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Environmental conditions and geomorphologic changes during the Middle–Upper Paleolithic in the southern Iberian Peninsula

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ABSTRACT

This study utilizes geomorphology, marine sediment data, environmental reconstructions and the Gorham's Cave occupational record during the Middle to Upper Paleolithic transition to illustrate the impacts of climate changes on human population dynamics in the Western Mediterranean. Geomorphologic evolution has been dated and appears to be driven primarily by coastal dune systems, sea-level changes and seismo-tectonic evolution. Continental and marine records are well correlated and used to interpret the Gorham's Cave sequence. Specific focus is given to the three hiatus sections found in Gorham's Cave during Heinrich periods 4, 3 and 2. These time intervals are compared with a wide range of regional geomorphologic, climatic, paleoseismic, faunal and archeological records. Our data compilations indicate that climatic and local geomorphologic changes explain the *Homo sapiens* spp. occupational hiatuses during Heinrich periods 4 and 3. The last hiatus corresponds to the replacement of *Homo neanderthalensis* by *H. sapiens*. Records of dated cave openings, slope breccias and stalactite falls suggest that marked geomorphologic changes, seismic activity and ecological perturbations occurred during the period when *Homo* replacement took place.

1. Introduction

The timing and geography of *Homo neanderthalensis*' extinction is well known, but the causes for the extinction remain in dispute (Finlayson et al., 2006). Specifically, the role environmental factors play in this extinction is much debated (e.g., Wolpoff, 1989; Lahr and Foley, 1998; Stringer, 2003; Horan et al., 2005; Roebroeks, 2006; Jiménez-Espejo et al., 2007; Tzedakis, et al., 2007; Banks et al., 2008; Finlayson et al., 2008a,b; Zilhão et al., 2010b). The use of combined archeological and paleoclimate data, together with continued improvements in radiocarbon chronology, can shed light on the relationship between past climate conditions and changes in *Homo* spp. populations (e.g., Bard et al., 2004; Mellars, 2006; Tzedakis et al., 2007; Vaks et al., 2007; González Sampériz et al., 2009; Blaauw, 2010; Müller et al., 2011; Pinhasi et al., 2011).

Archeological sites with well-dated *Homo* spp. presence over extended time intervals are most adequate for investigating the climate/environmental influence on population dynamics. Gorham's Cave (Gibraltar) is recognized as the last site occupied by Neanderthals (Finlayson et al., 2006; Jennings et al., 2011) with the youngest date for Mousterian Middle Paleolithic occupation, between 28,700 and 27,600 cal. yr BP, at the 1σ range Calpal calibration (Weninger et al., 2011) (Tables 1 and 2), and has been occupied for extended time intervals. It can thus be used to determine the relation between occupation and regional climate/environmental changes.

Gorham's Cave is located in the southern Iberian Peninsula, an area that functions as a major faunal refuge during the Pleistocene due to its topographic, climatic and latitudinal setting (Jennings et al., 2011). Despite the refuge character of this region several *Homo*

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Table 1
Results of AMS ^{14}C dates and errors from Gorham's Cave sequence from Finlayson et al. (2006), translated to Cariaco record depths following Tzedakis et al. (2007) Supplementary information. AMS ^{14}C date numbers correspond to those give in Finlayson et al. (2006).

Sample no.	Laboratory reference	AMS radiocarbon age (yr)	Err. ±	^{14}C added uncertainty (S+)	^{14}C subst. uncertainty (S−)	Shallowest depth C+>S− (cm)	Deepest depth S+>C− (cm)
8	Beta-184042	18,440	160	18,600	18,280	9.66	9.96
23	Beta-196782	23,360	320	23,680	23,040	12.36	12.66
15	Beta-185345	23,780	540	24,320	23,240	12.66	13.21
16	Beta-196775	24,010	320	24,330	23,690	12.65	13.21
9	Beta-196785	26,070	360	26,430	25,710	13.51	14.10
17	Beta-196773	26,400	440	26,840	25,960	13.77	14.18
11	Beta-185344	27,020	480	27,500	26,540	14.07	14.20
10	Beta-196784	28,360	480	28,840	27,880	14.23	14.69
18	Beta-196791	28,570	480	29,050	28,090	14.28	14.83
19	Beta-196779	29,400	540	29,940	28,860	14.69	15.30
12	Beta-196786	29,910	600	30,510	29,310	14.78	15.59
14	Beta-196792	30,310	620	30,930	29,690	16.07	17.16
20	Beta-196776	30,560	720	31,280	29,690	15.07	16.16
13	Beta-196787	31,480	740	32,220	30,740	15.45	16.73
25	Beta-196772	31,780	720	32,500	31,060	15.92	16.87
26	Beta-196789	32,100	800	32,900	31,300	15.69	17.16
30	Beta-196771	32,560	780	33,340	31,780	16.26	17.49

spp. hiatuses occurred at Gorham's Cave; the last one represents the extinction of the Neanderthals. The role that local, regional or global factors played in these hiatuses is poorly known, yet understanding linkages between climate and environmental change and the Neanderthals' extinction may shed light on the causes and timing of the final extinction (e.g., Higham et al., 2006, 2009; Pinhasi et al., 2011).

