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DOI: 10.1016/j.quaint.2007.11.016

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## Gorham's Cave, Gibraltar—The persistence of a Neanderthal population

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Available online 24 November 2007

### Abstract

The stratigraphy of the late Neanderthal occupation of Gorham's Cave, Gibraltar, between 33 and 24 ka BP, the latest known site of Neanderthal occupation, is discussed. Level IV at Gorham's Cave exclusively records Neanderthal occupation and is characterised by Mousterian technology and a sequence of 22 AMS dates. The overlying Level III is Upper Palaeolithic, and the earliest diagnostic culture is the Solutrean at around 18.5 ka BP. A dating interval of over four thousand years separates these two horizons. The ecological and bioclimatic characteristics of the site are considered as an explanation for the late survival of the Neanderthals in the region.

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### 1. Introduction

The 6-km long, 426 m high, Rock of Gibraltar is situated in the southernmost part of the Iberian Peninsula (36°N 05'W), 21 km from the coast of North Africa (Morocco). The significance of the archaeological and palaeontological record of its caves first came to the fore in the eighteenth century (Boddington, 1771; Mullens, 1913). The discovery of a Neanderthal cranium at Forbes' Quarry in 1848, eight years before that of the Neander Valley in Germany (Stringer, 2000a), and the subsequent discovery of a Neanderthal child's cranium in 1926 (Garrod et al., 1928) established the importance of the Rock in the context of Neanderthal presence. The long occupation of the site of Gorham's Cave by Neanderthals was first brought to light in the 1950s (Waechter 1951, 1964) and work at this site recommenced in the early 1990s (Stringer et al., 1999;

Stringer, 2000b). Excavations in the inner part of the cave, an area not previously systematically excavated, commenced in 1997. It is here that dating of a stratigraphic horizon (level IV), that included a Mousterian hearth, revealed late Neanderthal occupation to at least 28 ka BP and most probably down to 24 ka BP (Finlayson et al., 2006). The aim of this paper is to present a more detailed analysis of level IV at Gorham's Cave and discuss its significance in the wider context of Neanderthal extinction and the so-called Middle–Upper Palaeolithic transition.

### 2. The Gorham's Cave sequence

The area excavated in the innermost part of the cave in the period 1997–2005, includes the late Mousterian level IV and an Upper Palaeolithic level III, directly above (Fig. 1, Table 1). It contrasts with the upper part of the sequence, towards the exterior of the cave, first excavated by (Waechter, 1951, 1964) (Fig. 1), then re-excavated

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subsequently between 1991 and 1997 (Pettitt and Bailey, 2000). Zilhao and Pettitt (2006) located this excavation towards the cave interior when it was actually in the part of the cave that is more exposed to external conditions and is heavily bioturbated in places. The sedimentary environment in this part has been contributed by an aeolian infill formed by coastal dune sands that penetrated upwards towards the interior of the cave. This created a sloping

entrance, with a strong gradient (15–20°), in places sandy in nature and soft, with its sedimentary stratigraphy showing evidence of disturbance by animals and hominins. The deep part of the cave, however, is a depositional surface, with subhorizontal stratigraphy and lower sand content. The main post-depositional effects are, therefore, compaction through trampling, rather than bioturbation.

The stratigraphic integrity of level IV is beyond question on scientific grounds (Finlayson et al., 2006). Table 1 summarises the AMS dates obtained for level IV and contrasts it with level III, directly above it. There is therefore complete independence of the two levels on dating, cultural, mineralogical, geochemical and stratigraphic grounds. The position is strengthened further by the total absence of any pre-Solutrean Upper Palaeolithic technologies anywhere in the stratigraphy. The sequence of dates obtained were from significant pieces of charcoal (mean weight = 2.04 g, standard deviation 3.13) and corresponds closely with the archaeological sequence for the region. Here there is a general absence of Aurignacian (with the possible exception of the site of Bajondillo, Cortés Sánchez, 2007), and the Gravettian is rare (Ferreira Bicho, 2005), which appears concomitant with a late Mousterian presence instead.

