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Quaternary Science Reviews 26 (2007) 836–852

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Climate forcing and Neanderthal extinction in Southern Iberia: insights from a multiproxy marine record

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Received 28 May 2006; received in revised form 16 November 2006; accepted 21 December 2006

Abstract

Paleoclimate records from the western Mediterranean have been used to further understand the role of climatic changes in the replacement of archaic human populations inhabiting South Iberia. Marine sediments from the Balearic basin (ODP Site 975) was analysed at high resolution to obtain both geochemical and mineralogical data. These data were compared with climate records from nearby areas. Baexcces was used to characterize marine productivity and then related to climatic variability. Since variations in productivity were the consequence of climatic oscillations, climate/productivity events have been established. Sedimentary regime, primary marine productivity and oxygen conditions at the time of population replacement were reconstructed by means of a multiproxy approach. Climatic/oceanographic variations correlate well with Homo spatial and occupational patterns in Southern Iberia. It was found that low ventilation (U/Th), high river supply (Mg/Al), low aridity (Zr/Al) and low values of Baexcess coefficient of variation, may be linked with Neanderthal hospitable conditions. We attempt to support recent findings which claim that Neanderthals populations continued to inhabit southern Iberia between 30 and ~28 ky cal BP and that this persistence was due to the specific characteristics of South Iberian climatic refugia. Comparisons of our data with other marine and continental records appear to indicate that conditions in South Iberia were highly inhospitable at ~24 ky cal BP. Thus, it is proposed that the final disappearance of Neanderthals in this region could be linked with these extreme conditions.

1. Introduction

Human origins and the extinction of archaic populations have been the subject of intense debate in recent decades (e.g., Stringer and Andrews, 1988; Wolpoff, 1989; Brauer, 1992; Harpending et al., 1993; Lahr and Foley, 1998). Many hypotheses have been proposed for the extinction of such populations. Among the latter, research has focussed primarily on Neanderthals (e.g., Flores, 1998; Finlayson, 2004; Horan et al., 2005; Finlayson et al., 2006). The Neanderthal extinction took place mainly during Marine Isotope Stage 3 (MIS3), a period which has been considered highly unstable and which is characterized by conditions not existing in present-day environments (Stewart, 2005). Recent studies have suggested that climatic and environmental factors alone may have caused Neanderthal extinction, given that climatic stability was of crucial importance for their distribution (Finlayson and Giles-Pacheco, 2000; Stewart et al., 2003a; Stewart, 2004a, b). Climatic variability has been determined by using a number of proxies such as $\delta^{18}O$ (Stringer et al.,

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doi:10.1016/j.quascirev.2006.12.013

2003; Burroughs, 2005). However, the hypothesis based on climatic and environmental factors alone has not been widely accepted, despite the fact that it has been discussed in depth. It is well known that Neanderthal populations were in fact able to successfully adapt to significant climatic fluctuations for approximately 300 ky (Finlayson, 2004). Their adaptability is likely to have involved a profound knowledge of their environment and the capacity to exploit different habitats, as well as seasonal mobility strategies, occupation of rich biotope areas (Finlayson, 2004; Finlayson et al., 2004), improved tool-making skills and better lithic resource management (Baena et al., 2005). Local extinctions and abandonment were, however, frequent in Neanderthal ecology (Trinkaus, 1995).

Neanderthal extinction is an especially difficult topic since it requires that relevant existing data from a multitude of disciplines be brought together and correlated with an appropriate methodological rigour on which consensus among researchers is highly problematic. The difficulties include: aspects of climatic influence on archaeological records, complex relationships between fossils and climatic conditions, incomplete nearby continental records, biased interpretations of climatic records, the sources of cultural features, an overemphasis on artefacts, rudimentary excavation techniques, dates obtained through a variety of methods and materials, dating and age models, and the coexistence of different underlying paradigms. The consequence of such a panorama is a highly fragile epistemology (Vega Toscano, 2005).

It has been suggested that the late Neanderthal populations survived in Southern Iberia. In general, Southern Iberia has been considered a "cul du sac" (Zilhao, 1996; Finlayson, 1999), playing a passive role in human/biological evolution. From this traditional point of view, the presence of relict taxa has been attributed to the position of the Southern Iberian Peninsula and its isolation from the major source of Euro-Asiatic faunal/floral input (Taberlet et al., 1998, Hewitt, 2000). However, the presence of species in this area could be related to its character as a climatic refugium (Finlayson, 2006) and to the fact that it is a biodiversity hotspot (Mota et al., 2002). In the late Pleistocene, three areas have been identified as major temperate and/or Mediterranean vegetation refugia during glacial periods: the Iberian, Italian and Balkan Peninsulas, (Bennett et al., 1991; Willis, 1996; Carrión et al., 2000; Tzedakis et al., 2002; Finlayson, 2006). "Cryptic" refugia have also been described, thus explaining the presence of Neanderthals in the Belgian Ardennes during the late MIS 3 (Stewart and Lister, 2001, Stewart et al., 2003b). The populations living in these refugia re-colonized central and northern Europe several times during the Late Pleistocene. It should be kept in mind that the capacity of refugia to continue carrying an ecosystem is a function of their specific location. The main characteristics of Southern Iberian refugia are their large scale, relatively low continentality, relative climatic stability, insolation and topography. These characteristics can only be reconstructed on the basis of representative local paleoclimatic records (Finlayson, 2006). In the case of the Southern Iberian Peninsula, the Algero-Balearic and Alboran basins provide particularly reliable climatic records (e.g., Cacho et al., 1999). Research has shown that the climatic conditions in this region were subjected to significant variations, mainly as a result of Glacial–Interglacial oscillations, Heinrich Events (HE), Dansgaard–Oeschner (D/O) stadials and interstadials (Moreno et al., 2005a).

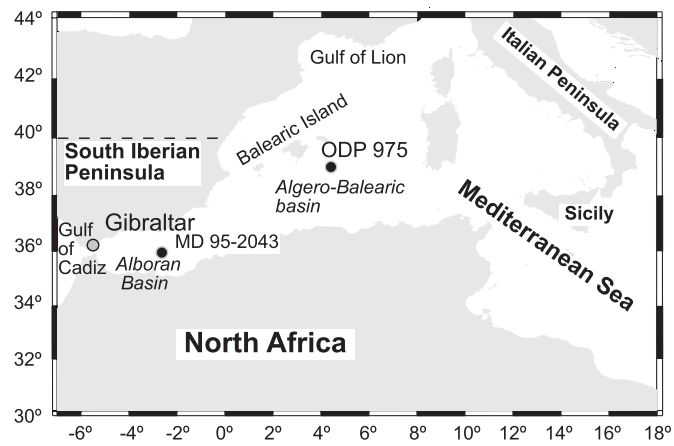

Fig. 1. Figure showing the locations of ODP Site 975 and one other related core (MD 95-2043).

In order to understand the paleoclimatic evolution in southern Europe and its relation to the aforementioned population refugia, a multi-proxy, high-resolution analysis was carried out in a marine sediment record from the western Mediterranean sea (WMS) (ODP core 975B-1H) (Fig. 1). This paper attempts to use Ba and Ba/Al ratios not only as paleoproductivity proxies, but also as an indicator of climatic stability. Mineral composition and trace element ratios have been used as paleo-proxies for paleoenvironmental reconstructions. K/Al and Mg/Al ratios, as well as quartz and clay minerals (e.g., illite and chlorite), were used to characterize river supply. Aeolian input has been characterized by Zr/Al and Ti/Al ratios. Trace elements sensitive to redox conditions (e.g., Fe, U, Co and Cr) have been used as paleo-redox and ventilation proxies. The results obtained have also been compared with other marine and continental climate records on regional and global scale in order to interpret the climatic conditions that may have affected Neanderthal populations.

2. Materials and methods

2.1. Site description and sedimentation rate

ODP Site 975 is located in the Northern margin of the Algerian-Balearic basin (Southeast Majorca island) (38° 53.795′ N 4° 30.596′ E; 2416 m.b.s.l.). Sediments at this site consist of nannofossils and calcareous clay, nannofossils and calcareous silty clay, and slightly bioturbated

nannofossil ooze (Comas et al., 1996). The upper 382 cm of core 975B 1H were sampled continuously every 2 cm. Sediment samples were divided into two portions, one dried and homogenized in agate mortar for mineralogical and geochemical analyses, the other used to separate marine planktonic foraminifers.

The age model is based on seven ^{14}C-AMS dates (accelerator mass spectrometry) using monospecific planktonic foraminifers (Leibniz-Labor for Radiometric Dating and Isotope Research, Kiel, Germany), stable isotope stratigraphy and biostratigraphic events were also used for age determination (Jiménez-Espejo et al., 2006). In order to compare our data with other paleoclimatic records, all ^{14}C-AMS ages were calibrated to calendar ages (cal. BP) using the Calib 5.0 software (Stuivert and Reimer, 1993). The age model was refined by graphic correlation with isotopic/geochemical data from well dated sections such as MD95-2043 (Cacho et al., 1999). This age model covers the last ~41 ky BP, whereas our study focuses on the interval of 20–41 ky BP. Linear sedimentation rates oscillate between 4 and 18 cm/ky. These variations in linear sedimentation rates at site 975B could be associated with gradual variations in terrigenous-detrital matter input during the time covered. Temporal resolution in the analytical series at this core is ~400 to ~100 yr, which is sufficient to distinguish millennial/centennial climatic oscillations, thereby allowing adequate millennial variance analyses.

2.2. Mineralogical and geochemical analyses

Bulk and clay mineral compositions were obtained by X-ray diffraction (XRD) following the international recommendations compiled by Kirsch (1991). X-ray diffractograms were obtained using a Philips PW 1710 diffractometer with Cu–Kα radiation and automatic slit. The resulting diffractograms were interpreted using the Xpowder software (Martín, 2004). Estimated semiquantitative analysis error for bulk mineralogy absolute values is 5% and error ranges from 5% to 10% for clay mineral proportions. FE-SEM analyses were performed to check barite origin.

Total organic carbon (TOC) and total nitrogen content were measured in separate portions of air-dried sediment samples by a CHN analyser (Perkin Elmer 2400 Series 2). Each powder sample processed for TOC was treated with HCl (12 N) in a silver cup, until mineral carbon was completely removed. Samples were wrapped after dehydration on a hot plate for 12 h. Standards and duplicate analyses were used as controls for the measurements, indicating an error of under 0.05%.

Major element measurements (Mg, Al, K, Ca, Mn and Fe) were obtained by atomic absorption spectrometry (AAS) (Perkin-Elmer 5100 spectrometer) with an analytical error of 2%. An X-ray Fluorescence scanner (University of Bremen) was also used to obtain K, Ca, Ti, Mn, Fe, Cu and Sr count fluctuations. The XRF-core scanner was set to determine bulk intensities of major elements on split sediment sections (Jansen et al., 1998; Rölh and Abrams, 2000) at intervals of 1 cm with an accuracy in standard powder samples of more than 0.20% (wt). The AAS and XRF-scanner data were compared and results indicating a high correlation between techniques. An average concentration of Ti in the core was obtained from XRF-core scanner data in order to normalize Ti to Al contents. This normalized average will be referred to as Ti_{mean}/Al. Analyses of trace elements including Ba were carried out using inductively coupled plasma-mass spectrometry (ICP-MS, Perkin Elmer Sciex Elan 5000) after HNO3 + HF digestion. Measurements were performed in triplicates using Re and Rh as internal standards. Variation coefficients determined by dissolution of 10 replicates of powdered samples were 3% and 8% for analyte concentrations of 50 and 5 ppm, respectively (Bea et al., 1996).

Stable carbon and oxygen isotope ratios of calcareous foraminifers were analysed to establish the stratigraphic framework of the samples from core 975B 1-1H. Approximately 25 specimens of *Globigerina bulloides* were picked from the >125 μm fraction and senescent forms were avoided. Foraminifers were cleaned in an ultrasonic bath to remove fine-fraction contamination, rinsed with distilled water and thoroughly washed in alcohol. Stable isotopes were measured using a GV Instruments Isoprime mass spectrometer. Analytical reproducibility of the method is +0.10‰ for both δ^{18}O and δ^{13}C based on repeated standards.

