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New dates and palaeoenvironmental evidence for the Middle to Upper Palaeolithic occupation of Higueral de Valleja Cave, southern Spain

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A B S T R A C T

A research programme has been set up at Higueral de Valleja Cave in southern Spain to investigate the late survival and eventual extinction of the southern Iberian Neanderthals and the arrival of modern humans. Of key interest in the first phase of research was to understand the depositional environment in the entrance chamber of the cave and to establish whether palaeoenvironmental and dating samples could be retrieved from the Middle and Upper Palaeolithic sequences. The outcome is a series of OSL, TL and radiocarbon dates showing that the cave was occupied by Neanderthal populations in Marine Isotope Stage (MIS) 3, if not earlier, and by modern human Solutrean populations during the last glacial maximum. Cave sediments provisionally indicate that the lower Middle Palaeolithic sequence (X–VIII) formed in warm and humid environments and the upper sequence (VIII–V) formed when the climate was cooler and drier. The presence of long grass phytoliths and of the small mammals *Microtus duodecimcostatus*, *Microtus brecciensis* and *Apodemus sylvaticus* in the upper sequence indicates that a range of habitat types persisted near the cave including grassland, scrubby vegetation, patchy tree cover and ponds. This raises the possibility that environmental factors were key factors in the late survival of Neanderthal populations at the cave.

1. Introduction

The fate of the Neanderthals is a topic of considerable interest in human evolutionary research. Perhaps the most widely accepted explanation for their disappearance is that they were replaced by incoming modern human populations, who with a marginally greater intelligence and superior tool-kit were able to displace the Neanderthals from their preferred habitats (Mellars, 2006). In recent years, the role of climate change has increased in significance as a primary causal factor with the observation in marine and ice cores of rapid climate oscillations during Marine Isotope Stage (MIS) 3 (c.59 000–24 000 BP). Stringer et al. (2003) demonstrated that climate conditions were most stressful for Neanderthal populations between 40 000 and 30 000 BP, which is the time when they are commonly thought to have disappeared. A contribution is made to this topic here with the presentation of the results of a programme of environmental sampling at Higueral de Valleja Cave in the south of the Iberian Peninsula. The cave is of particular interest because it is less than 80 km north of Gorham's Cave in Gibraltar (Fig. 1), where claims have recently been made for a very late persistence of the Middle Palaeolithic possibly even as young as 24 000 BP (Finlayson et al., 2006).

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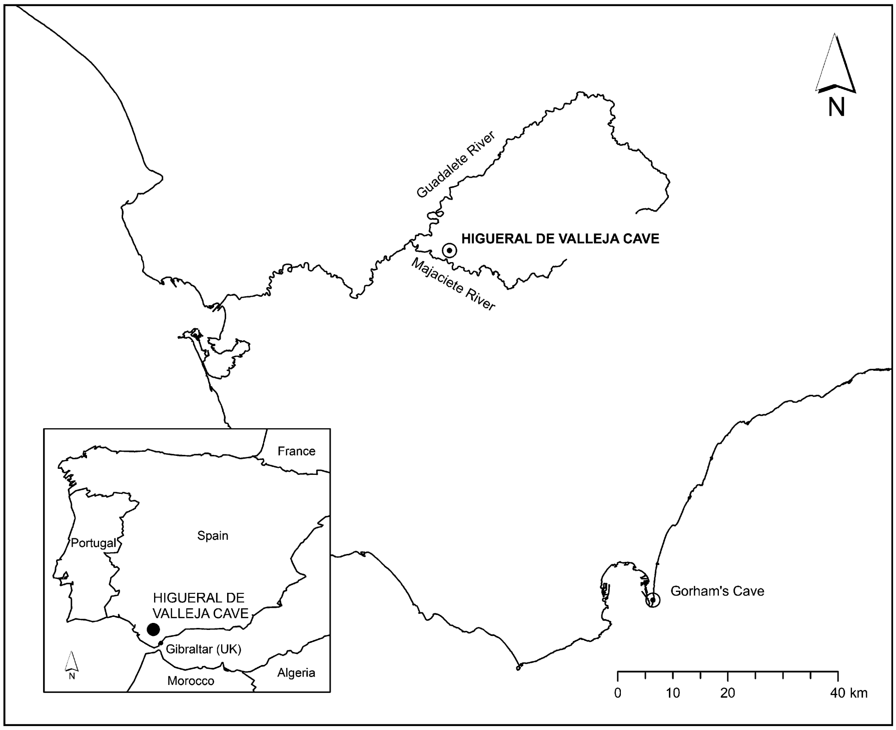

Fig. 1. Location of Higueral de Valleja Cave and excavation area.

Reasons for the late survival of Neanderthal populations in southern Iberia are currently under debate. Those who consider modern humans as primarily responsible for their extinction believe it is explained by geography and historical contingency: the region is the most southerly in Europe and was furthest from the initial expansion of modern human population into the continent, which took place as early as 46 000 years ago via the Levant (Mellars, 2006). However, while modern humans were in the north of Iberia by 41 000 BP, the earliest Upper Palaeolithic evidence in the south dates to ca. 35 000 uncal BP (Bajondillo Cave, Málaga, see Cortés Sánchez, 2003). Zilhão (2000) proposed that a biogeographical boundary – the Ebro Frontier – prevented the earlier arrival of modern humans in the south and west of Iberia. The boundary ran along the Ebro River in Cataluña and across the Iberian Peninsula. He regarded land to the south of the Ebro Frontier to have been too heavily forested during MIS 3 to allow a rapid southerly expansion by modern humans. A problem with this idea is that modern humans probably reached southern Iberia by following the coast, thus circumventing the hypothesised biogeographical frontier.

Finlayson (1999) attributed the late survival of the southern Iberian Neanderthals to the continued existence of their habitats in the region during MIS 3. Southern Iberia was an attractive occupation area at this time: its varied terrain meant a high number of environmental gradients would have been present; it was within the Mediterranean temperature biome; precipitation would have been high on the western windward side of the Betic Mountain System, the main mountains of southern Iberia; river networks were far reaching; and the coastline was extensive. All of these factors contributed to the biodiversity of the region during the last glacial. For Finlayson, the availability of a range of habitats was key to the success of the southern Iberian Neanderthals: it was this success that postponed the arrival of modern humans in the region. He also regarded modern humans as a species that favoured open plain environments, few of which existed in southern Iberia during the last glacial. His theories are supported by the results of Hewitt (2000), who used genetic evidence to show that southern Iberia functioned as a refuge for a range of plant and animal species at this time.