The dates within level IV do not appear in perfect stratigraphic sequence, as clearly shown and explained by Finlayson et al. (2006). The results obtained were, however, consistent with expectation of a level that had repeatedly been visited and re-occupied by generations of Neanderthals. The repeated use of one place as a hearth implies the removal of previous materials. These people would have disturbed the floor used and fires made by their predecessors when they occupied the site, so although a general temporal sequence of dates would be expected (as is the case with the chronology from Gorham's), it would be unrealistic to expect a perfect and precise stratigraphic sequence of charcoals and corresponding dates in fine detail. This kind of disturbance is very characteristic and the case in most Palaeolithic sites. It is well known on the basis of present models and other archaeological localities (e.g., Valverdú et al., 2005; Sergeant et al., 2006). This disturbance implies a minor

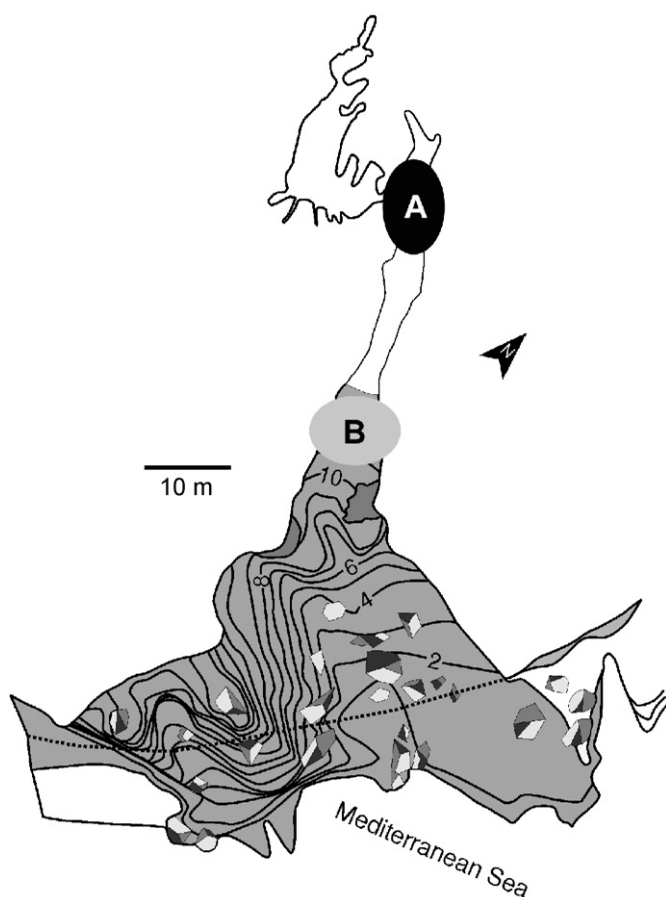


Fig. 1. Plan of Gorham's Cave, Gibraltar. Black ellipse (marked by A) is area in interior of cave excavated in period 1997–2005 and the area of late Neanderthal occupation. Grey ellipse (marked by B) is area excavated prior to 1999 by Waechter and later the Gibraltar Caves Project team, including Pettitt (erroneously marked in Zilhao and Pettitt, 2006).

Table 1  
Distribution of AMS dates from Gorham's Cave, Levels III and IV

	Number of AMS Dates < 24 kyr bp	Number of AMS dates > 24 kyr bp	Youngest Date (lower 95% confidence limit)	Oldest Date (upper 95% confidence limit)	Number of mousterian artefacts present	Number of upper Palaeolithic artefacts present	Mg/Al*	K/Al*	La/Lu*
Level III	8	0	10 800	18 600	0	240	0.285	0.70	117.1
Level IV	0	22	23 040	33 340	103	0	0.175	0.555	125.0

The difference between levels III and IV are highly significant: Fisher exact test,  $p < 0.00001$ . In the extreme situation presented, with the lowest 95% confidence limit for level IV contrasted with the oldest confidence limit for level III the age hiatus between the levels is 4,440 years. Any question of contamination of charcoal from level III into level IV is therefore discarded. These dates are supported by the completely separate geochemical signals identified for the two levels (this table and Finlayson et al. 2006 for details). There is furthermore a complete technological separation between the levels (Fisher exact test,  $p < 0.00001$ ).

\* Average values.

vertical disturbance and horizontal re-distribution of combustion remains that avoid a perfect vertical chronostratigraphic sequence.