3. Results

3.1. Paleoproductivity proxies

TOC and Ba content have been used to determine productivity fluctuations. TOC content oscillates between 0.2 and 0.35. C_{org}/N ratio values oscillate between 2 and 6, which suggests a marine provenance (Meyers, 1994). However, TOC content displays a low correlation with Ba content, probably indicating poor preservation of the TOC record, as has also been shown for Holocene sediments from this same site (Jiménez-Espejo et al., 2006). In contrast, the Ba record seems to be well preserved. The FE-SEM analyses corroborated the presence of barite crystals with morphologies corresponding to typical marine barite (1–7 μm in size with round and elliptical crystals). Despite discussion regarding paleoproductivity estimates based on Ba excess (Eagle et al., 2003; Eagle Gonneea and Paytan, 2006), at this site the Ba content can still be considered a good indication of productivity fluctuations, specifically since we established the presence of authigenic marine barite in the samples. Within the analysed time interval no substantial changes in sediment composition are detected suggesting that changes in Ba bearing phases are negligible and therefore the fluctuations obtained derive from productivity variations. Although uncertainties regarding the correction for silicate-associated Ba do not allow one to obtain quantitative

export production values, information on productivity variations is still valid. The latter has been obtained by subtracting the amount of terrigenous Ba from total Ba content (e.g., Eagle et al., 2003).

$$(Ba_{excess}) = (total - Ba) - Al(Ba/Al)_c,$$

where total−Ba and Al are concentrations and $(Ba/Al)_c$ is the crustal ratio for these elements. For this site we have used $(Ba/Al)_c = 0.002$, as estimated by Weldeab et al. (2003) for the Balearic Sea on the basis of surface sediments and current oligotrophic conditions. It is assumed that the $(Ba/Al)_c$ ratio of the terrigenous matter

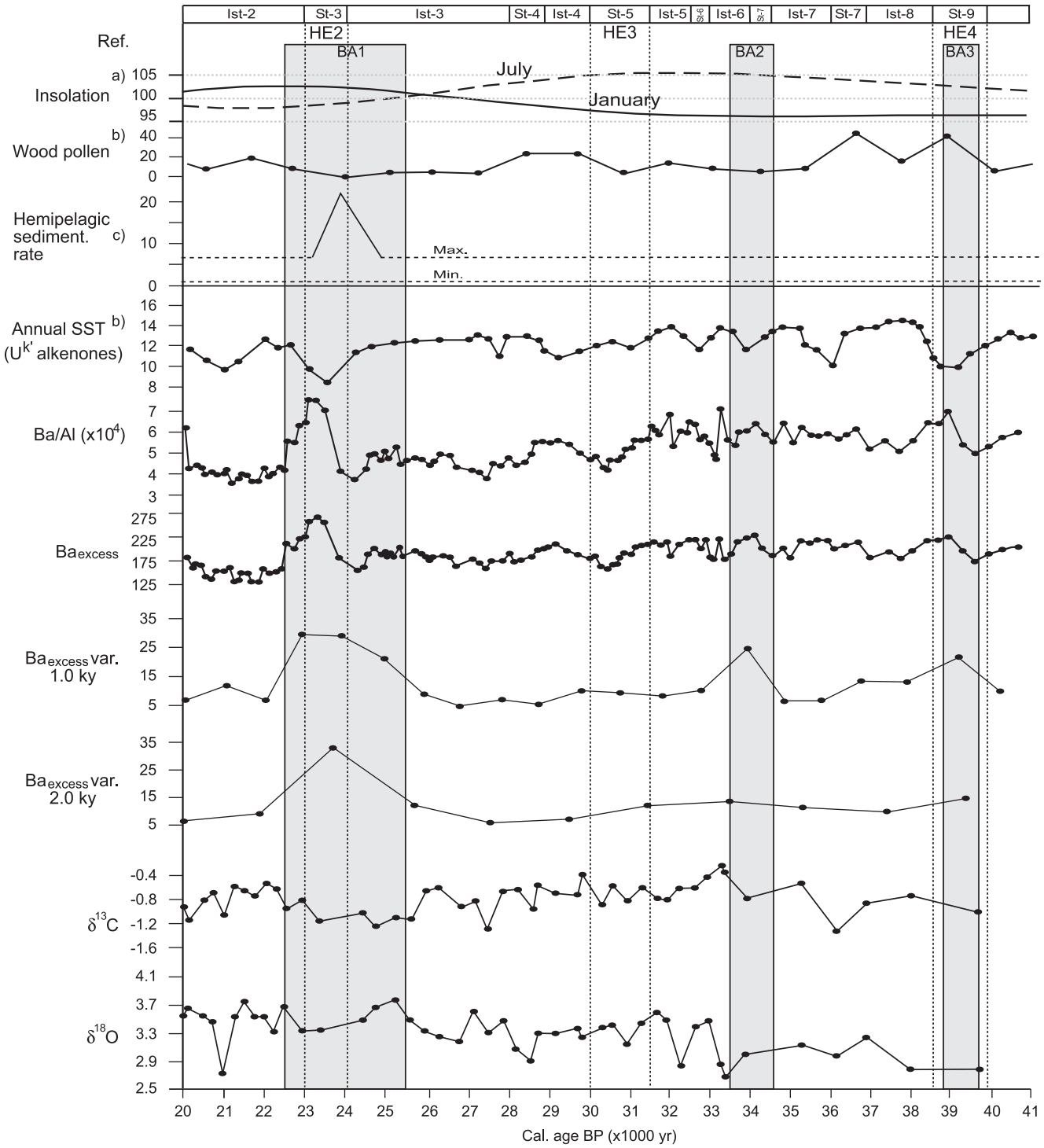

Fig. 2. Insolation curve, wood pollen, hemipelagic sedimentation rates on the Balearic abyssal plain, mean annual SST ($U^{k'}$ alkenones), Ba/Al ($\times 10^4$), Ba_{excess}, Ba_{excess} variability per 1.0 ky, Ba_{excess} variability per 2.0 ky and *G. bulloides* isotopic stratigraphy ($\delta^{18}O$ and $\delta^{13}C$, in ‰) according to age. $\delta^{18}O$ values are plotted with reversal *Y*-axis. References: (a) Berger, 1978 (b) Martrat et al., 2004 (c) Hoogakker et al., 2004.

remains constant over the period considered. Changes in catchment areas could affect the $(Ba/Al)_c$ ratio of the terrigenous matter, but the $(Ba/Al)_c$ ratio shows no significant changes during the last glacial period. The lack of correlation between Ba peaks and detrital elements also suggests a mainly authigenic origin for Ba enrichments. Maximum Ba_{excess} content is observed at ~23.3 ky BP (Fig. 2) along with other peaks (e.g., ~34, ~29.2, ~24.7 and ~20.5 ky cal BP). Ba_{excess} and TOC do not follow similar trends. Maximum TOC content during the last glacial period was reached at ~25.8 and ~20.3 ky cal BP with occasional, sharp low/high TOC values.

3.2. Sea surface conditions obtained through stable isotopes

The oxygen stratigraphic framework for the time interval analysed at site 975 can be correlated with episodes of changing temperature, resembling the global variation of the SPECMAC isotope curve (Martinson et al., 1987). The maximum amplitude between 20 and 41 ky cal BP of $\delta^{18}O$ *G. bulloides* in core 975B-1H lies between 2.67 ‰ and 3.76‰, with a total oscillation of 1.09 ‰. The $\delta^{18}O$ *G. bulloides* develops a cyclical pattern with sudden oscillations that could be associated with abrupt warmings (~21.3, ~28.8 and ~33.6 ky cal BP) or coolings (~21.8, ~22.8, ~25.5 and ~27.4 ky cal BP) (Fig. 2). Such variations could be related to the climate cycles defined by Moreno et al. (2005a) in the WMS. Values of $\delta^{13}C$ *G. bulloides* were found to be highly variable. Maximum amplitude of $\delta^{13}C$ *G. bulloides* is between −0.24‰ and −1.32 ‰, with a total oscillation of 1.08‰. $\delta^{13}C$ *G. bulloides* undergoes sudden increase/decrease shifts which may be correlated with variations in Atlantic inflow fertilization and/or gyre activities (Bárcena et al., 2001; Rogerson et al., 2004; Voelker et al., 2006).

3.3. Detrital and redox proxies

The terrigenous sediment fraction includes clay minerals (20–50%), quartz (15–30%), and minor amounts of feldspar (<5%), dolomite (<5%), and accessory minerals. Clay mineral assemblages consist of illite (55–80%), smectite (<5–15%) and kaolinite + chlorite (20–40%). These terrigenous sediments also included accessory minerals, such as zircon, rutile, apatite and biotite, while the authigenic minerals identified were anhydrite-gypsum, pyrite, Mn and Fe oxi-hydroxides. Fig. 3 shows the distribution of selected profiles of major and trace element ratios related with terrigenous input. Elemental concentrations have been normalized to Al. This normalization assumes that Al in these sediments is contributed only by terrigenous alumino-silicates (Calvert, 1990).

Ti and Zr are related with heavy minerals (e.g., zircon, rutile, anatase, titanite, ilmenite) and have been used by different authors as aeolian input proxies (e.g., Calvert et al.,

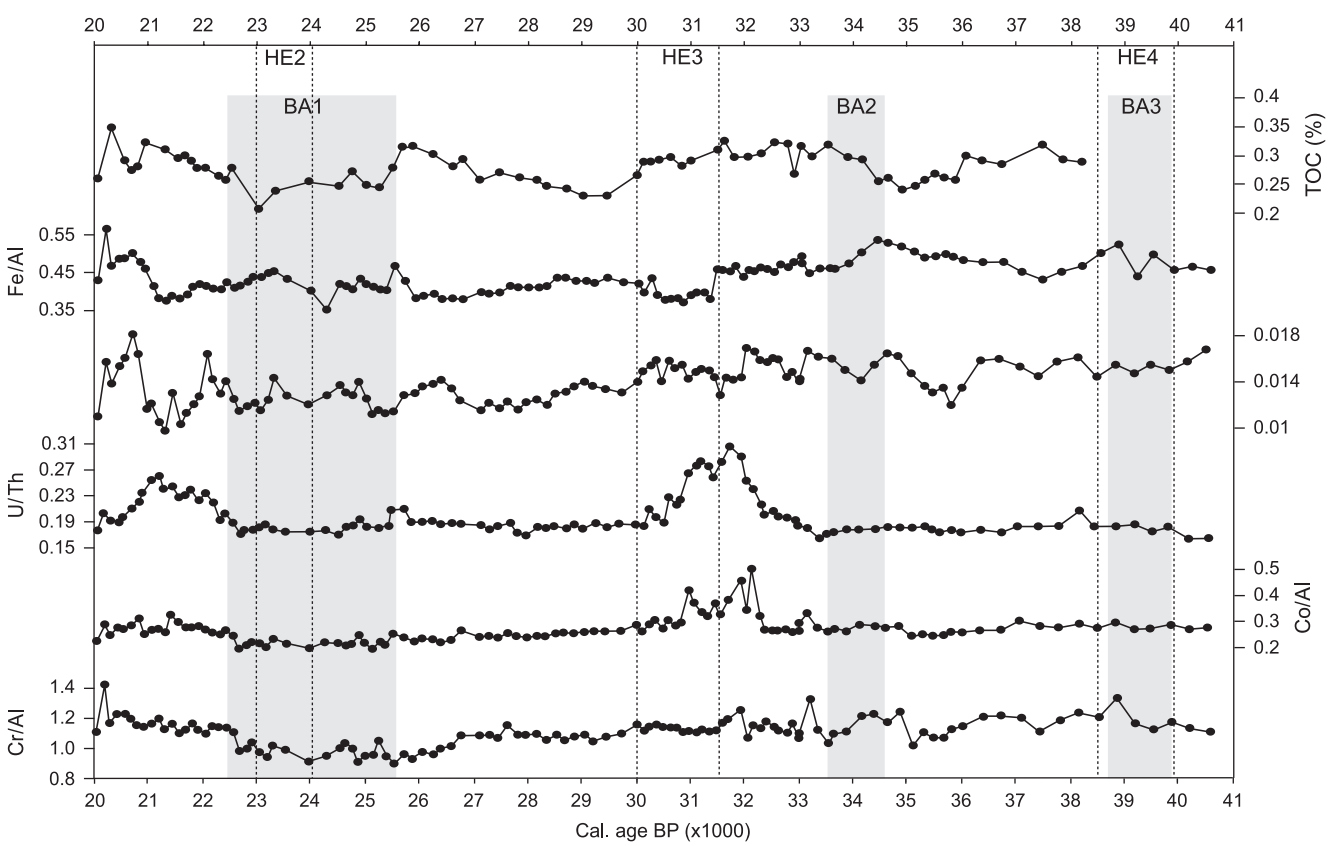

Fig. 3. TOC content (%), U/Th and other redox-sensitive trace elements/Al ($\times 10^4$) according to age. Vertical dotted lines indicate the time intervals of Heinrich events. Grey areas indicate BA events (for definitions of such events, see Section 4.3).

1996; Haug et al., 2003). Both elements are well correlated over almost the entire period studied. In contrast, they have a low correlation with other detrital elements (Al, K and Mg), suggesting a different origin and ruling out the presence of turbidites, which usually produce quartz and heavy mineral enrichment (Wehausen and Brumsack, 1999).