Nevertheless, the southern Iberian Neanderthals eventually disappeared. Finlayson (1999) proposed that millennial scale climate oscillations of late MIS 3 led to the eventual fragmentation of Neanderthal habitats and ultimately to population decline beyond the point of recovery. In his view, the arrival of modern humans was incidental to their extinction. d'Errico and Sánchez Goñi (2003) disagreed and stated that Heinrich Event 4, a major episode of ice raft deposition in the Atlantic Ocean ca 40 000 years ago, led to a modern human range expansion into the Iberian Peninsula and an eventual contact with the Neanderthal populations of southern Iberia. Both views are in need of substantiation with archaeological and environmental evidence. The latter drew upon pollen evidence from marine cores recovered in the Alborán Sea off the coast of southern Iberia to support their position, but the reliability of applying such data for environmental reconstruction was called into question by Finlayson et al. (2004) and Carrión (2004).

Higueral de Valleja was selected for environmental sampling because it is known to contain Middle and Upper Palaeolithic archaeological evidence (Giles Pacheco et al., 1998). In conjunction with a lithostratigraphic analysis of the cave sediments and the first radiometric dates to come from the site, the results offer new insights into the Neanderthal and modern human occupation of the region during MIS 3 and MIS 2.

2. Regional setting

Higueral de Valleja Cave is located on the northern flank of Sierra de Valleja in the province of Cádiz, Andalucía (N 36° 41′ 20″, W 005° 46′ 22″). This hill, which extends for 5.5 km and is aligned NE–SW, forms part of the Subbetic geological zone and is made of Jurassic dolomite. The cave is at an altitude of 190 m above sea level and is 1.5 km from the Majaciete River, which is the foremost

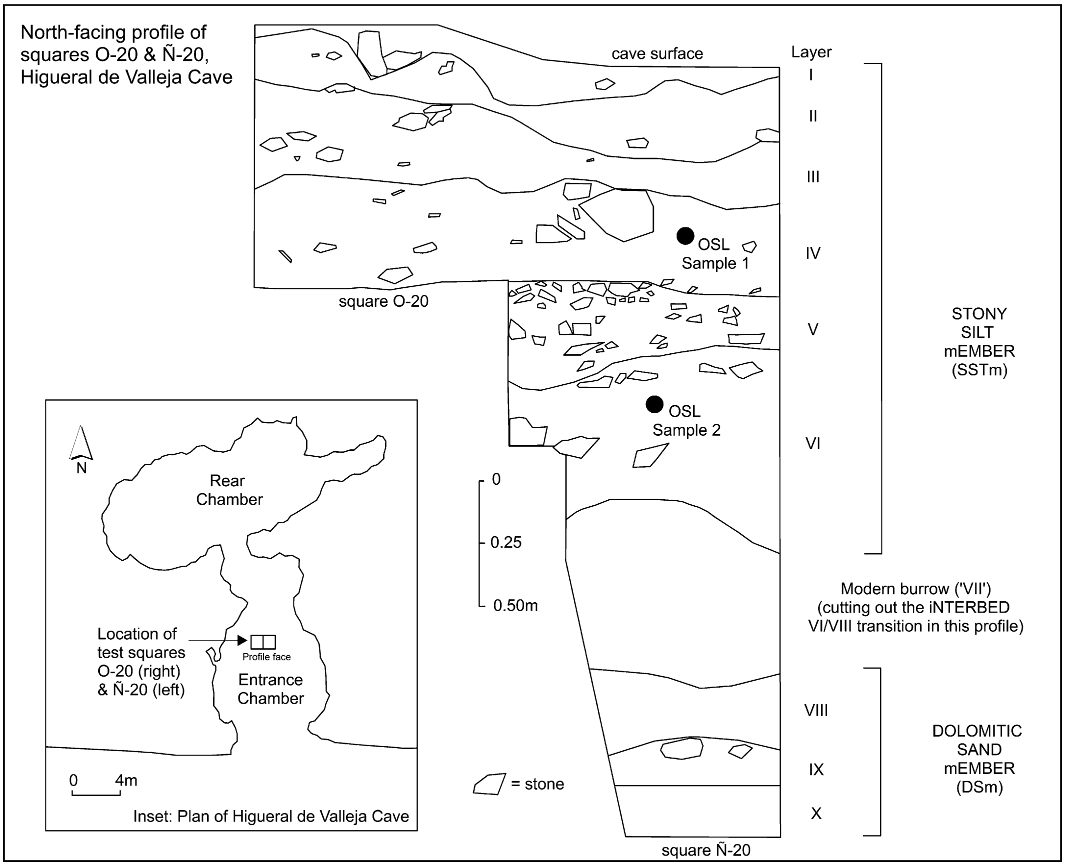

Fig. 2. Stratigraphic profile of squares O-20 and Ñ-20, Higueral de Valleja Cave.

tributary of the Guadalete River System. There are extensive views from the cave entrance of the surrounding landscape. The cave is in close proximity to a range of habitat types including the valleys of the Guadalete River System and the middle and high ranges of Sierra Grazalema.

The cave was formed by karstic processes and exposed at an unknown age as part of the ongoing erosion of the angled dolomite bedrock. It is made up of two connecting cavities: the entrance chamber and the back chamber. These are accessed through a 4 m wide by 1–3 m high northeast-facing entrance and linked by a 5 m long passageway with a low ceiling. The entrance chamber is oval-shaped (12 m deep by 10 m wide by 10 m high), aligned north-south, and has a 4 m by 3 m aperture in the roof that today provides ample natural light. The back chamber is more rectangular, is aligned roughly east–west, and measuring 10 m deep by 20 m wide by 10 m high is larger than the entrance chamber. It is partially lit by two smaller apertures in the western ceiling. It is difficult to make assumptions regarding how the cave may have appeared in the late Pleistocene. The presence of a platform and talus slope and a noticeable widening of the walls at floor level in both chambers suggest there is considerable depth to the cave sediment and that an original entrance may be concealed.

3. Excavation methodology

The current phase of fieldwork centred on the excavation of a cutting in the middle of the entrance chamber floor. It measured 2 m long by 1 m wide and was excavated in part to almost 3 m below the floor surface (Fig. 2, Table 1). The location was chosen because there was good natural light here for the excavation and it

Table 1
The stratigraphic column of square Ñ-20, Higueral de Valleja Cave.