The key question is the degree of stratigraphic integrity of level IV compared with the level directly above. The apparent absence of human activity for over four thousand years after the last Middle Palaeolithic occupation suggests Neanderthal abandonment of the site, or their extinction, which left level IV undisturbed. Subsequent, and apparently sporadic, occupation by modern humans did not intrude into level IV. Thus no Upper Palaeolithic artefacts appear in level IV, there are no charcoals dating to the Solutrean in level IV, and the mineralogical/geochemical signature is completely distinct. The use of geochemical ratio for materials characterisation is a well-developed technique (e.g., Romano et al., 2006). Levels IV and III originated by a combination of inorganic and organic inputs, and cultural artefacts. Inorganic input to the cave is associated with autochthonous cave minerals originating through calcite dissolution (the so-called “terra rossa”), and external inputs. External inputs are mainly related to aeolian input and surface or near-surface materials occurring around the cave, usually after suffering a certain degree of pedogenesis (Ellwood et al., 2001, 2004). *A priori*, the conditions of formation of every level must be unique and will generate a characteristic geochemical imprint that

could be relatively homogeneous across levels or at least show variations following gradual tendencies. Detrital proxies, in particular, tend to exhibit highly homogeneous values along similar stratigraphic levels. Among others, lateral progressive variations from entrance to deep locations, local disturbances, and diagenetic effects, could all affect the interpretation of the geochemical proxies.

In any case, at Gorham's Cave the hiatus between levels III and IV is confirmed following geochemical analysis in three separate excavation fronts (see Finlayson et al., 2006 for details), representing different depositional conditions. After analyzing major and trace elements, diverse detrital proxies have been investigated and Mg/Al, K/Al and La/Lu ratios (Table 1) have been selected as the most informative. In both levels the mineralogical phases associated with Mg and K have a detrital origin (chlorite, dolomite and ankerite as Mg sources and illite and K-feldspars for K). The other detrital proxy used, the La/Lu ratio (e.g., Hamroush and Stanley, 1990; Martinez-Ruiz et al., 2000), is related with the source of sediments. For level IV, the Mg/Al ratio ranged from 0.17 to 0.18 and from 0.55 to 0.56 for K/Al ratio (Table 1). At level IIIB Mg/Al ranged from 0.27 to 0.30, two times higher than level IV, and the K/Al ratio ranged from 0.69 to 0.71. The La/Lu ratio at level IV ranged from 124.5 to 125.5 and for the level III from 114.1 to 123.7 with an average value of