The ratios of specific elements to Al have been considered as redox sensitive proxies (e.g., Fe/Al, Mn/Al, U/Th, Co/Al, Cr/Al) (e.g., Mangini et al., 2001; Marin and Giresse, 2001) for oxygen conditions and digenetic remobilization. Regarding oxygenation, two major enrichment periods in redox sensitive elements have been detected from 33.2 to 30 ky cal BP and from 22.7 to 20.4 ky cal BP (see U/Th ratio on Fig. 4). Postdepositional alteration resulted in re-oxidation fronts promoting element mobilization along the sediment column (Fe and Mn), which provides information on reventilation processes.

4. Discussion

4.1. Continental and marine environments in the WMS during MIS 3

Different proxies have shown that MIS 3, like other interglacials, is characterized by a saw-tooth temporal temperature pattern. However some features unique to this period exist, specifically, the main difference between this period and the other MIS stages (1–7) is that it represents a time for which "non-analogue" conditions exist. This is evident in the mammalian fauna record (Stewart et al., 2003a; Stewart, 2005) and have also been observed in wind dust from marine sediment in the Algero-Balearic basin (Weldeab et al., 2003) and for the vegetation and fauna of Gibraltar (Finlayson, 2006). For example, $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios indicate that during MIS 3 the main dust source for the WMS was probably located between the Northwestern Sahara (Morocco/NW Algeria) and the Sahara and Sahelian regions; another unknown source could also be involved (Weldeab et al., 2003). These source areas are substantially different from those of other MIS stages (1–7). The response to this even in terrestrial flora is however not clear. Marine pollen records have been established in WMS cores corresponding to MIS 3. However, interpretations of pollen sources have not led to unequivocal conclusions. For example, D'Errico and Sánchez-Goñi (2003) have considered them to be Iberian, whereas Magri and Parra (2002) and Carrión (2004) disagree. On land, a rapid vegetational response to climatic changes has been observed (Sánchez-Goñi et al., 2005; González-Sampériz et al., 2006). At present,

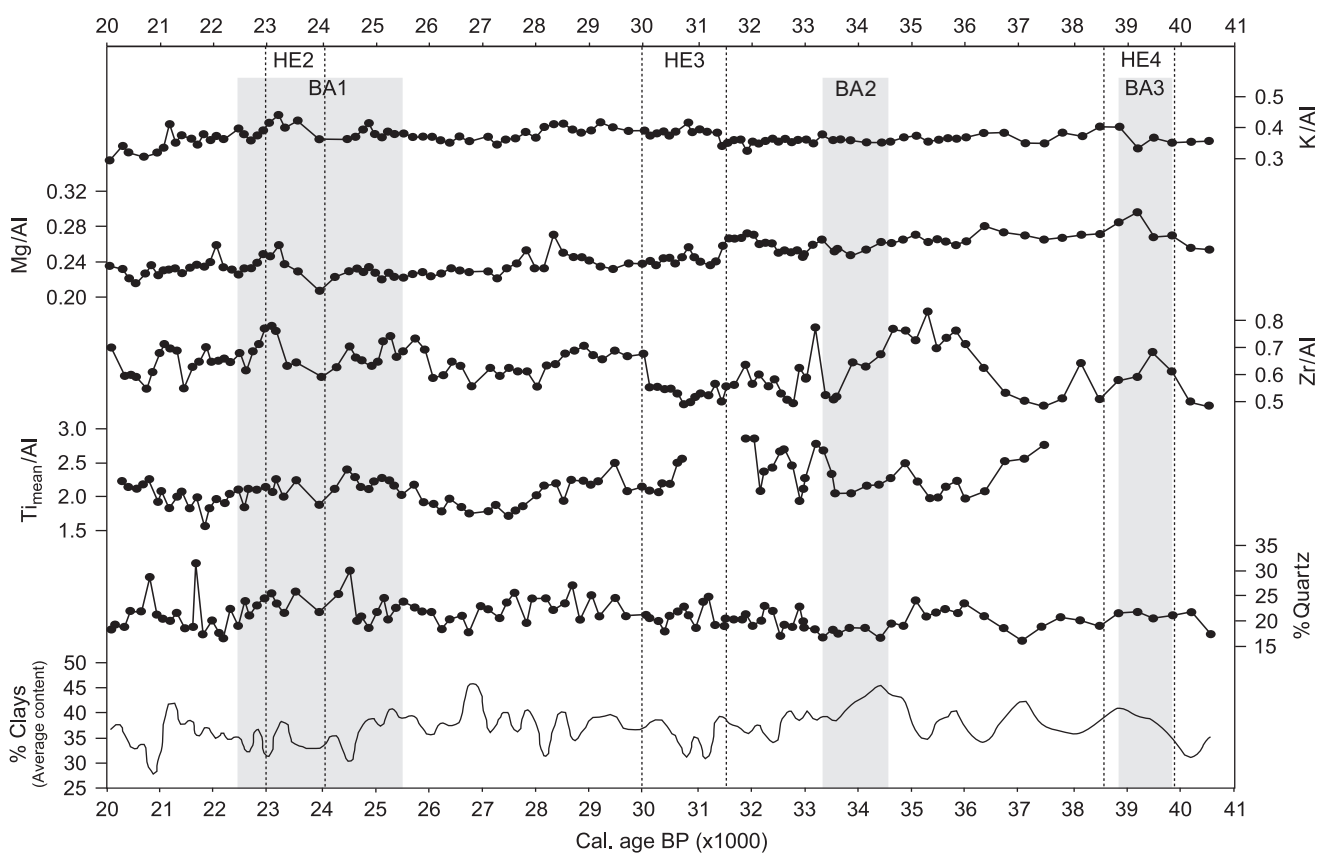

Fig. 4. Relative quartz and clay mineral average concentrations (%), and elemental/Al ($\times 10^4$) ratios according to age, plotted as lithogenic proxies. Ti_{mean} is an average value obtained by using an XRF-scanner. Vertical dotted lines indicate the time intervals of Heinrich events. Grey areas indicate BA events (for definitions of such events, see Section 4.3).

however, the resolution of age models does not allow for the identification of abrupt variations, such as those which took place during the D/O cycles as recorded in the marine record.

Marine records from the Iberian margin are especially suitable for paleoclimate research (Bard et al., 2004). Various multiproxy studies have been carried out (e.g., isotopic ratios, alkenones, pollen and geochemistry), which revealed significant climatic oscillations (e.g., Martrat et al., 2004). However, when looking into the effect of these changes on the terrestrial ecosystem, it should be noted that some of these variations can be assimilated by an ecosystem without major disturbances. Indeed, vegetal distribution is affected mainly by minimum temperatures, growth season and precipitation (Woodward, 1987), rather than mean sea surface temperatures (SST), sea level, or water chemistry. Thus, the use of marine records to measure variance in a continental ecosystem may be some times difficult (Robinson et al., 2006). However, several chemical elements in marine records are of mainly continental origin, for example, Mg/Al and K/Al ratios have been associated with fluvial input (precipitation), and Ti/Al and Zr/Al with aeolian input (wind). Thus, these ratios provide information on continental areas, although they are highly influenced by multiple physical/chemical phenomena (e.g., wind intensity/direction, erosion rate, soil alteration, pluvial regime, marine currents and catchment areas, etc.) which complicate their use for variance analyses.

4.2. Ba_{excess} as a climatic stability proxy

The use of Ba enrichments as a proxy for productivity has been intensely discussed since the early 1980s. This proxy is based on the strong correlation between the fluxes of excess Ba and organic matter in sinking particulates. It is also supported by the observations that Ba-rich sediments usually underlie high biologically productive (e.g., Dehairs et al., 1987; Dymond et al., 1992) areas and surface sediment barite accumulation rates correlate with upper water column productivity (Paytan et al., 1993, 1996). The use of this proxy assumes that the excess of Ba is related to barite crystals that originate in the water column. Only in such cases can Ba excess thus be used as a reliable proxy, assuming that Ba excess (total Ba normalized to Al) correspond to the Ba fraction that is not associated with terrigenous components. Data from different settings has shown that this proxy should be used with caution in diagenetic environments where reducing conditions may have compromised barite preservation (McManus et al., 1998). In addition, recent research (Eagle Gonneea and Paytan, 2006) has shown that Ba content in different phases depends not only on primary productivity, but also on sediment provenance, sedimentation rates and Ba cycling within sediments. Corrections for detrital Ba may be highly variable and Ba excess algorithms should therefore be used with extreme care when calculating export production (Eagle Gonneea and Paytan, 2006).

However, many studies have shown that Ba is an accurate indicator of past productivity in the Mediterranean Sea (e.g., De Lange et al., 1999; Emeis et al., 2000; Martínez-Ruiz et al., 2000). Paleoproductivity reconstructions using this proxy in marine Pliocene and Pleistocene sediments have confirmed that widespread deposition of sapropels resulted from enhanced export production fluxes. Increasing productivity was a consequence of changes in climatic conditions leading to higher nutrient supply. Sulfur isotope composition of marine barite from Mediterranean sapropels revealed that barite is an authigenic phase originating in the upper water column and is thus a reliable proxy for productivity at the time of sapropel deposition (Paytan et al., 2004). The high accumulation and good preservation of biogenic barite also indicate that bottom-water and pore water sulphate concentrations in Mediterranean basins were plentiful. The Ba_{excess} proxy is also of exceptional importance in Mediterranean basins because at some locations the organic matter in the original sapropels has been oxidized and erased from the sediment record. Although estimates of past productivity using Ba_{excess} may be inaccurate due to detrital Ba corrections or variable preservation, it is clear that Ba enrichments in Mediterranean sapropels indicate enhanced export productivity. In the deep areas of the Alboran and Algero-Balearic basins, productivity has been related to: (i) surface water fertilization, provoked by different water mass mixing and/or gyre activity (Bárcena et al., 2001); (ii) increases in nutrient supply due to high river runoff associated with wetter climates and/or melt water (Martínez-Ruiz et al., 2003; Moreno et al., 2004); (iii) pycnocline depth changes (Rohling et al., 1995; Flores et al., 1997) and, finally, (iv) highly fertilized Atlantic jet inflow (Rogerson et al., 2004). A change in productivity caused by pycnocline deepening has most likely only occurred once in the last 50 ky (at ~8 ky BP) (Flores et al., 1997). All other productivity fluctuations in this region are associated directly or indirectly with atmospheric conditions. Thus, abrupt variations in marine productivity mostly reflected major variations in atmospheric/oceanographic (climatic) conditions. Continental environments should therefore also be affected by such climatic variations. When statistical analyses are considered, the variance may indicate the disruptive potential of climate fluctuations. Especially within the time interval studied, statistical analyses have provided valuable information regarding climate stability. Fig. 2 represents the millennial and bi-millennial Ba_{excess} coefficient of variation (Ba_{excess} var.). High Ba_{excess} var. values may indicate periods characterized by highly unstable conditions in marine ecosystems. High values in Ba_{excess} var. coincide with major changes in planktonic foraminifera bioevents (see Table 1), (Perez-Folgado et al., 2003). This further supports the validity of Ba_{excess} var. as a tool for understanding the climatic/biological variability in the WMS area.

Table 1
BA events (see Section 4.3) and their relationship with planktonic foraminifera events defined in Perez-Folgado et al., 2003

High Ba_{excess} var. events	Bioevents					
	N. pachyderma (r.c.)	*N. pachyderma* (l.c.)	*T. quinqueloba*	*G. scitula*	*G. inflata*	*G. bulloides*
BA1	Pm2	Ps2	Q3	Sc2		B2
BA2			Q5 Bot.	Sc4 Bot.	I4 Max.	
BA3		Ps4 Bot.			I5 Top	B4 Bot.