Recent studies indicate that the cognitive capacities of the *H. neanderthalensis* and *Homo sapiens* were very similar (Zilhão et al., 2010a; Cortés-Sánchez et al., 2011), and there are doubts about the exclusivity of Neanderthals' Mousterian tools in Europe (Balter, 2011); genetic mixture was also possible (Green et al., 2010), thus we will use the term *Homo* spp. (*H.* spp.) to refer to both throughout the present study.

In order to recognize all the factors that controlled the occupational pattern of Gorham's Cave and other places located in the South Iberian refugia, we utilize information from extensive fieldwork, new dates, and a marine sediment record from South Iberia, to understand the environmental conditions affecting the last *H.* spp. transition. This multidisciplinary paleo-ecological study integrates geomorphological, climatic, paleoseismic, faunal, and archeological records. Calibrated radiometric ages provide a chronology for *H.* spp. cave occupation, allowing us to relate it to climatic and geomorphological reconstructions of representative marine and continental records. We also examine how local geomorphological characteristics correspond to climatic variations and how these events coincide with *H.* spp. population hiatuses in Gorham's Cave.

Table 2
Results of calibrated AMS ^{14}C dates and errors from Gorham's Cave sequence from Finlayson et al. (2006) using Calpal2007_Hulu (Weninger et al., 2011). AMS ^{14}C date numbers correspond to those given in Finlayson et al. (2006).

Sample no.	Laboratory reference	AMS radiocarbon age (yr)	Err. ±	Calibrated radiocarbon age (BP)	Err. ±	68% range (cal. BP)
8	Beta-184042	18,440	160	22,120	290	21,714–22,396
23	Beta-196782	23,360	320	28,190	300	27,666–28,698
15	Beta-185345	23,780	540	28,740	600	28,072–29,321
16	Beta-196775	24,010	320	28,920	450	28,406–29,326
9	Beta-196785	26,070	360	30,950	410	30,585–31,410
17	Beta-196773	26,400	440	31,160	440	30,714–31,612
11	Beta-185344	27,020	480	31,700	380	31,178–32,097
10	Beta-196784	28,360	480	32,870	510	32,320–33,413
18	Beta-196791	28,570	480	33,050	540	32,461–33,624
19	Beta-196779	29,400	540	33,700	490	33,182–34,182
12	Beta-196786	29,910	600	34,100	520	33,535–34,606
14	Beta-196792	30,310	620	34,540	530	33,997–35,206
20	Beta-196776	30,560	720	34,770	600	34,185–35,501
13	Beta-196787	31,480	740	35,760	910	34,865–36,750
25	Beta-196772	31,780	720	36,220	1130	35,084–37,293
26	Beta-196789	32,100	800	36,570	1190	35,398–37,796
30	Beta-196,771	32,560	780	37,000	1110	35,952–38,178

2. Topographic, climatic and Quaternary historical context of the study region

Gorham's Cave is located in the Gibraltar promontory (southernmost tip of Iberia; Fig. 1). It was repeatedly occupied by *H.* spp. populations and was not covered by glaciers during Pleistocene glaciations (Finlayson et al., 2006; Carrión et al., 2008). The limestone substrate in this region contributed to the development of caves and shelters with a unique potential for preserving human and environmental records (Finlayson et al., 2008a). In addition, this area underwent uplifting, which prevented the significant loss of deposit during periods of sea-level rise (Rodríguez-Vidal et al., 2004). Therefore, this unique setting resulted in an excellent archeological record close to the adjacent narrow Alborán marine basin, which is characterized by exceptionally high sedimentation rates, with continuous sedimentary records that allow precise climatic reconstructions (Cacho et al., 2002; Moreno et al., 2005; Martrat et al., 2007; Jiménez-Espejo et al., 2008; Rodrigo-Gámiz et al., 2011).

This region is also characterized by active seismicity linked to tectonic boundaries between the African and Iberian plates. Two major seismogenic zones are identified, one in the west, from Cape St. Vincent to the Gulf of Cádiz area (Baraza et al., 1999; Thiebot and Gutscher, 2006) and the other in the East Alboran Sea basin (Gracia et al., 2006). Evidence from the former indicates that high magnitude earthquakes took place within the Gibraltar area over time (Baptista et al., 1998; Ruiz et al., 2005; Gracia et al., 2006; Gutscher et al., 2006; Vizcaino et al., 2006). Such seismic activity may have also impacted the coastal environments (Benavente et al., 2006; Rodríguez-Vidal et al., 2011).

3. Climate records and age models

The climate record for the studied period was gathered from marine and continental archives. A marine sediment core (TTR-300G, Fig. 1a) from the westernmost Mediterranean Sea, in the Alborán Sea basin, was analyzed at very high resolution. The age model for this core is based on five ^{14}C-AMS dates obtained from monospecific planktonic foraminifera (*Globigerina bulloides*) at the Leibniz-Labor for Radiometric Dating and Isotope Research and Poznan Radiocarbon Laboratory. The ages were calibrated to calendar years (cal. yr BP) using Calpal software (Weninger et al., 2011) (Table 1). Stable oxygen