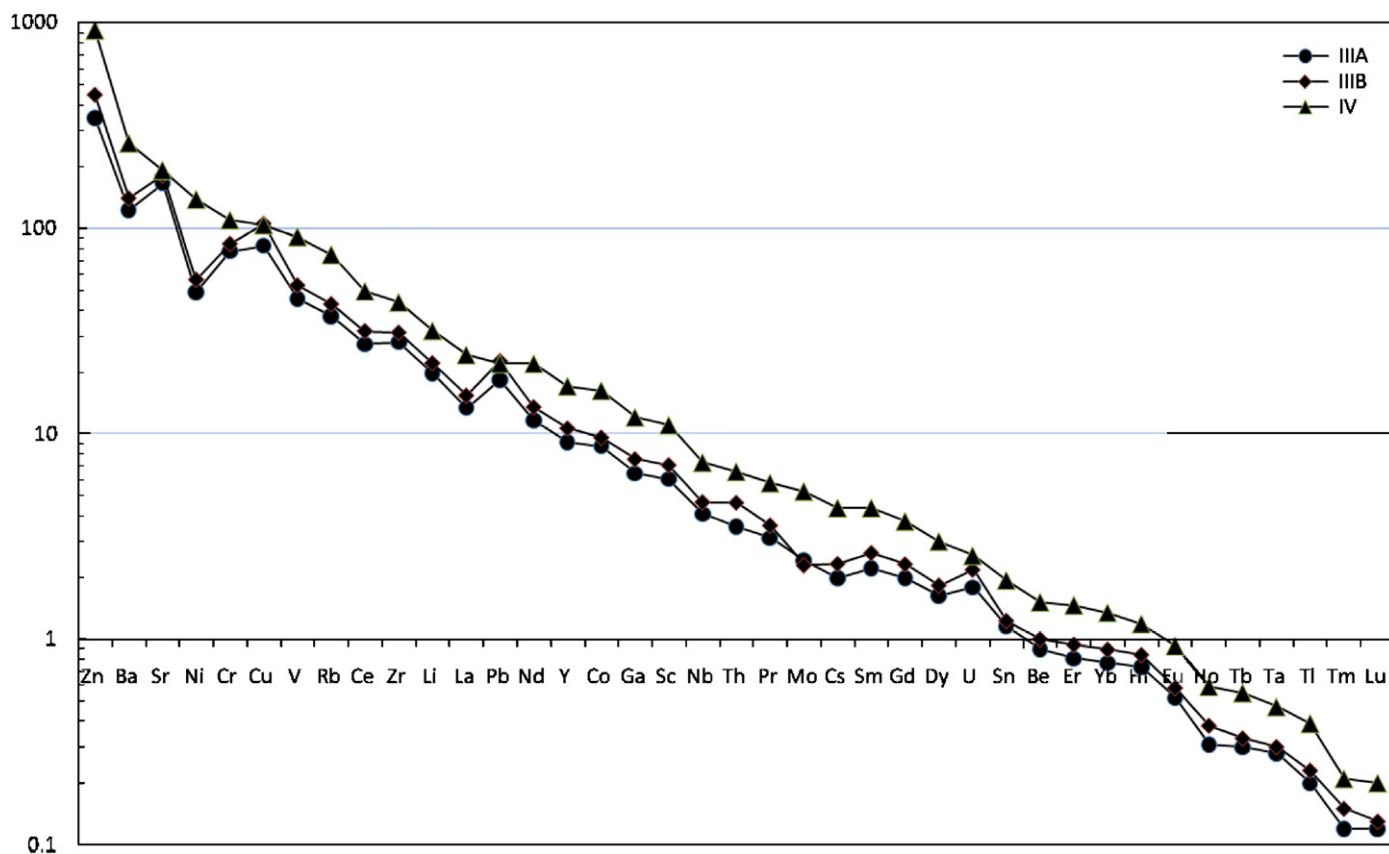


Fig. 2. Spider diagram of the mean concentrations of trace elements at different levels;  $n = 3$ , in ppm. ● = level IIIA, ◆ = level IIIB, ▲ = level IV. Note level III is distinguished between the upper part (A) and the lower part (B) that is closest to level IV.



117.1 (Table 1). These clear differences between levels have been also confirmed by the chemical characteristics of sediments (Fig. 2). The high resolution geochemical mapping developed using Tatscanner F-2 (Sakamoto et al., 2006) at each of the different cave levels indicate a laminar/subhorizontal (discarding brecciated or chaotic) deposition (Finlayson et al., 2006). All these geological data indicate a distinctive and highly homogeneous bed deposition for several geochemical ratios at each separate level, a relatively common phenomenon in caves with low levels of disturbance (e.g., Forbes and Bestland, 2007).

Finally, the suggestion of contamination of 24–30 ka BP charcoals from level III into level IV (Zilhao and Pettitt, 2006) begs the obvious question—why were no 24–30 ka BP charcoals found in level III? It seems very unlikely that all the 24–30 ka BP charcoals filtered down into level IV, leaving none behind in level III, and seems equally unlikely that no older charcoals migrated up into level III.

In total, the Gorham's Cave stratigraphy represents a sequence of about 18 m, covering the period from the Last Interglacial (Rodríguez-Vidal et al., 2007) to the Last Glacial Maximum and beyond, into the Neolithic and Protohistoric periods (Finlayson, 2006). However, regarding level IV, our previous conclusion seems the most reasonable: this was the uppermost part of a long sequence of occupation of Gorham's Cave by Neanderthals. The cave was not a refugium but rather a favoured habitation for the Neanderthals and the optimal conditions of the site and surrounding region enabled persistence of this population. In our view there is nothing diagnostically Aurignacian nor Gravettian in the sequence and there are no radiocarbon dates falling in the period 24–18.5 ka BP. The site was then occupied in the Solutrean after 18.5 ka BP. To suggest that dates in the 24–30 ka BP range were related to modern human activity would therefore require either:

- (a) that all 24–30 ka BP charcoals had percolated into level IV from level III without leaving any behind in level III; or
- (b) that the Solutrean culture here commenced in the period 24–30 ka BP, thousands of years before its commencement in the rest of southern Iberia. Even then, the Solutrean artefacts did not percolate into level IV while all the charcoals did; or
- (c) that people (Aurignacian or Gravettian or both) entered the cave between 24 and 30 ka BP, made fires, consumed animals, but left no artefacts in level IV. Tools attributed to the early Upper Palaeolithic were described by Waechter (1951, 1964) and reported (though not described) by Pettitt and Bailey (2000). These may well have been the products of Neanderthals, or of later Upper Palaeolithic modern humans. Alternatively, since these tools were recovered towards the front of the cave, it remains theoretically possible that there were sporadic visits by early Upper Palaeolithic humans who did not access the rear of the

cave, and impact the Neanderthal occupations in level IV. However, this possibility would require much more evidence before it could be seriously considered.

### 3. Why did Neanderthals survive late in Gorham's Cave?

The answer seems to lie in the ecological diversity of the environment that the Neanderthals exploited outside Gorham's Cave. To date, in level IV, two species of amphibian, seven reptiles, 11 large mammals and 44 bird species have been identified (Finlayson et al., 2006). At least 10 species of intertidal and shallow water molluscs have also been identified (Fa, in press). The flora and vegetation of the Gibraltar region and surrounding mountains also reveal great diversity within a small area (Carrión et al., 2005, in press; Finlayson et al., 2006; Finlayson and Carrión, 2007). It is this small scale mosaic of diversity, combining rocky habitat, open woodland, wetland and coast, which offered the Neanderthals opportunities for year-round subsistence, a strategy that they had successfully pursued for over 100 thousand years (Finlayson, 2006).

Such a strategy was pursued in mild Mediterranean bioclimatic conditions that strayed little beyond the range covered by thermo- and meso-Mediterranean thermotypes and subhumid and dry ombrotypes, with mean annual temperatures oscillating between 13 and 17 °C and annual rainfall between 350 and 1000 mm (Finlayson, 2006). Such conditions also appear to have pertained to the Solutrean occupation during OIS 2 (Finlayson et al., 2007).

### 4. What killed off the last Neanderthals?

Jiménez-Espejo et al. (2007) have shown that the most inhospitable conditions of the previous 250 ka BP affected the region surrounding Gibraltar between 22.5 and 25.5 ka cal BP (dates were calibrated to allow direct comparison with marine core sequences) and have linked this with unstable conditions, extremely cold, arid and highly variable related to Heinrich event 2 (HE2) that led to the final disappearance of the Neanderthals. This study was based on new data from marine cores as well as an extensive literature concerning marine palaeoenvironmental reconstructions (e.g., Cacho et al., 2002; Martrat et al., 2004; Moreno et al., 2005). We suggest that this event, particularly severe and short-lived around 24 ka cal BP, would have been sufficient to kill off any surviving Neanderthals.

At the population level, the process must have been spatially heterogeneous within southern Iberia (Finlayson and Carrión, 2007), and we may well keep the expectation that other populations will be dated between the most recent part of MIS3 and onset of MIS2. On this basis, it is not surprising that (subject to confirmation from further excavations) new dating results from Neanderthal-bearing beds in Carihuela Cave, northwards from Gibraltar in

continental Andalucía, fall within the 28–22 ka BP span (Fernández et al., 2007).

## 5. Discussion

### 5.1. Late southern Iberian Neanderthals—implications for the Lagar Velho child

The publication of the discovery of a juvenile human from the Gravettian period at the site of Lagar Velho, Portugal (Duarte et al., 1999) raised the possibility of hybridisation among Neanderthals and modern humans. That the Lagar Velho child was a hybrid at all has been seriously contested (e.g. see Tattersall and Schwartz, 1999). In any case, to base a taxonomic claim on a single, juvenile, specimen is difficult especially since the body proportion data potentially lie within the expected Gravettian range. Additionally, Pettitt et al. (2002) subsequently placed the age of the burial between 24 and 25 ka BP, relatively late for a Gravettian burial.