4.3. Conditions during intervals of high Ba_{excess} variability

As is the case for SST in the WMS (Cacho et al., 1999), the Ba signal is affected by D/O cycles (Moreno et al., 2005a). Three high Ba_{excess} variability periods can be recognized between 41 and 20 ky BP (we have established them as BA3, BA2 and BA1 events). Correlations of significant interest are obtained when such periods are compared with other paleoclimatic records:

(a) The BA3 event (aprox. 39–40 ky BP) can be correlated with the HE 4, which took place aprox. 38–39.5 ky BP (Bond et al., 1999; Hemming, 2004; Llave et al., 2006). Rapid changes in Atlantic deepwater currents and heat piracy between the Northern and Southern Hemispheres have been described for this period (Maslin et al., 2001; Seidov et al., 2001). HE 4 seems to be distinct from other HEs (Cortijo et al., 1997; Elliot et al., 2002; Cortijo et al., 2005). There was probably a cold current flowing from the Norwegian Sea along the European coast (Cortijo et al., 1997), with polar water reaching the WMS (Voelker et al., 2006). Recent studies indicate that ice-rafted debris were deposited in the Gulf of Cadiz (Llave et al., 2006), but apparently most of the melting took place in northern areas between 45°N and 55°N (Roche and Paillard, 2005). An increase in *N. pachyderma* recorded at core MD95-2043 (approx. 25%) confirms that cold waters arrived at the WMS. Temperature estimates from $U^{k'}$ alkenones indicate a mean annual SST of around 10 °C (Martrat et al., 2004). On the continent, a high degree of seasonality has been reported with large temperature fluctuations (Summer approx. 15–20 °C, Winter approx. −5 °C to 0 °C) (The Stage Three Project database). A major decline in *Pinus* and *Quercus*, and an increase in Ericaceae are observed (Roucoux et al., 2005). For this period results from ODP 975B indicate a relative increase in Zr/Al and a major decrease in K/Al (Fig. 3). This suggests that conditions were more arid and that wind velocities were stronger. Our results would seem to indicate a scenario in which the Iberian Peninsula was subjected to abrupt changes including an extreme, continental climate. Insolation variation was, however, very limited during this event despite the large climatic changes suggesting the influence of other causes and feedbacks (Cortijo et al., 1997).

(b) The BA2 event (approx. 33.5–34.5 ky BP) could be the culmination of progressive climate deterioration, which is characterized by short D/O (6 and 7 stadials–interstadials). D/O cycles in the WMS were apparently less severe than in the Atlantic (Hoogakker et al., 2004). Nevertheless, they imply major changes in high-latitude circulation and monsoonal weakness (D/O stadial) (Moreno et al., 2002) (Rohling et al., 2003). No ice-rafted debris have been observed in cores from the Atlantic Iberian margins during that time (Llave et al., 2006). However, cold waters penetrated the WMS during D/O stadial. SST ranged from aprox. 15 °C D/O interstadial to 11 °C D/O stadial for this period (The Stage Three Project database), which indicates more hospitable conditions than during HE 4. The aforementioned observations would together suggest a sudden change in temperature, and especially in humidity/rainfall in the Mediterranean area (Voelker and workshop participants, 2002). An input of cold water into the WMS could have promoted a reduction in evaporation and less precipitation throughout the Mediterranean area, with more significant effects in the Levant (Bartov et al., 2003; Begin et al., 2004). Fluctuations in the abundance of certain foraminifers species (e.g., *Turborotalia quinqueloba*) (Perez-Folgado et al., 2003) could reveal an unstable cold water input. This could have led to highly erratic rainfall in the Mediterranean area. In fact, the formation of talus flatiron, which requires alternation of aggradation and incision periods, has been detected on the Iberian Peninsula (Gutierrez et al., 2006). Pollen records indicate that *Quercus* almost disappeared in the Monticchio record (Allen et al., 2000) and that Ericaceae and *Pinus* shrunk in the Northwestern Iberian regions (Roucoux et al., 2005). The latter are less affected, which could be associated with the passing of tolerance limits for deciduous *Quercus*. However, Mediterranean forest continued to exist in coastal areas of SW, SE Spain and North Africa throughout MIS 3 (Carrión et al., 1995; Carrión, 2004; Finlayson, 2006). Results from Site ODP 975 indicate major changes in Zr/Al and Ti_{mean}/Al that could be related to high variations in aeolian input into the basin. Moreover, K/Al and Mg/Al, which are related to fluvial sediment input, did not undergo significant changes. Redox sensitive ratios present an inflexion

point following the end of the BA2 event, with increases in U/Th, Cr/Al and Co/Al that point to less ventilated bottom waters. In the Gulf of Cadiz a more intense Mediterranean outflow water has been described during cold phases (Llave et al., 2006). This intensification resulted from colder, drier Mediterranean conditions. The expansion of the polar vortex generated masses of cold air, responsible for Western Mediterranean Deep Water (WMDW), which, in turn, ventilated the Balearic basin (Cacho et al., 2000; Rohling et al., 2003; Jiménez-Espejo et al., 2006). These low ventilation conditions came to an end around 30 ky BP, with the onset of the HE 3 (30.5 ky BP). Cold conditions have been described in Iberian lacustrine records (e.g., El Portalet, González-Sampériz et al., 2006). No significant changes appear in Ba_{excees} var. during HE 3. This could be related to the gradual, rather than abrupt HE 3 pattern (Gwiazda et al., 1996) and to its particular features (Elliot et al., 2002), which differ from other HE's. No evidence of ice-rafted debris has been found in Southern Iberian latitudes (Llave et al., 2006).

(c) The BA1 event (approx. 22.5–25.5 ky cal BP) can be related to the transition from MIS 3 to MIS 2 and to the HE 2. A bi-phase signal has been described for HE 2 in the Iberian region, one centred at 25 ky (HE 2b) and the other at 23.5 (HE 2a) (Sánchez-Goñi et al., 2000; Turon et al., 2003). Within this period, the most inhospitable conditions of the previous 250 ky were reached in the WMS (Martrat et al., 2004). During HE 2, an armada icebergs reached the Portugal margin (Abreu et al., 2003). No ice-rafted debris have been detected in the Gulf of Cadiz, although a high percentage of coarser fraction (>63μ) suggests a very strong Mediterranean outflow water current (Llave et al., 2006). Despite a reduced supply of icebergs, the lowest temperatures of the last 250 ky were reached, with an annual mean SST of around 8 °C ($U^{k'}$ index) (Martrat et al., 2004). These low temperatures can be associated with strong thermohaline circulation and/or with the minimum daily total solar radiation, the latter resulting from orbital geometry (Berger, 1978). A minimum in seasonality was reached at 24 ky BP, (Berger, 1978) and probably affected marine currents. Indeed, previous summer insolation minima (40–45 ky BP) have been linked with high variations in sedimentation rates in nearby areas (Voelker et al., 2006). On land, pollen analysis results indicate extreme conditions in Iberia during HE 2. A minimum of arboreal pollen correlates with a maximum in *Artemisia* and Chenopodiaceae (e.g., Turon et al., 2003; Roucoux et al., 2005), thus indicating a dominance of steppic group taxa that was not reached during the previous 65 ky. Low seasonality can be expected for this period, with cooler summers and warmer winters than during previous BA events. Indeed, relatively warm winters are necessary to explain the presence of traces of *Quercus* (deciduous) pollen in Padul (SE Spain) (Allen and Huntley, 2000). Detrital proxies at Site 975 indicate a minimum Mg/Al ratio at 24 ky BP, which could points to a pronounced decrease in riverine input. K/Al ratio oscillations could be related to a highly unstable river discharge from the Rhône, or with mineralogical changes. Rapid oscillations have also been detected in other global records (e.g., 4–6 °C warming in less than 50 years at ~22 ky cal BP (Taylor et al., 2004). Aeolian input, as indicated by the Zr/Al ratio, shows low values at 24 ky and reaches a relative maximum at 23 ky. These variations could be linked with abrupt changes in atmospheric conditions. An inflexion point in our age model also reveals a change in the linear sedimentation rates during this period. Other cores from the Algero-Balearic basin also reveal abnormal accumulation rates at 24 ky, up to three times higher than any other value during at least the last 130 ky (Hoogakker et al., 2004). These oscillations have been interpreted as being due to higher aeolian input, the latter being a consequence of increasing aridity and/or higher wind speeds (Hoogakker et al., 2004). Furthermore, an unusually high thermohaline circulation, transporting material from an unknown source to the Algero-Balearic basin, cannot be ruled out. In any case, major changes can be observed in the WMS borderlands, which may not have undergone such extreme conditions in previous periods. Redox sensitive ratios indicate well-oxygenated conditions between 25.5 and 22.5 ky BP, an interval during which a few of the ratios reach their lowest values (e.g., Cr/Al). Afterwards, a period of less ventilated conditions began, promoting an increase in redox sensitive ratios (e.g., U/Th and Co/Al). These ventilation conditions are once again correlated with Mediterranean outflow water activity in the Gulf of Cadiz (Llave et al., 2006).

4.4. The role of climatic variability for archaic populations

Fig. 5 indicates frequency distribution of Solutrean, Gravettian, Aurignacian and Mousterian dated sites per millennium in the Southern Iberia Peninsula (modified from Finlayson et al., 2006 and unpublished database) (CalPal 2005 SFCP). Cross calibration is fundamental for the comparison of marine and continental data. Moreover, uncertainties associated with calibration methods, continuous updates and different calibration curves/programs, lead to a certain degree of confusion among researchers (Housley et al., 2001; Turney et al., 2006). In the case of Calpal, regularly updated internationally standardized calibration curves are available (Reimer et al., 2006). The use of millennial scale and average values attempt to avoid such uncertainties. This information can be considered highly representative, although it is incomplete, as is otherwise to be expected from the nature of the fossil record itself, as well as the fact that the Southern Iberian

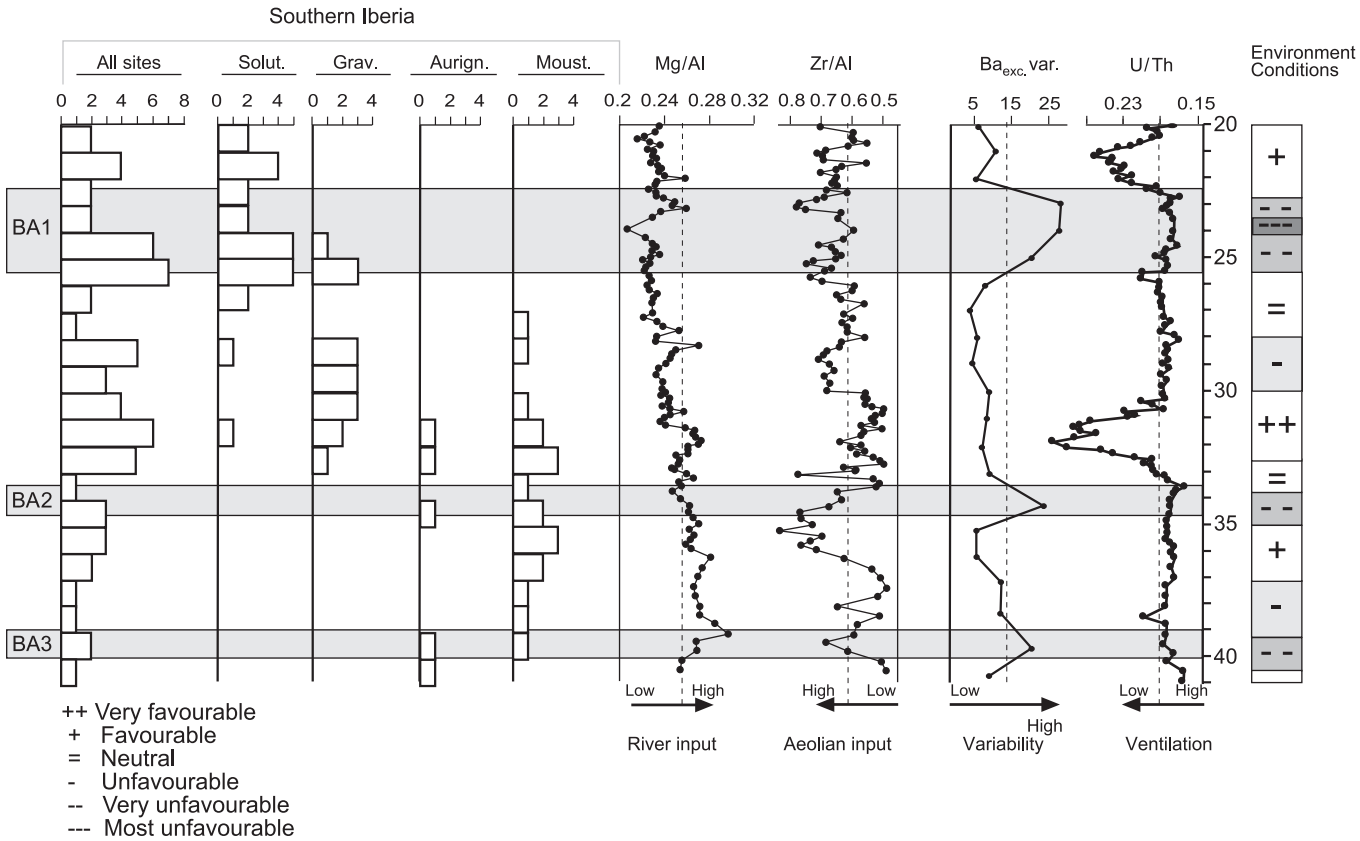

Fig. 5. Frequency distributions of Solutrean, Gravettian, Aurignacian and Mousterian calibrated dated sites per millennium in South Iberia. These distributions are compared with Ba_{excess} var., U/Th, Zr/Al and Mg/Al according to age. Such proxies are interpreted as climatic stability, deep-water ventilation, aeolian input and fluvial input, respectively. Environmental conditions have been interpreted on the basis of combinations of these factors. Uncalibrated data base distribution follows a similar "peak and valleys" pattern, and relationship between industrial replacements do not change.