Layer	Lith-ostratigraphy	Depth below datum (m)	Depth below cave floor (m)	Average layer thickness (m)	Environmental samples (no of sediment bags)	Archaeology	Lithic count[a]
I	STONY SILT mEMBER (SSTm)	2.10–2.20	0.00–0.10	0.10	–	Modern	–
II		2.20–2.40	0.10–0.30	0.20	–	Modern	–
III		2.40–2.65	0.30–0.55	0.25	5	U Palaeolithic (Solutrean)	200
IV		2.65–2.90	0.55–0.80	0.35	10	U Palaeolithic (Gravettian)	137
V		2.90–3.30	0.80–1.20	0.40	11	M Palaeolithic	28
VI		3.30–3.85	1.20–1.75	0.55	41 (incl. 7 VI-a)	M Palaeolithic	126
	iNTERBED transition	3.85–4.30	1.75–2.20	0.45	9	Burrow (“VII”)	27
VIII		4.30–4.60	2.20–2.50	0.30	7	M Palaeolithic	5
IX	DOLOMITIC SAND mEMBER (DSm)	4.60–4.80	2.50–2.70	0.20	9	M Palaeolithic	5
X		4.80–5.00[b]	2.70–2.90[b]	0.20[b]	3	M Palaeolithic	10

[a] Excludes those lithics within environmental samples.
[b] Full depth of layer not reached.

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Table 2
Description of the lithostratigraphy of square Ñ-20, Higueral de Valleja Cave.

Layer	
STONY SILT mEMBER (SSTm)	
III	Silt with angular grit; uncommon limestone clasts of various sizes, roughly horizontal bedding; the unit slopes gently downwards across the chamber to the west and possibly also inwards to the north; compact to strongly compact, slight overall matrix cementation, with a few more strongly cemented patches; no obvious bioturbation structures; colour dark brown 7.5YR 3/2.5 with some lighter patches; up to 30 cm thick (almost certainly truncated at top), quite strong undulating, moderately clear lower boundary.
IV	Gritty silt; common medium-scale relatively angular dolomitic clasts, many of which have slightly altered and/or pitted surfaces; roughly horizontal bedding, the unit as a whole appears to slope very gently downwards across the chamber to the west and possibly also inwards to the north; compact, no obvious cementation; charcoal; no obvious bioturbation structures; colour very dark brown 7.5YR 2.5/2; 30–45 cm thick, slightly undulating, moderately clear lower boundary.
V	Clay-silt to very clean silt, grittier nearer stone groupings; common platy medium-scale angular dolomitic clasts, lying mostly horizontal but perhaps with a very slight tendency towards smaller stones disposed in very shallow and small-scale concave-up groupings (no true stone nests or garlands apparent); clasts larger and more densely packed towards top of layer but normally still matrix-supported; the unit slopes gently downwards across the chamber to the west and possibly also inwards to the north; reasonably compact, no obvious cementation; no obvious bioturbation structures; colour dark brown 7.5YR 3/2.5; 20–35 cm thick, slightly undulating, moderately clear lower boundary
VI	Slightly clayey silt with angular limestone grit, uncommon larger stones but base often has large (40 cm diameter) relatively angular dolomitic blocks; the unit slopes gently downwards across the chamber to the west and possibly also inwards to the north; relatively compact, no obvious cementation; colour uniform brown 7.5YR 4/3; no obvious bioturbation structures. Layer VIa is an ashy component of layer VI.
iNTERBED transition	
VI–VIII Transition	Very patchy texture on a small scale, from gritty sand to silt or an intimate mix of the two; both rotted and perfectly sound limestone clasts of various sizes; no bedding structures whatsoever, chaotic particle orientation; patchy consistency, from moderately firm to compact; apparently reworked, lightly to strongly cemented sandy aggregates; charcoal and rare burnt bone fragments; common traces of apparently internal bioturbation structures (5–15 cm diameters, grossly tubular), usually in complex superimposed suites; patchy colours, ground of very dark brown 7.5YR 2.5/2 with a few lighter flecks and spots; 20–40 cm thick, lower boundary sharp but very irregular, showing strong tight undulations as much as 30 cm deep and wide, impinging upon Layer 8 Upper beneath. This Transition Layer 6/8 had previously been included in the base of Layer 6; it is possible that the previously described "Layer 6a" may also be attributed to the mixed Transition Layer. Artefact content currently undifferentiated from that of Layer 6.
DOLOMITIC SAND mEMBER (DSm)	
VIII Upper	Gritty sand, much of which is dolomitic, with some clay-silt; extremely altered (rounded, unsound) medium-to-fine grade dolomitic limestone clasts, sometimes rotted down to grey sand-ghosts; diffuse but persistent horizontal bedding, probably mostly coarse lenticular but with very laterally restricted traces of thin laminar sets (rather blurred and fragmented by small scale bioturbation); very compact overall, strong secondary cementation throughout; small scale (<1 cm), apparently secondary red–orange–grey nodular concretions; void-cored carbonate branching tube casts (probably rhyzoliths and possibly modern); manganese staining; very common charcoal, bone fragments and tiny burnt bone debris; some extremely unsound 'curved platelets' which could be molluscan shell fragments; some apparently mostly internal bioturbation structures (2–4 cm diameter scale, grossly tubular, plus much finer structures which could have an infaunal faecal origin such as 'worm casts'); very specked colours, overall colour weak red 2.5YR 4.5/2.5, with light and black speckles, as well as zones tending to dirty whites; minor intra-unit high-angle normal faulting; at least 40 cm thick, very diffuse and bioturbated lower boundary. No stone artefacts yet reported.
VIII Lower	Gritty sand, most of which is dolomitic, with clay-silt; extremely altered (rounded, unsound) medium-to-fine grade limestone clasts, sometimes rotted down to grey sand-ghosts; possibly grossly horizontally bedded; very compact overall, with often strong matrix cementation; common charcoal, both rounded and angular fragments; bone fragments and tiny burnt bone debris; common bioturbation structures (2–3 cm diameter scale, grossly tubular); overall colour weak red 2.5YR 4/2.5, with light and black speckles, as well as zones tending to dirty whites; at least 20 cm thick, lower boundary diffuse and bioturbated
IX	Texturally uniform dolomitic medium-to-fine sand with a minor silty clay content; some large, deeply rotted but still cohesive limestone clasts; very light patchy point-cementation; probable manganese enrichment; no obvious bedding structures; relatively uniform colour dark reddish brown 5YR 2.5/2.
X	Gritty dolomitic sand with some clay-silt; extremely altered (rounded, unsound) medium-to-fine grade limestone clasts; traces of diffuse horizontal bedding, compact overall, with patchy but often strong concretion, colour weak red 2.5YR 4.5/2.5, with light and black speckles; more than 25 cm thick, not bottomed in the present sounding.

