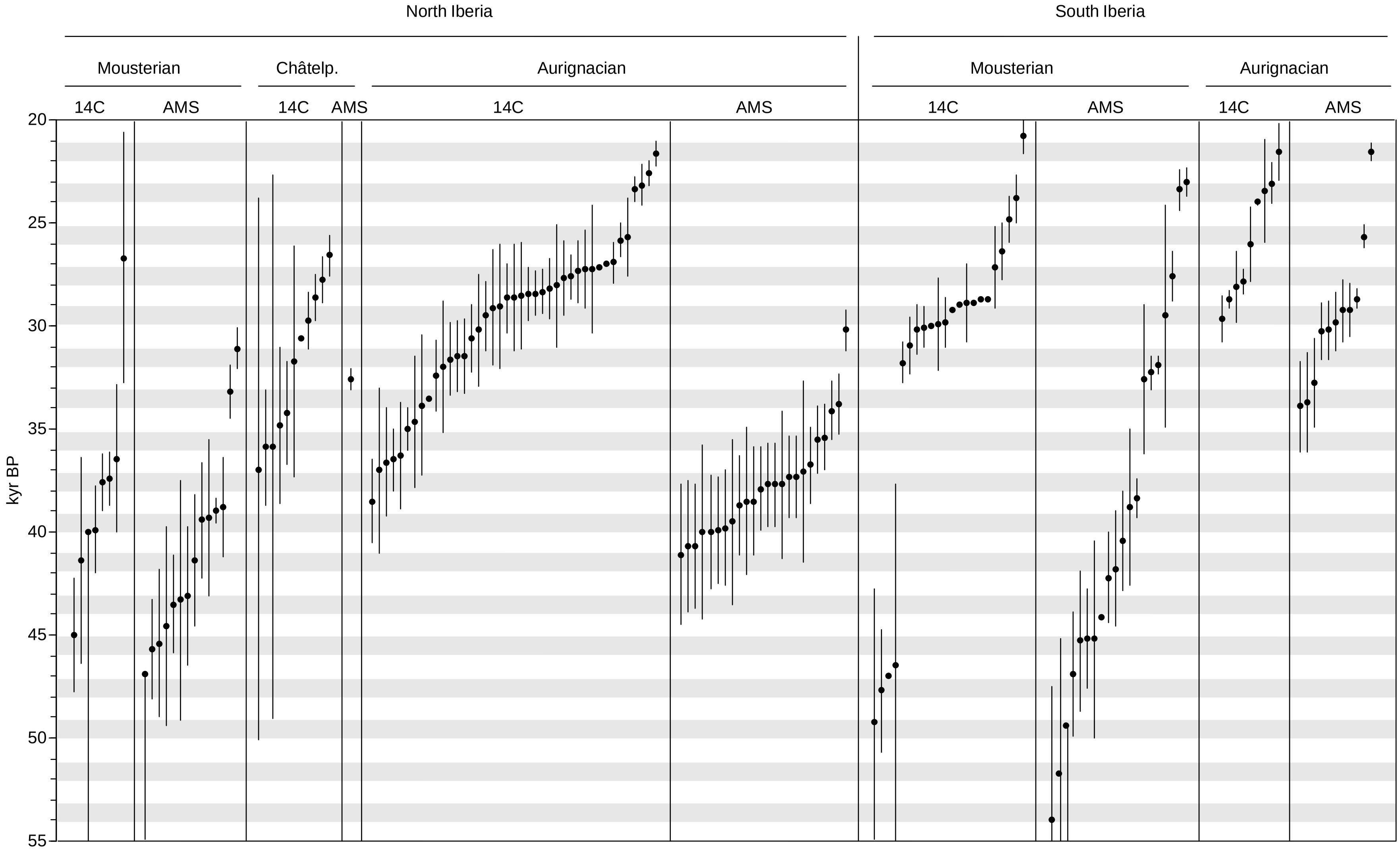

Fig. 4. Conventional and AMS ^{14}C radiocarbon dates from Mousterian, Châtelperronian and Aurignacian sites in northern and southern Iberia. Error bars are given at 2 sigmas.