Peninsula has yet to be studied more exhaustively. The database has been compared with Ba_{excess} var., deep-water ventilation, and aeolian and fluvial input characterized by the U/Th, Zr/Al and Mg/Al, respectively. Two main observations can be made: (i) archaeological outcrops are more abundant during conditions of low Ba_{excess} var. and low ventilation and (ii) the number of outcrops is clearly affected by BA3, BA2 and BA1 events. During BA3 a low number of Mousterian sites has been registered. This appears to coincide with a weak early presence of the Aurignacian in the Iberian Peninsula associated with the most extreme climatic conditions (cold and dry). Between BA3 and BA2, a progressive increase in Mousterian sites occurred with the disappearance of Aurignacian sites. During this period (40–35 ky) the number of Mousterian sites reached a maximum and probably dominated southern Iberia. During BA2 there was a dramatic decrease in Mousterian sites, with a reappearance of Aurignacian ones. The most hospitable conditions occurred between 30.5 and 34 ky cal BP and Mousterian population reached a new maximum. Moreover, a progressive increase in Gravettian sites is synchronous with decrease in Mousterian sites. Therefore, relict Mousterian sites prevailed during the relatively hostile 30–25 ky period (Fig. 5). During the prolegomena of the BA1 event, Solutrean industries were dominant and Gravettian and Mousterian industries probably disappeared. During the latter part of the BA1 event, Solutrean sites also underwent a decrease in number. Apparently major technological replacements took place during unstable periods. This could indicate that the proliferation of these industries was impacted by climate and a selection of cultural styles occurred. Indeed, in the second half of MIS 3 a number of "transitional industries" (e.g., Uluzzian, Bohunician and Szeletian) could represent cultural diversification as a response to new challenges (Finlayson and Giles-Pacheco, 2000; Finlayson, 2004).

The present study does not attempt to address the issue of whether the main Modern expansion in Europe took place during the H4 event or whether it occurred during improved conditions associated with the Hengelo interstadial (mainly 41–42 ky cal BP) (Mellars, 2006). The idea of a new species displacing an earlier (more primitive) one to a peripheral area has been shown repeatedly to be inadequate (e.g., Coope, 1979). It is almost impossible to demonstrate inter- or intra-specific competition on the basis of the fossil record (Finlayson, 2004). Neanderthals and Moderns probably coexisted for a prolonged period of time. Such coexistence started at least during MIS 5 in western Asia (Bar-Yosef, 1998) and could be the origin of a

gradient in the "Neanderthalization" of industries (Moncel and Voisin, 2006). Nevertheless, it is unlikely that climatic changes and synchronous human events were a fortuitous coincidence.

4.5. The southern Iberian Neanderthal habitat

During the MIS 3 Neanderthals successfully occupied transitional areas, such as the edges of limestone massifs adjacent to lowland plains (Davies et al., 2003) in the Overlap Province defined by Stewart et al. (2003a). However, persistent Neanderthal populations inhabited the Southern part of Iberia (Finlayson, 2004, 2005). Thus, the characteristics that distinguish the Southern Iberian from the Northern European Neanderthal habitats must be adequately taken into account. Neanderthal populations living in Southern Iberian probably took advantage of the following factors: (i) Mediterranean forest, rich in fatty fruits, and mainly controlled by climatic change and a heterogeneous topography (Cowling et al., 1996); (ii) a rich biotope area promoted by a complex topographical pattern which produced many environments and microclimatic conditions (e.g., Finlayson et al., 2001; Mota et al., 2002); (iii) a more diversified nutritional pattern, partially composed of Pine nuts, bivalves, shellfish (Finlayson et al., 2001) and marine mammals (Antunes, 2000); this diet may have generated a lower maternal foetus–infant mortality rate and higher life expectancy (Hockett and Haws, 2005); a highly diversified geological bedrock (e.g., ultramafic, volcanic acid and sedimentary rocks) may also have helped to provide essential nutrients via plants and/or herbivores; (iv) a "buffered climate" promoted by the WMS, which has its own thermohaline circulation system (Brankart and Brasseur, 1998); climate changes are slower and more moderate in the Alboran Sea, as compared to the Gulf of Cadiz or the Tyrrhenian Sea (Cacho et al., 2002); and finally, (v) one of the highest insolation coefficients in Europe, which must have guarantied hospitable diurnal temperatures, even during cold periods.

The complexity of such factors makes it necessary to analyse local climate records in order to reconstruct the paleoclimatic conditions. To date, paleoclimatic models have not taken topography into account and are based mainly on the Padul record (Huntley et al., 2003; Ortiz et al., 2004). However, since the latter is an intramountain basin, the temperatures for Southern Iberian may seem cooler in climatic reconstructions based on this location than they actually were.

4.6. The end of the southern Iberian Neanderthals

Glacial Maxima were critical periods during which extinction rates were exceptionally high. For example, tens of megafaunal species disappeared during the Last Penultimal Glacial Maxima (e.g., Wroe et al., 2006). Southern European refugia were also affected by such crises (O'Regan et al., 2002). For this reason, the number of warm species in present-day Iberian fauna is comparatively low (Blondel and Aronson, 1999). It is thought by some workers that Neanderthals were highly skilled in adapting to climatic changes and that their adaptive capacities were similar to those of Moderns (Boëda et al., 1996; d'Errico et al., 2001). Neanderthals may even have been able to survive during stable conditions of extreme cold. However, high climatic variability provokes generalized effects in ecosystems. Continuous variations in seasonal moisture or temperature tend to produce stressed environments. It has been shown that in current environments, which display a slight warming trend, imbalances can be observed in insect populations (Harrison et al., 2006), certain illnesses have widened their spread (e.g., Flahault et al., 2004), and there have been synchronous multi-biotope crises (Moreno et al., 2005b), as well as alterations in migrational-altitudinal patterns (e.g., Peñuelas and Filella, 2001; Peñuelas and Boada, 2003). Variations in vegetation type, plant digestibility, consumption rates and growth/mortality in herbivores, can be expected under such conditions (e.g., Lawler et al., 1997). Deficiencies in soil moisture caused by cold marine waters could lead to shorter growth seasons and an increase in days of snow cover, thus affecting herbivorous mammals and their occurrence ratios (Markova, 1992; Musil, 2003, Hernández Fernández and Vrba1, 2005). Any one of these factors could have provoked periods of poor nutritional quality or famine, leading to the extinction of highly regional populations. The last Neanderthals in southern Iberia were probably subjected to such isolated conditions from the BA2 event onwards. The disappearance of other reduced European populations around 30 ky BP may have been due to the aforementioned or other causes, such as genetic swamp and increasing continentality (Finlayson, 2004). It is also possible, however, that the extinction of the last southern Iberian Neanderthal populations occurred during the BA1 event, especially during a hypothetical extreme thermohaline activity event. Fig. 6c) represents this event mainly on the basis of our and other marine data (e.g., Sánchez-Goñi et al., 2000; Moreno et al., 2002) and models (Finlayson, 2006). The Neanderthal archaeological proxies found in southern Iberia and dated at between 25 and 30 ky BP could be accounted for by situating Neanderthal extinction during BA1. On the other hand, it is thought that the last Neanderthals were located in various European climatic refugia, such as the Iberian, Italian and Balkan peninsulas. However, the more favourable conditions characterizing the Iberian refugia (see Section 4.5) may have allowed them to survive longer (Finlayson and Giles-Pacheco, 2000; Stewart et al., 2003b; Finlayson, 2004). In any case, recent studies appear to indicate that, despite their greater adaptability to open environments (e.g., the North Plains) (Finlayson, 2004), Moderns were also subjected to conditions of isolation during the subsequent Last Glacial Maximum in southern European refugia (Hewitt and Ibrahim, 2001; Jobling et al., 2004).

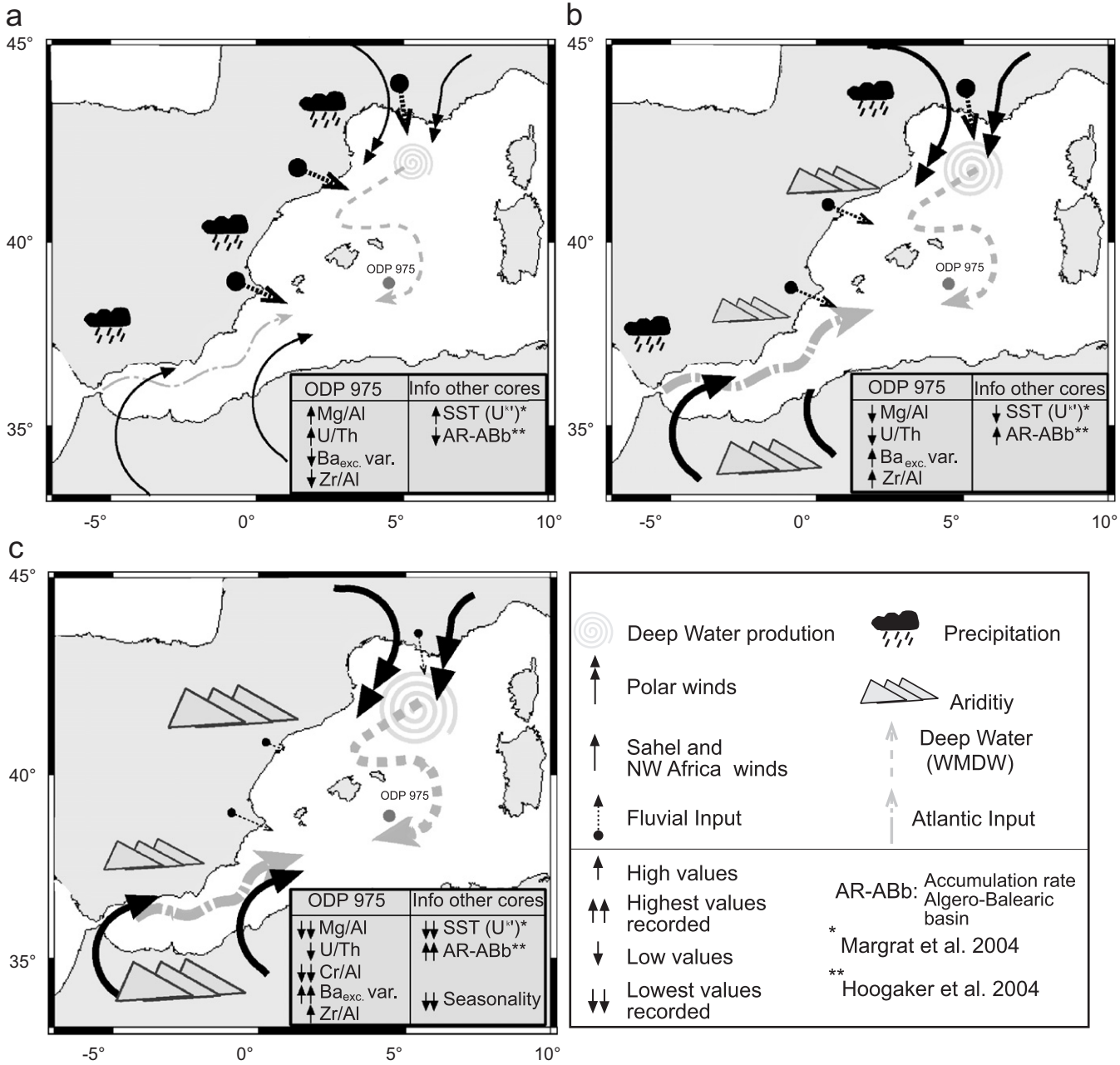

Fig. 6. Hypothetical climatic conditions constructed on the of basis of models (Finlayson, 2006), our data and marine records (e.g., Sánchez-Goñi et al., 2000 and Moreno et al., 2002) between 40 and 20 ky BP. (a) Favourable periods: D/O interstadials. (b) Non-favourable periods: D/O stadials and Heinrich events. (c) Extreme conditions during the BA3 event probably between 25 and 24 ky cal BP.