was immediately adjacent to one of the 1979–1982 excavated areas. The backfill from the old cutting was removed and the existing sections were cleaned back and recorded. Taking advantage of the exposed stratigraphy, a column sample that measured 1 m long by 0.30 m wide by 2 m deep was excavated for the recovery of the environmental samples. The cutting was deepened by the sampling in square Ñ-20 of a further metre of deposit. The excavated sediments were dry sieved on site (1 mm mesh size) and then wet sieved in the laboratory.

4. Results

4.1. Lithostratigraphy

Two provisional sediment members were noted in the excavation (Fig. 2, Table 2). They are written in this publication in reverse capital designations to show that full lithostratigraphic analysis of the cave sediments is not yet possible due to their limited exposure in the chamber. The lower division is the DOLOMITIC SAND mEMBER (DSm) and the upper the STONY SILT mEMBER (SSTm). The presence of a significant amount of bioturbation at the point of contact between the DSm and the SSTm meant that the safest lithostratigraphic solution was to designate an iNTERBED at this point, belonging to neither mEMBER but having the characteristics of both. Given major differences between the mEMBERs, a long time passage is suggested for the transition, although this cannot be proven. Instead, the iNTERBED creates a non-sequence with unknown temporal characteristics.

Twelve layers identified in the course of the excavation were correlated with the two mEMBERS. The deepest four layers (X, IX, VIII Lower and VIII Upper) formed the DSm. These contained evidence of Middle Palaeolithic occupation. The upper eight layers formed the SSTm. The oldest three of this group (VI, VIa and V) were also Middle Palaeolithic. Above these were two Upper Palaeolithic (IV and III) and two modern layers (II and I). A major modern burrow that was dug through one of the 1979–1982 cuttings into Layer VI was given the designation ("VII"). To show the iNTERBED, Transition Layer VI/VIII is used.

The deposits of the DSm suggested that mild, damp, biologically active conditions once existed in the cave, and plausibly in the exterior environment as well. The presence of highly rotted limestone, manganese enrichment areas and localised laminar structures indicated continual dampness in the deposits. There were areas of secondary cementing that appeared to have involved

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considerable carbonate mobilisation, presumably from the bedrock. There was also a strong charcoal component in the deposits and hints that organic matter may have been present in large quantities, probably imported into the cave as animal droppings.

The deposits of the SSTm revealed a different story. They appeared to be a mix of local, unweathered limestone and wind-blown silts, with no obvious carbonate mobilisation present. These factors suggested a much drier climate than that recorded for the DSm. The 'traditional' explanation for the angular limestone clasts would be cryoclasticism ('freeze–thaw'), although many other processes could create rockfall, some of them wholly unrelated to the immediate environment/climate. There were no obvious signs of ground-ice (e.g. no major silt-lensing or stone-nesting) but this is not particularly surprising given the location of the cutting well inside the cave. The most reliable conclusion to draw from these sediments is that they formed in relative dryness, although a cold environment is in no way contradicted.

The iNTERBED was recorded as Transition Layer VI/VIII and was clearly a physical mix of silts and sands. Its upper boundary was diffuse but, because the DSm was well cemented at its summit, the lower boundary was irregular and sharp. The Transition Layer was present in all existing sections, save for areas in which it was cut out by the major modern burrow of "Layer VII". Strong and moderate scale bioturbation caused by rabbits probably accounts for its existence. Burrow traces showed up well where blotchiness involving 'lower' sands and 'upper' silts was present. It is suggested that burrowing took place during the actual accretion of the Transition sedimentary interval rather than afterwards. The only observed burrow originating higher in the sequence was "Layer VII". Bioturbation structures might be much more difficult to see within the silty matrix of the SSTm although such fills would probably stand out if present in the mixed sediment of the iNTERBED.

Sediments at the top of the SSTm were compact and contained a thin layer of modern material. It was not always continuous and Solutrean lithic artefacts of layer III were occasionally visible on the ground. The surface of the deposits was remarkably flat in both chambers. This suggested that significant deposits must have been removed in the Holocene. Furthermore, it would be inconceivable that sedimentation should have all but ceased before the end of the Pleistocene. A weak stain along parts of the wall in the entrance chamber suggests that up to a metre thickness of sediment may be missing in places.

4.2. Lithic artefacts

Although only a restricted number of finds was recovered due to the scale of the excavation, a preliminary study of more than five hundred lithic artefacts showed a noticeable degree of variability in both raw material selection and tool types. Middle Palaeolithic artefacts characteristic of the south of the Iberian Peninsula were recorded in layers V–X. The use of Levallois technique was recognised in layers VI and V with the discovery of a Levallois core and Levallois flakes. Discoidal cores and their by-products including a retouched denticulate from Layer V and two notched pieces in Layer V1 occurred throughout the Middle Palaeolithic sequence. A denticulate with inverse retouch measuring 13 cm long was found in layer X.

The highest proportion of lithics came from two distinctly Upper Palaeolithic layers of the column. Layer III contained two leaf point fragments and a high frequency of fine-grained greenish-grey chert. Layer IV yielded two bladelet cores and a small backed blade that resembled a Valencian style Gravettian microlaminar point (cf. Villaverde and Dídac, 2004). This type-fossil is the first possible indication of a Gravettian industry in the cave (but see Section 5 below). Unlike the flake dominated Middle Palaeolithic, layer IV was characterised by a well-developed bladelet technology. The fine-grained chert on which the bladelets were made ranged in colour from a very dark-brown to a brownish-yellow and was of high quality. This contrasted markedly with the Middle Palaeolithic layers where cherts of more variable quality were employed with a predominance of mottled grey-banded types. An exception was the layer X denticulate, which was made of high quality grey, banded chert.