The late date of the burial, supposedly long after the last Neanderthals had disappeared from Iberia, led to the argument that hybridisation must have been widespread among Neanderthals and modern humans for such mosaic features to survive so recently in an individual (Zilhao and Trinkaus, 2002). The findings related to level IV at Gorham's Cave suggest that the Lagar Velho child could have been contemporaneous with the southern Iberian Neanderthals, but we have no evidence of how far north any surviving Neanderthals extended. Even accepting the contentious position of the individual being a hybrid, the

argument that it represented widespread admixture now becomes increasingly difficult to sustain.

### 5.2. There was no Ebro Frontier

Much has been made of an apparent division of occupation of the Iberian Peninsula into that north of the Ebro River (largely occupied by Aurignacian modern humans) and south of it (largely occupied by Neanderthals) until ~30–20 ka BP (Zilhao, 2000). However, recent work has provided evidence that the apparent stasis for five thousand years across the so-called Ebro stable biocultural frontier is an artefact of the dates chosen to represent each side of the division. There were, in fact, modern humans south of this frontier and Neanderthals north of it during the presumed frontier period between 35 and 30 ka BP (Finlayson, 2004; Vaquero et al., 2006).

The processes of Neanderthal extinction and modern human colonisation are a major bone of contention. These processes may be viewed as independent events in which Neanderthal populations survived longest in the thermo- and meso-Mediterranean zones of southern Iberia, particularly the south-west and south-east (Finlayson, 2006), with a slow entry into Mediterranean zones of modern humans from the Eurosiberian region to the north (Fig. 3).

Zilhao and Pettitt (2006) interpret the statement by Finlayson et al. (2006) that during the transition between the Middle and Upper Palaeolithic in southern Iberia human populations were at low densities, to estimate that the remaining Neanderthal population needed a minimum land area of 50,000 km<sup>2</sup> (at a population density of a single

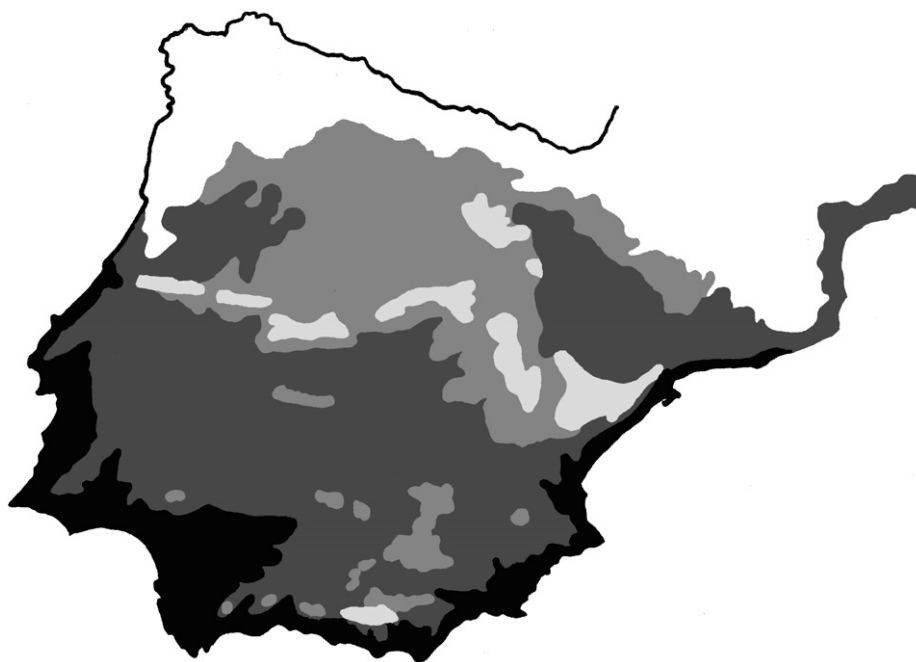


Fig. 3. Distribution of major bioclimatic belts of the Iberian Peninsula (from Finlayson, 2004). White—Eurosiberian; pale grey—Mediterranean; grey—supra-Mediterranean; dark grey—meso-Mediterranean; and black—thermo-Mediterranean.