4.7. To what extent were climatic conditions really influential?

Because it is only in archaeological outcrops that direct interaction between humans and environment can be recorded, it is highly probable that the underlying causes of Neanderthal extinction will be found in such sites (Vega Toscano, 2005). However, due to the extremely complex sedimentation of archaeological deposits, their use in the reconstruction of climatic conditions is cumbersome. These complexities may be better handled by multidisciplinary studies which closely examine depositional systems and taphonomical features, thus enabling more coherent interpretations. Indeed, climatic factors could be linked to occupational patterns in coastal outcrops by geochemical research using non-destructive techniques, such as XRF core scanner (Jiménez-Espejo et al., 2006) and stable isotope analysis (Delgado-Huertas, pers. com.), in combination with other disciplines, (e.g., Yll et al., 2006).

If climate did play an important role in the extinction of the Neanderthals and the expansion of the Moderns, some of the hypotheses regarding this process are likely to be corroborated. Climatic variability during cold periods probably acted as a "territory cleanser", thus favouring a subsequent colonization by Moderns. Stable "frontiers" could be expected when hospitable conditions prevailed. It is likely that the most important episodes of replacement took place over relatively short periods, coinciding with adverse climatic conditions. For as yet unknown reasons, these areas were apparently more successfully recolonized by Moderns during subsequent periods of hospitable conditions. Therefore, the temporal–spatial location of the outcrops may play a major role in confirming climatic influence. North Africa also deserves particular attention, since chronological patterns could have been similar and disappearances may have been simultaneous.

5. Conclusions

Geochemical and mineralogical proxies show evidence of significant paleoenviromental changes in the WMS at time of Neanderthal extinction. Comparisons of different records suggest that from 250 ky down to 24 ky BP, the most extreme conditions in WMS were reached between 24 and 25 ky cal BP. Climatic changes apparently affected the number and distribution of Modern and Neanderthal sites in southern Iberia. Especially high values in millennial Ba_{excess} var. (BA events) are well correlated with some of the changes in the number of sites and in replacements of industries. Cold, arid and highly variable conditions could be associated with the penetration and presence of Modern industries. This suggests that climatic variability during cold periods in the non-analogue MIS 3 could have affected Neanderthal populations, thus promoting weakness, isolation or extinction. Indeed, the definitive disappearance of Neanderthals could be linked with the unfavourable conditions during BA1 (22.5–25.5 ky cal BP). However, in order to further clarify the causes of this disappearance, more in-depth studies should be carried out on outcrops in southern Iberia and North Africa.

Acknowledgements

This work was financed by Projects REN2003-09130-CO2-01 and CGL2006-13327-C04-04 (MEC), project RNM 432 and Research Group RNM 179 (Junta de Andalucía). We also thank project CSD2006-00041 (TOPOIBERIA). We would like to thank the ODP Core Repository (Bremen, Germany) for their assistance with sampling, and the university of Bremen for the use of the XRF core scanner. Other geochemical analyses were performed at the "Centro de Instrumentación Científica" (University of Granada), the Department of Mineralogy and Petrology (University of Granada), and the Japan Agency for Marine–Earth and Science Technology (JAMSTEC) laboratories. Our thanks to E. Abarca, E. Holanda, J. Montes, C. Niembro and D. Ortega for their laboratory assistance. Dr. J.S. Carrion and one anonymous reviewer are greatly thanked for constructive comments and reviews. The authors also are grateful to P. González-Sampériz and A. Moreno for their stimulating suggestion. Thorough editing of the original English manuscript was done by M. Bettini.

References

Abreu, L., Shackleton, N.J., Schönfeld, J., Hall, M., Chapman, M.R., 2003. Millennial-scale oceanic climate variability off the Western Iberian margin during the last two glacial periods. Marine Geology 196, 1–20.

Allen, J.R.M., Huntley, B., 2000. Weichselian palynological records from southern Europe: correlation and chronology. Quaternary International 73–74, 111–125.

Allen, J.R.M., Watts, W.A., Huntley, B., 2000. Weichselian palynostratigraphy, palaeovegetation and palaeoenvironment; the record from Lago Grande di Monticchio, southern Italy. Quaternary International 73–74, 91–110.

Antunes, M., 2000. The Pleistocene fauna from Gruta do Figueira Brava: a synthesis. In: Antunes, M. (Ed.), Last Neanderthals in Portugal: Odontologic and Other Evidence. Memorias da Academia das Ciencias de Lisboa, Lisbon, pp. 259–282.

Baena, J., Carrión, E., Ruiz, B., Sesé, C., Yravedra, J., Jordá, J., Uzquiano, P., Velázquez, R., Manzano, I., Sánchez-Marco, A., Hernández, F., 2005. Paleoecología y comportamiento humano durante el Pleistoceno Superior en la comarca de Liébana: la secuencia de la Cueva de El Esquilleu (Occidente de Cantabria, España). In: Barquín, R. M., Lasheras, J.A. (Coord.). Museo de Altamira, Monograph No. 20, Santander, pp. 461–487.

Bar-Yosef, O., 1998. The chronology of the Middle Paleolithic of the Levant. In: Akazawa, T., Aochi, K., Bar-Yosef, O. (Eds.), Neandertals and Modern Humans in Western Asia. Plenum Press, New York, pp. 39–56.

Bárcena, M.A., Cacho, I., Abrantes, F., Sierro, F.J., Grimalt, J.O., Flores, J.A., 2001. Paleoproductivity variations related to climatic conditions in the Alboran Sea (western Mediterranean) during the last glacial–interglacial transition: the diatom record. Palaeogeography, Palaeoclimatology, Palaeoecology 116, 337–357.

Bard, E., Rostek, F., Menot-Combes, G., 2004. Radiocarbon calibration beyond 20,000 14C yr B.P. by means of planktonic foraminifera of the Iberian Margin. Quaternary Research 61, 204–214.

Bartov, Y., Goldstein, S.L., Stein, M., Enzel, Y., 2003. Catastrophic arid episodes in the Eastern Mediterranean linked with the North Atlantic Heinrich events. Geology 31, 439–442.

Bea, F., Montero, P., Stroh, A., Baasner, J., 1996. Microanalysis of minerals by an Excimer UV-LA-ICP-MS system. Chemical Geology 133, 145–156.

Begin, Z.B., Stein, M., Katz, A., Machlus, M., Rosenfeld, A., Buchbinder, B., Bartov, Y., 2004. Southward migration of rain tracks during the last glacial, revealed by salinity gradient in Lake Lisan (Dead Sea rift). Quaternary Science Reviews 23, 1627–1636.

Bennett, K.D., Tzedakis, P.C., Willis, K.J., 1991. Quaternary Refugia of north European trees. Journal of Biogeography 18, 103–115.

Berger, A.L., 1978. Long term variations of daily insolation and Quaternary climatic changes. Journal of the Atmospheric Sciences 35, 2362–2367.

Blondel, J., Aronson, J., 1999. Biology and Wildlife of the Mediterranean Region. Oxford University Press, Oxford.

Bond, G.C., Showers, W., Elliot, M., Evans, M., Lotti, R., Hajdas, I., Bonani, G., Johnson, S., 1999. The North Atlantic's 1–2 kyr climate rhythm: relation to Heinrich events, Dansgaard/Oescher cycles and the Little Ice Age. In: Clark, P.U., Webb, R.S., Keigwin, L.D. (Eds.), Mechanisms of Global Climate Change at Millennial Time Scales. Geophysical Monograph, vol. 112, pp. 35–58.

Boëda, E., Connan, J., Dessort, D., Muhesen, S., Mercier, N., Valladas, H., Tisnérat, N., 1996. Bitumen as a Hafting material on Middle Palaeolithic artefacts. Nature 380, 336–337.

Brankart, J.M., Brasseur, P., 1998. The general circulation in the Mediterranean Sea: a climatic approach. Journal of Marine Systems 18, 41–70.

Brauer, G., 1992. Africa's place in the evolution of modern humans. In: Brauer, G., Smith, F.H. (Eds.), Continuity or Replacement. Controversies in *Homo sapiens* Evolution. A A Balkema, Rotterdam, pp. 63–98.

Burroughs, W., 2005. Climate Change in Prehistory: The End of the Reign of Chaos. University of Cambridge, Cambridge.

Cacho, I., Grimalt, J.O., Pelejero, C., Canals, M., Sierro, F.J., Flores, J.A., Shacklenton, N.J., 1999. Dansgaard–Oeschger and Heinrich event imprints in Alboran Sea temperatures. Paleoceanography 14, 698–705.

Cacho, I., Grimalt, J.O., Sierro, F.J., Shackleton, N., Canals, M., 2000. Evidence for enhanced Mediterranean thermohaline circulation during rapid climatic coolings. Earth and Planetary Science Letters 183, 417–429.

Cacho, I., Grimalt, J.O., Canals, M., 2002. Response of the Western Mediterranean Sea to rapid climatic variability during the last 50,000 years: a molecular biomarker approach. Journal of Marine Systems 33–34, 253–272.

Calvert, S.E., 1990. Geochemistry and origin of the Holocene sapropel in the Black Sea. In: Ittekkot, V., Kempe, S., Michaelis, W., Spitzy, A. (Eds.), Facets of Modern Biogeochemistry. Spring, Berlin, pp. 326–352.

Calvert, S.E., Bustin, R.M., Ingall, E.D., 1996. Influence of water column anoxia and sediment supply on the burial and preservation of organic carbon in marine shales. Geochimica et Cosmochimica Acta 60, 1577–1593.

Carrión, J.S., 2004. The use of two pollen records from deep sea cores to frame adaptive evolutionary change for humans: a comment on "Neanderthal extinction and the millennial scale climate variability of OIS 3" by F. d'Errico and M.F. Sánchez-Goñi. Quaternary Science Reviews 23, 1217–1219.

Carrión, J.S., Dupre, M., Fumanal, M.P., Montes, R.A., 1995. Paleoenvironmental study in the semi-arid southeastern Spain: the palynological and sedimentological sequence at Perneras Cave (Lorca, Murcia). Journal of Archaeological Science 22, 355–367.

Carrión, J.S., Munuera, M., Navarro, C., Sáez, F., 2000. Paleoclimas e historia de la vegetación cuaternaria en España a través del análisis polínico: viejas falacias y nuevos paradigmas. Complutum 11, 115–142.

Comas, M.C., Zahn, R., Klaus, A., et al., 1996. Proceedings of the ODP Initial Reports 161. Ocean Drilling Program, College Station, TX.

Coope, G.R., 1979. Late Cenozoic fossil coleoptera: evolution, biogeography and ecology. Annual Review of Ecology and Sistematics 10, 247–267.

Cortijo, E., Labeyrie, L., Vidal, L., Vautravers, M., Chapman, M., Duplessy, J.-C., Elliot, M., Arnold, M., Turon, J.-L., Auffret, G., 1997. Changes in sea surface hydrology associated with Heinrich event 4 in the North Atlantic Ocean between 40° and 60 °N. Earth and Planetary Science Letters 146, 29–45.

Cortijo, E., Duplessy, J.-C., Labeyrie, L., Duprat, J., Paillard, D., 2005. Heinrich events: hydrological impact. Comptes Rendus Geosciences 337, 897–907.

Cowling, R.M., Rundel, P.W., Lamont, B.B., Arroyo, M.K., Arianoutsou, M., 1996. Plant diversity in Mediterranean-climate regions. Trends in Ecology and Evolution 11, 362–366.

Davies, W., Valdes, P., Ross, C., van Andel, T., 2003. The human presence in Europe during the last glacial period III: site clusters, regional climates and resource attractions. In: van Andel, T.H., Davies, W. (Eds.), Neanderthals and Modern Humans in the European Landscape during the Last Glaciation, 60,000 to 20,000 Years Ago: Archaeological Results of the Stage 3 Project. McDonald Institute Monograph Series, pp. 167–190.

Dehairs, F., Lambert, C.E., Chesselet, R., Risler, N., 1987. The biological production of marine suspended barite and the barium cycle in the western Mediterranean Sea. Biochemistry 4, 119–139.

De Lange, G.J., Van Santvoort, P.J.M., Langereis, C., Thomson, J., Corselli, C., Michard, A., Rossignol-Strick, M., Paterne, M., Anastasakis, G., 1999. Palaeo-environmental variations in eastern Mediterranean sediments: a multidisciplinary approach in a prehistoric setting. Progress in Oceanography 44, 369–386.

Dymond, J., Suess, E., Lyle, M., 1992. Barium in deep-sea sediments: a geochemical proxy for paleoproductivity. Paleoceanography 7, 163–181.

d'Errico, F., Sánchez-Goñi, M.F., 2003. Neandertal extinction and the millennial scale climatic variability of OIS 3. Quaternary Science Reviews 22, 769–788.

d'Errico, F., Henshilwood, C., Nilssen, P., 2001. An engraved bone fragment from c. 70,000-year-old Middle Stone Age levels at Blombos Cave, South Africa: implications for the origin of symbolism and language. Antiquity 75, 309–318.