4.3. Environmental evidence

The environmental sampling programme undertaken at Higueral de Valleja Cave revealed that a wide range of evidence types was preserved in its deposits: phytoliths, charcoal, small mammals, large mammals, herpetofauna, and mollusc shells. Samples were taken from all the layers of the SSTm and DSm although a complete study of the environmental evidence of the latter is still forthcoming. The results discussed below revolve around the presence and absence of particular species given that the quantity of evidence recovered was insufficient at this preliminary research stage for rigorous statistical analyses. However, some interesting initial observations have been made:

4.3.1. Phytoliths

Phytoliths were analysed from layer I and from layers IV to X (Fig. 3). The results showed that the highest proportion of Panicoid morphotypes, phytoliths indicative of tall grasses and a warm and wet climate, was found in layers X, IX and VI. A measure of the density of woodland elements (the D/P ratio, see Alexandre et al., 1997) indicated that high amounts of woody taxa were also associated with these layers, although this ratio may be misleading, as wood collected for fuel may have influenced the samples. The highest proportion of Chloridoid morphotypes, phytoliths that are indicative of warm and dry conditions, occurred in layer IV. The lowest proportion was in layer V. Pooid morphotypes, phytoliths which prefer a temperate climate like that experienced in the region today, were found on the cave floor surface (layer 1) and, as anticipated, in the fill of the disturbed deposit 'layer VII'.

The adaptation to aridity index (a measure of the ability of plants to adapt to an arid environment, Diester-Haas et al., 1973) showed that peaks of aridity occurred in levels VIa and IV with index values of 89% and 87% respectively. This suggested that short xeric grassland elements existed in the ecosystem. However, a high index value of 80% for layer VIII (Upper), which on lithological grounds appears to have formed in warm and wet conditions, is an indication of how careful our inferences are required to be. Layers X, IX and VI have lower aridity values indicating a greater presence of tall mesic Panicoid grasses associated with moist conditions. The climatic index (a measure of the influence of climate upon the C4 and C3 plant morphotypes (Twiss, 1987)) shows that C4 grasses dominated all layers with the exception of the modern ones, which contain milder, more temperate favouring C3 grasses.

Layer X had one of the highest proportions of dendritic phytolith forms. These are commonly found in mature grass panicles. Their presence suggests that the cave was occupied during the spring and early summer when mature grass spikelets would have been in evidence. While one cannot discount the possibility that spikelets entered the cave simply through wind action or in animal coprolites, the presence might be reflective of human activity in the form of fuels for fire or bedding. Layer X also contained irregular morphotypes, which are often indicative of ligneous tissues.

4.3.2. Charcoal

Few diagnostic carbonised plant remains were collected during excavation but some large quantities of extremely small pieces

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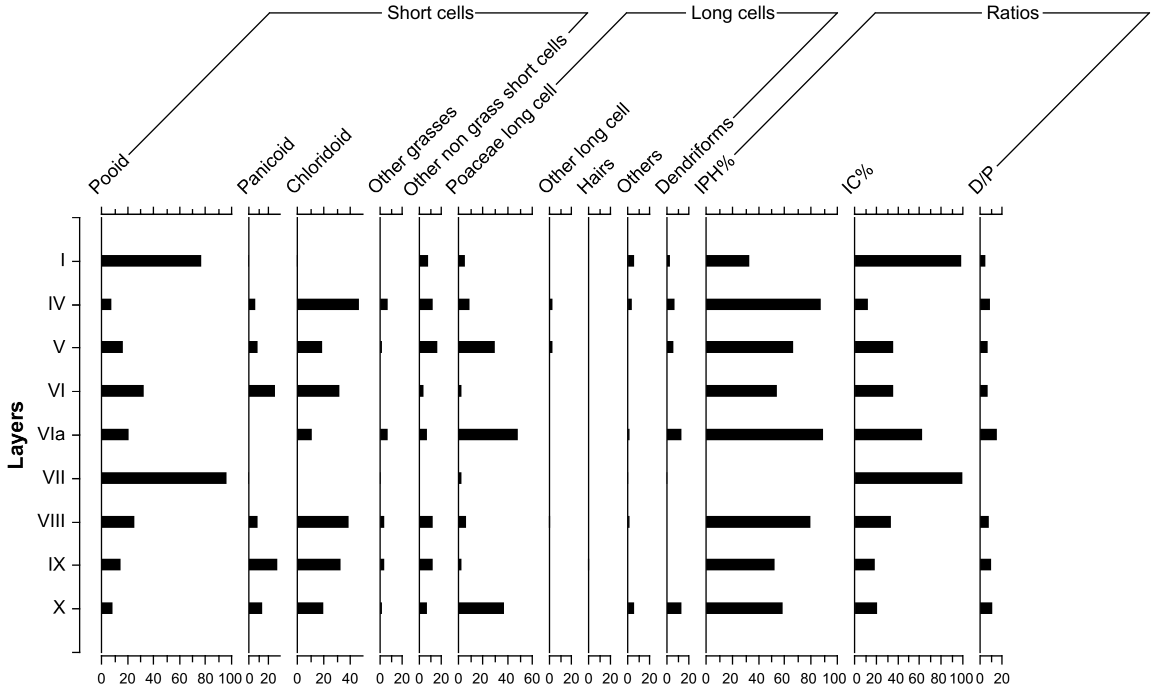

Fig. 3. Phytolith percentage diagram of Ñ-20, Higueral de Valleja Cave.

were recovered from the sieving of bulk samples. These lacked the woody structure necessary for identification to beyond genus level. The DSm had substantial pieces preserved within its grey precipitate matrix, although these were poorly formed. Pieces from layer VIII (Upper) included seeds, nutshells or possibly tubers, which were identified by their thick cell walls, and degraded conifer, which was not identified to genus. However, diagnostic tracheid or ray pitting on the radial surface of the conifer allowed the elimination of pines of the sylvestris group such as *Pinus nigra*, a montane pine that is indicative of a cool climate. The small size of the charcoal pieces in the SSTm meant it was difficult to be certain of their identification and provenance.

4.3.3. Small mammals

The small mammal evidence (Table 3), which was examined from the SSTm [layers VI–III] only, correlated well with the lithostratigraphy and phytolith studies. Present in the layers were *Apodemus sylvaticus* (wood mouse), *Microtus duodecimcostatus* (pine vole), *Microtus brecciensis* (extinct vole) and the ubiquitous *Oryctolagus cuniculus* (rabbit). The habitat favoured by these species is a mixture of scrubby vegetation and patches of tree cover. There was some variability within the layers of the SSTm. The presence of *Talpa* sp. (mole) in layers VI and V indicates that soil depth was good in the vicinity, with the cave sediments themselves perhaps the habitat in question. The identification of *Arvicola* sp. (water vole) in layer V implies that a water source with abundant vegetation existed in the cave catchment area (Mitchell-Jones et al., 1999).