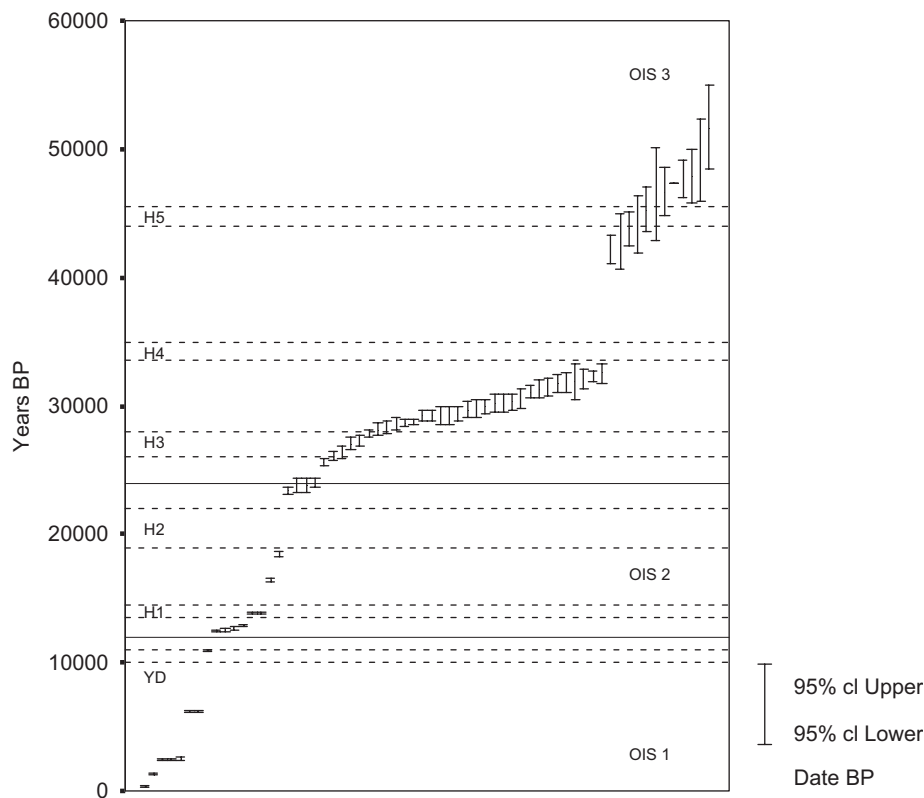


Fig. 4. Distribution of 63 AMS dates for Gorham's Cave, Gibraltar. Dotted lines mark the position of cold Heinrich (H) events and the Younger Dryas (YD). Oxygen Isotope Stages (OIS) are separated by solid lines.

Neanderthal for every 100 km<sup>2</sup>). Based on this hypothetical model they go on to state that Neanderthals and Moderns in this region must have lived in total sympatry, with extensively overlapping mating networks, and query how no exchange of genes or culture could have resulted. In the first instance, there is no requirement for a minimum population size of 500 individuals since we know that the existing Neanderthal population eventually went extinct. Secondly, their model ignores the spatio-temporal mosaic that is an intrinsic part of Finlayson et al.'s scenario. By failing to consider the extremely heterogeneous nature of the southern Iberian Peninsula and the generally accepted premise that these humans would have moved around this environment in small, possibly family, groups, both factors that would have significantly decreased encounter rates, they provide a model that is unrealistic.

At Gorham's Cave, in the extreme south, events are seen in terms of regular periods of occupation by Neanderthals, interrupted at times that in some cases at least can be related to cool periods associated with Heinrich (HE) Events. By HE2 the last Neanderthals had left the cave, (Fig. 4), but on this occasion they did not return. Subsequent visits by modern humans later appear much more sporadic. These fluctuating periods of occupation of the cave were independent of modern humans, who were not in the area for the greater part of the time. As we move north-eastwards and Mediterranean and Eurosiberian zones are compressed more closely (Fig. 3), the probability

of contact between the populations is greater, thus providing a functional explanation for the strikingly different patterns observed in Cataluña and Cantabria (Vaquero et al., 2006) when compared to the deep south. It was in the extreme south-west, the haven within the refugium, that the last Neanderthals survived.

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