Eagle, M., Paytan, A., Arrigo, K., Van Dijken, G., Murray, R., 2003. A comparison between excess barium and barite as indicators or export production. Paleoceanography 18, 21.1–21.13.

Eagle Gonneea, M., Paytan, A., 2006. Phase associations of barium in marine sediments. Marine Chemistry 100, 124–135.

Elliot, M., Labeyrie, L., Duplessy, J.-C., 2002. Changes in North Atlantic deep-water formation associated with the Dansgaard–Oeschger temperature oscillations (10–60 ka). Quaternary Science Reviews 21, 1153–1165.

Emeis, K.C., Struck, U., Schulz, H.-M., Rosenberg, R., Bernasconi, S., Erlenkeuser, H., Sakamoto, T., Martínez- Ruiz, F., 2000. Temperature and salinity variations of Mediterranean Sea surface waters over the last 16,000 years from records of planktonic stable oxygen isotopes and alkenone unsaturation ratios. Palaeogeography, Palaeoclimatology, Palaeoecology 158, 259–280.

Finlayson, C., 1999. Late Pleistocene Human Occupation of the Iberian Peninsula. Journal Iberian Archaeology 1, 59–68.

Finlayson, C., 2004. Neanderthals and Modern Humans: An Ecological and Evolutionary Perspective. Cambridge University Press, Cambridge.

Finlayson, C., 2005. Biogeography and evolution of the genus *Homo*. Trends in Ecology and Evolution 20, 457–463.

Finlayson, G., 2006. Climate, vegetation and biodiversity—a multiscale study of the South of the Iberian Peninsula. Ph.D. Thesis, Anglia Ruskin University.

Finlayson, C., Giles-Pacheco, F., 2000. The southern Iberian Peninsula in the late Pleistocene: geography, ecology, and human occupation. In:

Stringer, C.B., Barton, R.N.E., Finlayson, J.C. (Eds.), Neanderthals on the Edge. Oxbow Books, Oxford, pp. 139–159.

Finlayson, C., Barton, R., Stringer, C., 2001. The Gibraltar Neanderthals and their extinction. In: Zilhao, J., Aubry, T., Carvalho, A. (Eds.), Les Premiers Hommes Modernes de la Peninsule Iberique. Inst. Portugues de Arqueologia, Trabalhos de Arqueologia 17, Lisbon, pp. 117–122.

Finlayson, C., Fa, D., Finlayson, G., Giles-Pacheco, F., Rodríguez-Vidal, J.R., 2004. Did the moderns kill off the Neanderthals? A reply to F. d'Errico and Sánchez-Goñi. Quaternary Science Reviews 23, 1205–1209.

Finlayson, C., Giles Pacheco, F., Rodríguez-Vidal, J., Fa, D.A., Gutierrez López, J.M., Santiago Perez, A., Finlayson, G., Allue, E., Baena Preysler, J., Cáceres, I., Carrión, J.S., Fernández Jalvo, Y., Gleed-Owen, C.P., Jiménez-Espejo, F.J., López, P., López Sáez, J.A., Riquelme Cantal, J.A., Sánchez Marco, A., Giles Guzman, F., Brown, K., Fuentes, N., Valarino, C.A., Villalpando, A., Stringer, C.B., Martinez-Ruiz, F., Sakamoto, T., 2006. Late survival of Neanderthals at the southernmost extreme of Europe. Nature advance online publication 13 September 2006, doi:10.1038/nature05195.

Flahault, A., Viboud, C., Pakdaman, K., Boëlle, P.Y., Wilson, M.L., Myers, M., Valleron, A.J., 2004. Association of influenza epidemics in France and the USA with global climate variability. International Congress Series 1263, 73–77.

Flores, J.A., Sierro, F.J., Frances, G., Vazquez, A., Zamarreno, I., 1997. The last 100,000 years in the western Mediterranean: sea surface water and frontal dynamics as revealed by coccolithophores. Marine Micropaleontology 29, 351–366.

Flores, J.C., 1998. A mathematical model for Neanderthal extinction. Journal of Theoretical Biology 191, 295–298.

González-Sampériz, P., Valero-Garcés, B.L., Moreno, A., Jalut, G., García-Ruiz, J.M., Martí-Bono, C., Delgado-Huertas, A., Navas, A., Otto, T., Dedoubat, J.J., 2006. Climate variability in the Spanish Pyrenees during the last 30,000 yr revealed by the El Portalet sequence. Quaternary Research, in press.

Gutierrez, M., Gutierrez, F., Desir, G., 2006. Considerations on the chronological and causal relationship between talus flatirons and palaeoclimatic changes in central and northeastern Spain. Geomorphology 73, 50–63.

Gwiazda, R.H., Hemming, S.R., Broecker, W.S., 1996. Tracking the sources of icebergs with lead isotopes: the provenance of ice-rafted debris in Heinrich layer 2. Paleoceanography 11, 77–93.

Harpending, H., Sherry, S.T., Rogers, A.L., Stoneking, M., 1993. The genetic structure of ancient human populations. Current Anthropology 34, 483–496.

Harrison, P.A., Berry, P.M., Butt, N., New, M., 2006. Modelling climate change impacts on species' distributions at the European scale: implications for conservation policy. Environmental Science and Policy 9, 116–128.

Haug, G.H., Günther, D., Peterson, L.C., Sigman, D.M., Hughen, K.A., Aeschlimann, B., 2003. Climate and the collapse of Maya civilization. Science 299, 1731–1735.

Hemming, S.R., 2004. Heinrich events: massive late pleistocene detritus layers of the North Atlantic and their global climate imprint. Reviews of Geophysics 42, RG1005.

Hernández Fernández, M., Vrba1, E.S., 2005. Rapoport effect and biomic specialization in African mammals: revisiting the climatic variability hypothesis. Journal of Biogeography 32, 903–918.

Hewitt, G.M., 2000. The genetic legacy of the Quaternary ice ages. Nature 405, 907–913.

Hewitt, G.M., Ibrahim, K.M., 2001. Infering glacial refugia and historical migrations with molecular phylogenies. In: Silvertown, J., Antonovics, J. (Eds.), Integrating Ecology and Evolution in a Spatial Context. British Ecological Society. Blackwell-Science, Oxford.

Hockett, B., Haws, J.A., 2005. Nutritional ecology and the human demography of Neanderthal extinction. Quaternary International 137, 21–34.

Hoogakker, B.A.A., Rothwell, R.G., Rohling, E.J., Paterne, M., Stow, D.A.V., Herrle, J.O., Clayton, T., 2004. Variations in terrigenous dilution in western Mediterranean Sea pelagic sediments in response to climate change during the last glacial cycle. Marine Geology 211, 21–43.

Horan, R.D., Bulte, E., Shogren, J.F., 2005. How trade saved humanity from biological exclusion: an economic theory of Neanderthal extinction. Journal of Economic Behavior and Organization 58, 1–29.

Housley, R.A., Gamble, C.S., Pettitt, P., 2001. Reply to Blockley, Donahue and Pollard. Antiquity 74, 119–121.

Huntley, B., Alfano, M.J., Allen, J.R.M., Pollard, D., Tzedakis, P.C., Beaulieu, J.L., Gruger, E., Watts, B., 2003. European vegetation during Marine Oxygen Isotope Stage-3. Quaternary Research 59, 195–212.

Jansen, J.H.F., Van der Gaast, S.J., Koster, B., Vaars, A.J., 1998. CORTEX, a shipboard XRF-scanner for element analyses in split sediment cores. Marine Geology 151, 143–153.

Jiménez-Espejo, F.J., Martínez-Ruiz, F., Sakamoto, T., Iijima, K., Harada, N., 2006. Paleoenvironmental changes in the Baleraric basin since the last glacial: linking western and eastern climate responses in the Mediterranean. Palaeogeography, Palaeoclimatology, Palaeoecology, doi:10.1016/j.palaeo.2006.10.005.

Jobling, M.A., Hurles, M.E., Tyler-Smith, C., 2004. Human Evolutionary Genetics: Origins, Peoples & Disease. Garland Science, New York.

Kirsch, H.J., 1991. Illite crystallinity: recommendations on sample preparation, X-ray diffraction settings, and interlaboratory samples. Journal of Metamorphic Geology 9, 665–670.

Lahr, M.M., Foley, R., 1998. Towards a theory of modern human origins: geography, demography, and diversity in recent human evolution. Yearbook of Physical Anthropology 41, 137–176.

Lawler, I.R., Foley, W.J., Woodrow, I.E., Cork, S.J., 1997. The effects of elevated CO_2 atmospheres on the nutritional quality of *Eucalyptus* foliage and its interaction with soil nutrient and light availability. Oecologia 109, 59–68.

Llave, E., Schönfeld, J., Hernández-Molina, F.J., Mulder, T., Somoza, L., Diaz del Rio V. Sánchez-Almazo, I., 2006. High-resolution stratigraphy of the Mediterranean outflow contourite system in the Gulf of Cadiz during the late Pleistocene: the impact of Heinrich events. Marine Geology 227, 241–262.

Magri, D., Parra, I., 2002. Late Quaternary western Mediterranean pollen records and African winds. Earth and Planetary Science Letters 200, 401–408.

Mangini, A., Jung, M., Laukenmann, S., 2001. What do we learn from peaks of uranium and of manganese in deep sea sediments? Marine Geology 177, 63–78.

Marin, B., Giresse, P., 2001. Particulate manganese and iron in recent sediments of the Gulf of Lions continental margin (north-western Mediterranean Sea): deposition and diagenetic process. Marine Geology 172, 147–165.

Markova, A.K., 1992. Influence of paleoclimatic changes in the middle and Late Pleistocene on the composition of small mammal faunas: data from Eastern Europe mammalian migration and dispersal. Events in the European Quaternary. Courier Forschung-Institut Senckenberg 153, 93–100.

Martín, J.D., 2004. Qualitative and quantitative powder X-ray diffraction analysis. URL:http://www.xpowder.com ISBN: 84-609-1497-6.

Martínez-Ruiz, F., Kastner, M., Paytan, A., Ortega-Huertas, M., Bernasconi, S.M., 2000. Geochemical evidence for enhanced productivity during S1 sapropel deposition in the eastern Mediterranean. Paleoceanography 15, 200–209.

Martínez-Ruiz, F., Paytan, A., Kastner, M., González-Donoso, J.M., Linares, D., Bernasconi, S.M., Jiménez-Espejo, F.J., 2003. A comparative study of the geochemical and mineralogical characteristics of the S1 sapropel in the western and eastern Mediterranean. Palaeogeography, Palaeoclimatology, Palaeoecology 190, 23–37.

Martinson, D.G., Pisias, N.G., Hays, J.D., Imbrie, J., Moore, T.C., Shackleton, J., 1987. Age dating and the orbital theory of the Ice Ages: development of a high-resolution 0 to 300,000-year chronostratigraphy. Quaternary Research 27, 1–29.

Martrat, B., Grimalt, J.O., López-Martínez, C., Cacho, I., Sierro, F.J., Flores, J.A., Zahn, R., Canals, M., Curtis, J.H., Hodell, D.A., 2004.

Abrupt temperature changes in the Western Mediterranean over the past 250,000 years. Science 306, 1762–1765.

Maslin, M., Seidov, D., Lowe, J., 2001. Synthesis of the nature and causes of rapid climate transitions during the Quaternary. In: Seidov, D., Haupt, B.J., Maslin, M. (Eds.), The Oceans and Rapid Climate Change: Past, Present and Future. Geophysical Monograph, vol. 126. EGU, pp. 9–51.

McManus, J., Berelson, W.M., Klinkhammer, G.P., Johnson, K.S., Coale, K.H., Anderson, R.F., Kumar, N., Burdige, D.J., Hammond, D.E., Brumsack, H.J., 1998. Geochemistry of barium in marine sediments: implications for its use as a paleoproxy. Geochimica et Cosmochimica Acta 62, 3453–3473.

Mellars, P., 2006. A new radiocarbon revolution and the dispersal of modern humans in Eurasia. Nature 439, 931–935.

Meyers, P.A., 1994. Preservation of elemental and isotopic source identification of sedimentary organic matter. Chemical Geology 114, 289–302.

Moncel, M.-H., Voisin, J.-L., 2006. Les «industries de transition» et le mode de spéciation des groupes néandertaliens en Europe entre 40 et 30 ka. Comptes Rendus Palevol 5, 183–192.

Moreno, A., Cacho, I., Canals, M., Prins, M.A., Sánchez-Goñi, M.-F., Grimalt, J.O., Weltje, G.J., 2002. Saharan dust transport and high-latitude glacial climatic variability: the Alboran sea record. Quaternary Research 58, 318–328.