Layer IV contained the only evidence for *Crocidura russula* (the greater white toothed shrew), a mammal that today favours open or semi-open grassland and old terraces with dry stone walls (Mitchell-Jones et al., 1999). The same can be said of *Eliomys quercinus* (garden dormouse) identified in layer III, which although it is associated with mature woodland is equally at home in scrubby vegetation and rocks (Mitchell-Jones et al., 1999). Absent from the SSTm sequence was *Microtus arvalis* (common vole), a cool climate indicator recorded at the upland Middle Palaeolithic sites of Horá Cave (Vega Toscano, 1988) and Cariguela Cave (Carrión, 1992). This suggests that Higueral de Valleja was not in an especially cool environment during the last glacial.

4.3.4. Large mammals

The number of large mammals recovered was good considering the small size of the cutting excavated. The most common species found was *Cervus elaphus* (red deer), which was present in all the main layers of the SSTm (Table 3). It was also present in layers VIII, IX and X of the DSm. Faunal records show that red deer was widespread throughout Europe, mirroring its current distribution. These cervids mainly live in open deciduous woodland today, but are increasingly found on open moorland and mountains (Corbet and Ovenden, 1980). Although the current range of habitats is partly the result of introductions, it does illustrate the adaptability of the species, which is also reflected in its Pleistocene record. Red deer has been found in interglacial and interstadial contexts in association with temperate, coniferous and boreal woodlands and in open herbaceous conditions during cold stages, alongside mammoth and woolly rhinoceros.

Equus sp. (wild horse) was another vertebrate identified in both the SSTm and the DSm (layer IX), suggesting that like red deer it is not a sensitive indicator for environmental reconstruction. As a grazer, it required open grassland. Pleistocene records show that it ranged across Europe and was most commonly associated with predominantly treeless landscapes with herbaceous vegetation, although it is also well known from temperate periods where grasslands may have been reduced to glades between wooded areas. Terrestrial pollen records at Padul in Granada Province (Pons and Reille, 1988) suggest that both biogeographical zones were present in southern Iberia during the late Pleistocene. *Capra* sp. (ibex) was identified in one instance in layer V. The habitats of the two species found in Spain today (the alpine ibex and the Spanish ibex) are the same. They are montane species remaining above the tree line for most of the year and ranging up as far as the snow line. They feed on all kinds of alpine vegetation such as dwarf shrubs, grass, sedges and lichens (Corbet and Ovenden, 1980). Bos/Bison

Table 3
Faunal species recovered from the Stony-silt mEMBER and transitional layer of square Ñ-20, Higueral de Valleja Cave.

Scientific name	Common name	Layer III	Layer IV	Layer V	Layer VI	Layer VIa	Layer VII
Large mammals							
C. elaphus	Red deer	+	+	+	+	+	+
Capra sp.	Ibex			+			
Equus sp.	Horse	+	+	+	+	+	+
Bos/Bison	Aurochs/Bison	+	+				
Canis lupus?	Wolf	+		+			
F. sylvestris	Wild cat				+		
Small mammals							
A. sylvaticus?	Wood mouse	+	+	+	+	+	+
E. quercinus	Garden dormouse	+	+	+	+	+	
M. brecciensis	Extinct vole	+	+	+	+	+	+
Microtus cabrera?	Cabrera's vole			+			
Microtus sp.	Vole		+			+	+
C. russula	White toothed shrew		+				
Crocidura sp.	Shrew				+		+
Pitymys sp.	Vole			+	+	+	+
Pitymys duodecimcostatus	Pine vole		+	+	+		+
Talpa	Mole			+	+	+	
A. sapidus	Southern water vole			+			
Murid	Murid				+		
Lepus	Hare				+		
Oryctolagus	Rabbit	+	+	+	+	+	+
Chiropterus	Bat	+	+	+	+	+	+
Aves	Bird			+	+		
Herpetofauna							
Pleurodeles waltl	Sharp-ribbed salamander						+
Discoglossus galganoi	Iberian painted frog						+
Discoglossus sp.	Painted frog			+			
Pelobates sp.	Spadefoot toad			+			
Bufo calamita	Natterjack toad		+				
Bufo sp.	Toad			+			
Hyla sp.	Tree frog						+
Rana sp.	Ranid frog			+			
Rana or *Discoglossus* sp.	Frog	+		+			+
Testudo sp.	Tortoise						
Tarentola mauritanica	Moorish gecko	+	+	+	+		+
Acanthodactylus erythrurus	Spiny-footed lizard				+		
Psammodromus cf. *Algirus*	Large Psammodromus lizard						
Psammodromus sp.	Psammodromus lizard				+	+	
Lacertidae indet.	Lacertid lizard			+	+	+	+
Chalcides sp.	Skink			+	+		+
Sauria indet.	Sauria lizard		+	+	+	+	+
Malpolon monspessulanus	Montpellier snake		+		+		
Coluber hippocrepis	Horseshoe whip snake				+		
Elaphe scalaris	Ladder snake		+	+	+		+
Natrix natrix	Grass or ringed snake			+	+		
Natrix maura	Viperine snake		+				
Natrix sp.	Natricine snake			+			
Coronella girondica	Southern smooth snake			+	+		
Colubridae indet.	Colubrid snake		+	+	+	+	+
Vipera latastei or *aspis*	Lataste's or asp viper			+			
Vipera sp.	Viper				+		+
Ophidia indet.	Snake	+	+	+	+	+	+

was identified in layers III and IV of the SSTm and layer X of the DSm. A single bone of *Felis sylvestris* (wild cat) was identified in layer VI. Wild cats are usually associated with deciduous woodlands, but also occur in Mediterranean, savannah and steppe zones of Palaearctic Africa and India (Corbet and Ovenden, 1980). Fossil records indicate occurrences during warm stages.