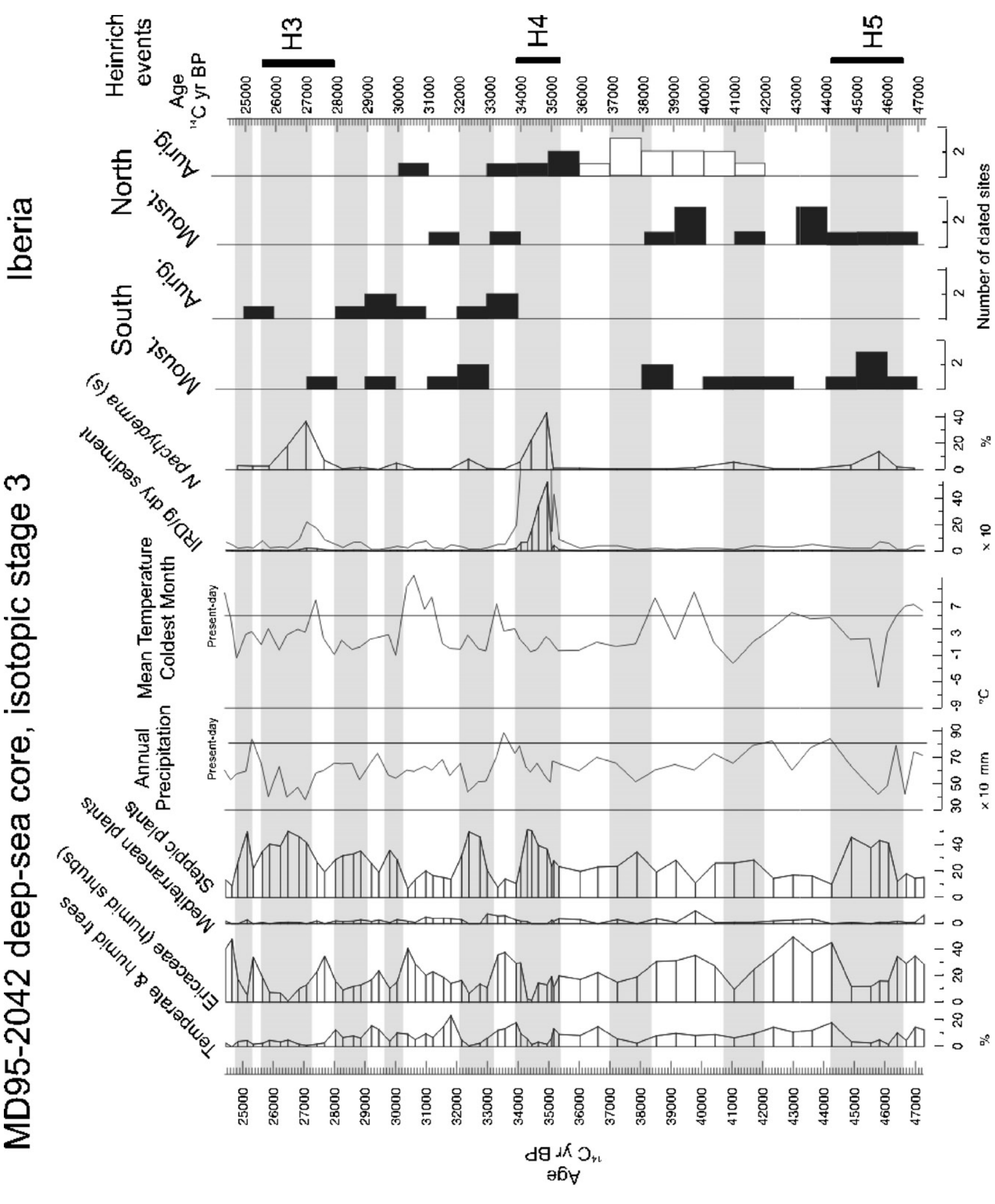

Fig. 5. Correlation between the palaeoclimatic record from core MD95-2042 and the frequency distribution of AMS ^{14}C dates for Mousterian and Aurignacian sites from the South and the North of the Iberian Peninsula. Empty bars indicate sites of controversial cultural attribution. Gray intervals indicate Heinrich events (H5, H4 and H3) and other Dansgaard-Oeschger stadials.