Moreno, A., Cacho, I., Canals, M., Grimalt, J.O., Sánchez-Vidal, A., 2004. Millennial-scale variability in the productivity signal from the Alboran Sea record, Western Mediterranean Sea. Palaeogeography, Palaeoclimatology, Palaeoecology 211, 205–219.

Moreno, A., Cacho, I., Canals, M., Grimalt, J.O., Sánchez-Goñi, M.F., Shackleton, N., Sierro, F.J., 2005a. Links between marine and atmospheric processes oscillating on a millennial time-scale. A multi-proxy study of the last 50,000 yr from the Alboran Sea (Western Mediterranean Sea): Quaternary land–ocean correlation. Quaternary Science Reviews 24, 1623–1636.

Moreno, J.M., (Coord.) et al., 2005b. Principales conclusiones de la evaluación preliminar de los impactos climáticos en España por efecto del cambio climático. Oficina Española de cambio climático. Ministerio de Medio Ambiente.

Mota, J.F., Perez-García, F.J., Jiménez, M.L., Amata, J.J., Peñas, J., 2002. Phytogeographical relationships among high mountain areas in the Baetic Ranges (South Spain). Global Ecology and Biogeography 11, 497–504.

Musil, R., 2003. The middle and upper Palaeolithic game suite of central and southeastern Europe. In: van Andel, T.H., Davies, W. (Eds.), Neanderthals and Modern Humans in the European Landscape During the Last Glaciation, 60,000 to 20,000 Years Ago: Archaeological Results of the Stage 3 Project. McDonald Institute Monograph Series, pp. 167–190.

O'Regan, H.J., Turner, A., Wilkinson, D.M., 2002. European Quaternary refugia: a factor in large carnivore extinction? Journal of Quaternary Science 17, 789–796.

Ortiz, J.E., Torres, T., Delgado, A., Julir, R., Lucini, M., Llamas, F.J., Reyes, E., Soler, V., Valle, M., 2004. The palaeoenvironmental and palaeohydrological evolution of Padul Peat Bog (Granada, Spain) over one million years, from elemental, isotopic and molecular organic geochemical proxies. Organic Geochemistry 35, 1243–1260.

Paytan, A., Kastner, M., Martin, E.E., Macdougall, J.D., Herbert, T., 1993. Marine barite as a monitor of seawater strontium isotope composition. Nature 366, 445–449.

Paytan, A., Kastner, M., Chavez, F.P., 1996. Glacial to interglacial fluctuations in the Equatorial Pacific as indicated by marine barite. Science 274, 1355–1357.

Paytan, A., Martínez-Ruiz, F., Ivy, A., Eagle, M., Wankel, S.D., 2004. Using sulfur isotopes in barite to elucidate the origin of high organic matter accumulation events in marine sediments. In: Amend, J.P., Edwards, K.J., Lyons, T.W. (Eds.), Sulfur Biogeochemistry: Past and Present. GSA Special Paper 379, Boulder CO, pp. 151–160.

Peñuelas, J., Filella, I., 2001. Responses to a warming world. Science 294, 793–794.

Peñuelas, J., Boada, M., 2003. A global change-induced biome shift in the Montseny mountains (NE Spain). Global Change Biology 9, 131–140.

Perez-Folgado, M., Sierro, F.J., Flores, J.A., Cacho, I., Grimalt, J.O., Zahn, R., Shackleton, N., 2003. Western Mediterranean planktonic foraminifera events and millennial climatic variability during the last 70 kyr. Marine Micropaleontology 48, 49–70.

Reimer, et al., 2006. Comment on "Radiocarbon calibration curve spanning 0 to 50,000 years BP based on paired $^{230}Th/^{234}U/^{238}U$ and ^{14}C dates on pristine corals" by R.G. Fairbanks et al. (Quaternary Science Reviews 24 (2005) 1781–1796)$ and "Extending the radiocarbon calibration beyond 26,000 years before present using fossil corals" by T.-C. Chiu et al. (Quaternary Science Reviews 24 (2005) 1797–1808). Quaternary Science Reviews 25, 855–862.

Robinson, S.A., Black, S., Sellwood, B.W., Valdes, P.J., 2006. A review of palaeoclimates and palaeoenvironments in the Levant and Eastern Mediterranean from 25,000 to 5,000 years BP: setting the environmental background for the evolution of human civilisation. Quaternary Science Reviews.

Roche, D.M., Paillard, D., 2005. Modelling the oxygen-18 and rapid glacial climatic events: a data–model comparison. Comptes Rendus Geosciences 337, 928–934.

Rogerson, M., Rohling, E.J., Weaver, P.P.E., Murray, J.W., 2004. The Azores Front since the Last Glacial maximum. Earth and Planetary Science Letters 222, 779–789.

Rohling, E.J., Den Dulk, M., Pujol, C., Vergnaud-Grazzini, C., 1995. Abrupt hydrographic change in the Alboran Sea (western Mediterranean) around 8000 yrs BP. Deep-Sea Research I 42, 1609–1619.

Rohling, E.J., Mayewski, P.A., Challenor, P., 2003. On the timing and mechanism of millennial-scale climate variability during the last glacial cycle. Climate Dynamics 20, 257–267.

Roucoux, K.H., Abreu, L., Shackleton, N.J., Tzedakis, P.C., 2005. The response of NW Iberian vegetation to North Atlantic climate oscillations during the last 65 kyr. Quaternary Science Reviews 24, 1637–1653.

Rölh, U., Abrams, L.J., 2000. High-resolution, downhole, and nondestructive core measurements from Sites 999 and 1001 in the Caribean Sea: application to the late Paleocene Thermal Maximum. In: Leckie, R.M., Sigurdsson, H., Acton, G.D., Draper, G. (Eds.), Proceedings of the ODP, Science Results, vol. 165, College Station, TX. pp. 191–203.

Sánchez-Goñi, M.F., Turon, J.L., Eynaud, F., Gendreau, S., 2000. European climatic reponse to millenial-scale changes in the atmosphere–ocean system during the Last Glacial period. Quaternary Research 54, 394–403.

Sánchez-Goñi, M.F., Loutre, M.F., Crucifix, M., Peyron, O., Santos, L., Duprat, J., Malaize, B., Turon, J.-L., Peypouquet, J.-P., 2005. Increasing vegetation and climate gradient in Western Europe over the Last Glacial Inception (122–110 ka): data–model comparison. Earth and Planetary Science Letters 231, 111–130.

Seidov, D., Barron, E.J., Haupt, B.J., 2001. Meltwater and the global ocean conveyor: northern versus southern connections. Global and Planetary Change 30, 257–270.

Stewart, J.R., 2004a. Neanderthal-modern human competition? A comparison between the mammals associated with middle and upper Palaeolithic industries in Europe during OIS 3. International Journal of Osteoarchaeology 14, 178–189.

Stewart, J.R., 2004b. The Fate of Neanderthals a special case or simply part of the broader Late Pleistocene megafaunal extinctions? The Upper Palaeolithic Acts of the XIVth UISPP Congress, Liege, Belgium. BAR International Series, vol. 1240, pp. 261–273.

Stewart, J.R., 2005. The ecology and adaptation of Neanderthals during the non-analogue environment of Oxygen Isotope Stage 3: armageddon or entente? The demise of the European Neanderthals in Isotope Stage 3. Quaternary International 137, 35–46.

Stewart, J.R., Lister, A.M., 2001. Cryptic northern refugia and the origins of modern biota. Trends in Ecology and Evolution 16, 608–613.

Stewart, J.R., van Kolfschoten, M., Markova, A., Musil, R., 2003a. The mammalian faunas of Europe during Oxygen Isotope Stage three. In: van Andel, T.H., Davies, W. (Eds.), Neanderthals and Modern

Humans in the European Landscape During the Last Glaciation 60,000 to 20,000 Years Ago: Archaeological Results of the Stage Three Project. McDonald Institute Monograph Series, pp. 103–129.

Stewart, J.R., van Kolfschoten, M., Markova, A., Musil, R., 2003b. Neanderthals as part of the broader Late Pleistocene megafaunal extinctions? In: van Andel, T.H., Davies, W. (Eds.), Neanderthals and Modern Humans in the European Landscape During the Last Glaciation 60,000 to 20,000 Years Ago: Archaeological Results of the Stage Three Project. McDonald Institute Monograph Series, pp. 221–231.

Stringer, C., Andrews, P., 1988. Genetic and fossil evidence for the evolution of modern humans. Science 239, 1263–1268.

Stringer, C., Pälike, H., van Andel, T.H., Huntley, B., Valdez, P., Allen, J.R.M., 2003. Climatic stress and the extinction of the Neanderthals. In: van Andel, T.H., Davies, W. (Eds.), Neanderthals and Moderns Humans in the European Landscape during the Last Glaciation, 60,000 to 20,000 Years Ago: Archaeological Results of the Stage Three Project. McDonalds Institute Monograph Series, pp. 233–240.

Stuivert, M., Reimer, P.J., 1993. Radiocarbon calibration program. Radiocarbon, 125–230.

Taberlet, P., Fumagalli, L., Wust-Saucy, A.-G., Cosson, J.-F., 1998. Comparative phylogeography and postglacial colonization routes in Europe. Molecular Ecology 7, 453–464.

Taylor, K.C., White, J.W.C., Severinghaus, J.P., Brook, E.J., Mayewski, P.A., Alley, R.B., Steig, E.J., Spencer, M.K., Meyerson, E., Meese, D.A., 2004. Abrupt climate change around 22 ka on the Siple Coast of Antarctica. Quaternary Science Reviews 23, 7–15.

Trinkaus, E., 1995. Neanderthal mortality patterns. Journal of Archaeological Science 22, 121–142.

Turney, C.S.M., Roberts, R.G., Jacobs, Z., 2006. Progress and pitfalls in radiocarbon dating. Arising from: P. Mellars. Nature 439, 931–935.

Turon, J.L., Lezine, A.M., Denefle, M., 2003. Land–sea correlations for the last glaciation inferred from a pollen and dinocyst record from the portuguese margin. Quaternary Research 59, 88–96.

Tzedakis, P.C., Lawson, I.T., Frogley, M.R., Hewitt, G.M., Preece, R.C., 2002. Buffered tree population changes in a Quaternary refugium: evolutionary implications. Science 297, 2044–2047.

Vega Toscano, L.G., 2005. El final del Paleolitico Medio y el inicio del Paleolitico Superior: más allá de los datos Cantábricos. In: Barquín, R. M., Lasheras, J.A., (Coord.) Neandertales Cantábricos: estado de la cuestión, Museo de Altamira, Monograph No. 20. Santander, pp. 541–556

Voelker, A.H.L., and workshop participants, 2002. Global distribution of centennial-scale records for Marine Isotope Stage (MIS) 3: a database. Quaternary Science Reviews 21, 1185–1212.

Voelker, A.H.L., Lebreiro, S.M., Schönfeld, J., Cacho, I., Erlenkeuser, H., Abrantes, F., 2006. Mediterranean outflow strengthening during northern hemisphere coolings: a salt source for the glacial Atlantic? Earth and Planetary Science Letters 245, 39–55.

Wehausen, R., Brumsack, H.-J., 1999. Cyclic variations in the chemical composition of eastern Mediterranean Pliocene sediments: a key for understanding sapropel formation. Marine Geology 153, 161–176.

Weldeab, S., Siebel, W., Wehausen, R., Emeis, K.C., Schmiedl, G., Hemleben, C., 2003. Late Pleistocene sedimentation in the Western Mediterranean Sea: implications for productivity changes and climatic conditions in the catchment areas. Palaeogeography, Palaeoclimatology, Palaeoecology 190, 121–137.

Willis, K.J., 1996. Where did all the flowers go? The fate of temperate European flora during the glacial periods. Endeavour 20, 110–114.

Wolpoff, M., 1989. Multiregional evolution: the fossil alternative to Eden. In: Mellars, P., Stringer, C. (Eds.), The Human Revolution. Edinburgh University Press, Edinburgh, pp. 62–108.

Woodward, F.I., 1987. Climate and Plant Distribution. Cambridge University Press, Cambridge.

Wroe, S., Field, J., Grayson, D.K., 2006. Megafaunal extinction: climate, humans and assumptions. Trends in Ecology and Evolution 21, 61–62.

Yll, R., Carrión, J.S., Marra, A.C., Bonfiglio, L., 2006. Vegetation on the basis of pollen in Late Pleistocene hyena coprolites form San Teodoro Cave (Sicily, Italy). Palaeogeography, Palaeoclimatology, Palaeoecology 237, 32–39, doi:10.1016/j.palaeo.2005.11.027

Zilhao, J., 1996. The extinction of Iberian Neanderthals and its implications for the origins of modern humans in Europe. Actes du XIII Congres des Sciences Prehistoriques et Protohistoriques 2, 299–312. Forli, Abaco.