4.3.5. Herpetofauna

Herpetofaunal remains were only examined from the SSTm (Table 3). Even though they are few, they contained a relatively diverse assemblage with the most number of species deriving from layer VI. Amongst the lizards identified in this sequence, the Moorish gecko was present throughout. The ocellated lizard was also common, and the remains included some particularly large and massive jaws with well-worn teeth. By comparison with recent dentary and maxilla lengths, some of the fossil remains were from lizards with a snout-vent length of ca. 0.35 m, which could represent a total length of 1.00 m or more. This size meets and may exceed the record lengths reported in the literature for this species (Crespo and Oliveira, 1989; Arnold and Ovenden, 2002). It is also important to consider that they were a possible food source in the Middle Palaeolithic for Neanderthals. Indeed, ocellated lizards are regarded as a delicacy in parts of Spain today.

There were relatively few amphibian species recorded in the sequence. At Gorham's Cave in Gibraltar, there tended to be a dominance of one amphibian species over all of the other herpetofauna (Gleed-Owen, 2001). It suggests that during the formation of the SSTm the appropriate habitats for amphibians, namely the presence of water bodies, were limited. It may equally reflect, however, a difference in altitude, terrain or in the types of taphonomic agents at work. Three amphibian species (the tree frog, sharp-ribbed newt and an amphisbaenian) were only recorded in the disturbed 'layer VII' and as such were regarded as almost certainly intrusive. Layers III, IV and VIa lacked amphibians almost entirely, while layer VI contained horizons that yielded no herpetofauna at all. The relative paucity of common, natterjack and spadefoot toads reflects the inland position of the cave.

4.4. Dating evidence

Thirteen radiometric dates were obtained from the excavation: seven ^{14}C dates on charcoal, four TL dates on burnt chert and two OSL dates on sediment. These are presented in Tables 4 and 5 and discussed in Section 5. Three dating techniques were applied because determining the ages of late Pleistocene cave deposits is a difficult proposition. There are two key problems: the dating techniques are not sufficiently refined to provide the accuracy needed to allow occupation layers to be correlated with the millennial scale climate oscillations recorded in marine and ice cores; and cave sediments are often subjected to bioturbation, human, chemical and physical alteration and many other post-depositional processes that cause the inversion of ages.

The radiocarbon ages described in this paper have not been calibrated (cal) into sidereal time, since the limit of the tree-ring calibration extends only to 9908 BC (van der Plicht, 2004), with a combination of U/Th marine corals and European varved sequences extending the calibration curve of the INTCAL04 dataset to 26 000 cal BP (Bard et al., 2004a). Beyond 26 kcal BP there is no agreed calibration dataset, with the two principal records (Lake Suigetsu varves, Japan (Kitagawa and van der Plicht, 1998); Bahamian speleothem (Beck et al., 2001)) showing poor agreement before this period. Recently published ^{14}C data from the Cariaco Basin (Venezuela) sediments, spanning 15 000–50 000 cal BP (Hughen et al., 2004), coupled with data collected from a marine core off the Iberian coast (Bard et al., 2004b), imply strongly that

Table 4
Radiocarbon dating determinations from square Ñ-20, Higueral de Valleja Cave.

Layer	Lab Code	Sample identifier	Species	Conventional ^{14}C age BP
V	12270	16	Oak	20 780 ± 80 BP
VI	12362	64	Conifer tree	32 840 ± 210 BP
VII	12272	105	Nutshell/olive[a]	37 220 ± 290 BP
VII	12271	108	Nut kernal?	33 950 ± 200 BP
VIII	13279	CHV03/4.55/001-5	Seeds/nutshell/tuber	56 800 ± 2900 BP
VIII	13280	CHV03/4.55/006	Conifer	52 400 ± 2100 BP
VIII	13417	CHV03/4.30/008	Nut/seeds	>42 900 BP

All samples were dated at the Oxford Radiocarbon Accelerator Unit (ORAU), University of Oxford. Plant/charcoal remains were pretreated using one of two different chemical steps. "ZR" pre-treatment codes denote samples treated using an acid–base–acid (A–B–A) protocol comprising an initial treatment with 1 M HCl at 80 °C (1 h), a rinse with hot 0.1 M NaOH and a final HCl wash. Interspersed between each treatment the samples were rinsed to neutrality with distilled water. Finally the sample was dried and weighed. The "RR" code refers to a milder version of the ZR treatment, used in instances where samples are small or fragile, or when humic contamination is not considered to be highly probable. These samples were pretreated using an initial 1 M HCl wash at RT, followed by rinsing with distilled water, a further acid wash in HCl at RT this time with 0.1 M acid, and a final water rinse. NaOH treatments were observed carefully in case they brought significant proportions of humic acids into solution, which can sometimes be of different ^{14}C concentration; they did not. Weight (mg) is the starting weight prior to pre-treatment, the yields (also mg) of which are shown in column 9. In one instance, the pretreatment yield was low, which resulted in small amount of dateable carbon after combustion and a >42 900 BP result. In all other cases the yields were acceptably high. Pretreated samples were combusted and analysed using a Europa Scientific ANCA-MS system, comprising a 20-20 IR mass spectrometer interfaced to a Roboprep CHN sample converter unit operating in continuous flow mode. δ^{13}C values are reported in per mille (‰) with reference to VPDB (Coplen, 1994). Graphite was prepared by reduction of CO_2 over an iron catalyst in an excess H_2 atmosphere at 560 °C prior to AMS radiocarbon measurement (Bronk Ramsey and Hedges, 1999; Bronk Ramsey et al., 2000).
[a] The nutshell was sampled for AMS dating.

a consensus calibration over the contentious 33 000–41 000 cal BP range will eventually emerge (Bard et al., 2004a).

5. Discussion

A promising amount of information has emerged from the environmental sampling of Higueral de Valleja Cave. The results are divided into three sections: the layers of the dolomitic lithostratigraphic divisions: Layers X–VIII (Middle Palaeolithic), and the layers of the stony-silt divisions: Layers VI–V (Middle Palaeolithic) and Layers IV–III (Upper Palaeolithic).

Table 5
OSL and TL dating determinations from square Ñ-20, Higueral de Valleja Cave. TL age estimates represent burnt flint using combined additive and regenerative TL methods, while OSL ages were measured using multiple-grain quartz single aliquot regenerative-dose determinations. All measurements were performed using Risø automated equipment at Oxford (X755, X756, X1869, X1870) or at the Australian National University (K0308, K0310). All procedures followed those described in Bouzouggar et al. (2007), and incorporated in situ determination of the gamma dose rate.