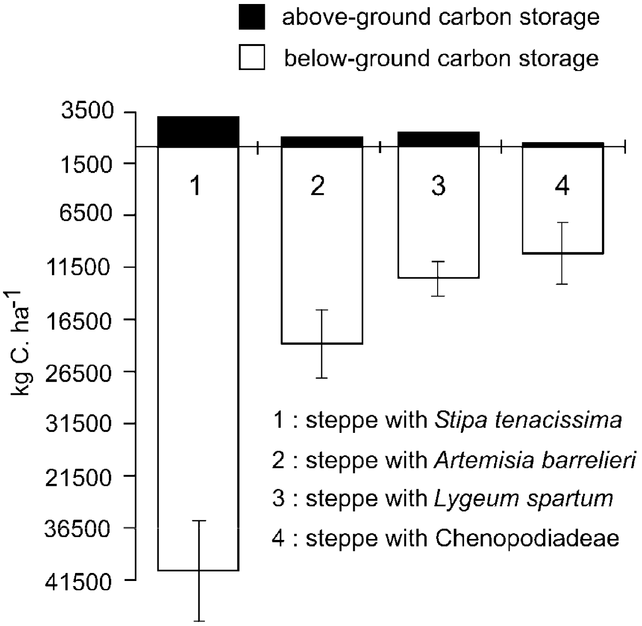

Fig. 6. Comparison of above-ground and below-ground carbon storages of different Andalusian steppes (modified after Gauquelin et al., 1998).

South of Iberia is due to the low biomass of this area during the H4 event. Aurignacian subsistence strategies were probably ill-adapted to cope with the arid and poor environments that characterised this area during the H4 event. Thus Modern populations took advantage of these latitudes only when milder Mediterranean conditions returned at the end of the H4 event. While undoubtedly reducing the size of the Neandertal communities occupying the South of the Peninsula, it is probable that this climatic event did not drive Neandertals to extinction. Previous similar abrupt cooling such as the H6 and H5 events were unable to produce this effect and AMS ^{14}C dates seem to indicate that there were still Neandertals in the South of the peninsula after the H4 event. It is likely that they persisted in refugium zones before expanding again at the end of the H4. Although two AMS ^{14}C dates indicate that Neandertals may have survived in the North during and slightly after the H4, this evidence is not robust enough to take this hypothesis for granted. Neandertals seem to disappear rather quickly in France after the arrival of the Aurignacian Moderns where we find no sites AMS dated younger than 35 kyr BP. And we know that, contrary to the South, Aurignacian Moderns were present in the North since at least 36.5 kyr BP. Thus the hypothesis of a late survival of Neandertals in the North implies an unlikely long coexistence, in the same area, of the two competing populations.

While additional dating of late Mousterian sites from the North will probably solve this issue, it is clear that the *coup de grâce* to the last Neandertals was given by competition with Moderns colonising the South of the peninsula after the H4 event. In sum, not only our results suggest that climate was not the main factor determining the Neandertal extinction but also, and paradoxically, that it was probably the H4 deterioration that allowed the late survival of the Neandertals in southern Iberia.

In northern midlatitudes, the expansion of Moderns does not appear to have been hindered by the H4 cooling, and the cold adapted nature of their subsistence mode seems even demonstrated by the development of the Aurignacian during this event. Climate, however, might have conditioned the timing of their colonisation of the Mediterranean regions.

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