Layer	Technique	Lab code	Identifier	Dose rate (mGy/a)	Age (yrs before 2000 AD)
II	TL	X756	CHV01: TL-2	0.86 ± 0.12	10 400 ± 2500 BP
IV	TL	X755	CHV01: TL-1	0.94 ± 0.12	15 500 ± 3700 BP
IV	TL	K0308	CHV02: 113	0.74 ± 0.10	18 300 ± 4800 BP
IV	OSL	X1869	CHV03: OSL–1	1.28 ± 0.11	33 200 ± 3100 BP
VI	OSL	X1870	CHV03: OSL–2	1.15 ± 0.11	54 900 ± 5600 BP
VI	TL	K0310	CHV02: 120	1.32 ± 0.23	54 400 BP ± 9700 BP

5.1. Dolomitic deposits with Middle Palaeolithic evidence (Layers X–VIII)

The sediments of layer X were part of the DSm and as such indicative of a warm and wet climate. The oldest known archaeological evidence in the cave was found in this layer. It contained ten Middle Palaeolithic artefacts, one of which was a high quality denticulate on a very large piece of fine-grained chert 0.13 m long. An abundance of dendritic phytoliths suggested that the cave was occupied in the spring or summer months. The presence of irregular phytolith morphotypes, charcoal, burnt pinecone scales and ash might have been a natural occurrence but could relate to the collection and deliberate use of wood as a source of fuel. Some of the morphotypes belonged to the Pinaceae family, hinting at a dominance of *Pinus*. The remains of pine kernels were found in the layer and similar occurrences at Gorham's and Vanguard Caves in Gibraltar and in Amud Cave in Israel have been used to argue for the consumption of roasted pine nuts by Neanderthals (Barton, 2000; Madella et al., 2002). Long bones of red deer and a species of Bos/Bison were also found although with no cut marks visible to suggest human butchery.

The main evidence for occupation in layer IX was a single retouched flake. Red deer and horse were identified in the same layer but with an absence of human butchery cut marks. Layer VIII (Upper) contained two pinecone scales that were AMS radiocarbon dated to 56 800 uncal BP and 52 500 uncal BP, and a seed that was dated to >42 900 uncal BP. The pinecone scales were encased in cemented material and it is unlikely that they had worked their way down from younger layers above. If taken literally, the determinations equate to an early MIS 3 age. There were certainly lengthy warm and wet interstadials occurring at that time. However, the dates are at the limit of the radiocarbon technique and an earlier age is equally probable. The lithostratigraphic interpretation is consistent with the layer having formed in one of the warmer stages of MIS 5.

5.2. Stony-silt deposits with Middle Palaeolithic evidence (Layers VI–V)

The next phase of Middle Palaeolithic occupation is securely dated to MIS 3. This equates to layer VI, the lowest deposit of the SSTm. An OSL date of 54 900 BP ± 5600 BP, a TL date on burnt flint of 54 400 ± 9700 BP, and an AMS radiocarbon date on charcoal of 32 840 ± 210 uncal BP were obtained for the layer. The discrepancy in radiocarbon and luminescence values strengthens the argument that raw radiocarbon dates beyond current calibration limits might be significantly younger than realised Whether they were as much as ca 40%, as is the case in this layer, is debatable, but the same level of difference when applied to the radiocarbon dates of layer VIII pushes those dates back to MIS 5 and thus in line with the lithostratigraphic evidence. The presence in the sediments of an unconformity (the iNTERBED) at this point could explain any significant temporal differences between the ages of layers VIII and VI, which also marked the DSm–SSTm transition.

Given that the dated piece of charcoal from layer VI was fine and was recovered from wet sieving it is possible that it derived from a large modern burrow that cut into layer VI. Two charcoal samples from the burrow had similar values: 33 950 ± 200 uncal BP and 37 220 ± 290 uncal BP. Either all three dates are conceivably too young or the fill of the burrow derived from another part of the cave where younger sediments exist.

The high standard deviations of the OSL and TL dates preclude the assignment of the layer to a specific millennial scale climate episode. In addition, the lithostratigraphic interpretation suggests that the layer represents a palimpsest of perhaps thousands of years of sediment deposition, mixing and erosion, meaning that it is very difficult to match precisely the deposits with high-resolution marine or ice core records. It is thus only possible to speak generally about the Neanderthal occupation of the cave in early MIS 3. The presence of lesser quality lithic artefacts might suggest that raw materials were less readily available than during the DSm. These appear to have been sourced as pebbles from the Guadalete or Majaciete river terraces.

The latest Middle Palaeolithic occupation is recorded in layer V. Despite a range of techniques being applied, the only successful date derived from a small charcoal fragment recovered during wet sieving. It produced an age of 20 780 ± 80 uncal BP. Given the recent late dates for the Middle Palaeolithic at the back of Gorham's Cave (Finlayson et al., 2006), one cannot disregard the possibility that Neanderthals could have survived until this date in Higueral de Valleja. As will be discussed below, the next occupation of the cave was probably in the Solutrean. Taking an alternative point of view, the dated charcoal could conceivably have migrated into layer V from above and could tie in with Solutrean occupation layers. One also has to explain the OSL date in layer IV of 33 200 ± 3100 BP.

Palaeoenvironmental evidence suggests that the climate was slightly cooler in layer V than in layers VI and IV but not noticeably wetter as would be expected during an episode of cryoclasticism, which might traditionally be used to account for the presence of the dolomitic blocks in the layer. The number of phytoliths found and the low D/P ratio indicate sparse vegetation outside the cave. The presence of *M. duodecimcostatus* (pine vole), *M. brecciensis* (extinct vole) and *A. sylvaticus* (wood mouse) also implies a cooler and drier climate. However, the appearance of *Arvicola sapidus* (water vole) suggests that ponds formed near the cave. Taphonomic displacement may explain the occurrence of this species in this layer but, equally, it may be because Higueral de Valleja is situated in an area of high biodiversity.

None of the 28 lithics recovered from layer V were diagnostically Upper Palaeolithic. A Middle Palaeolithic technology is suggested by a denticulate with inverse retouch, a notched piece, and a Pseudo Levallois Point. It is too soon in this current programme of research at Higueral de Valleja to comment on aspects of late Neanderthal behaviour. However, the presence of a *Pecten maximus* (scallop) shell in layer V is of archaeological interest. Research at Gorham's Cave has shown that Neanderthal populations probably exploited a small geographical range as raw materials and economic resources could have been acquired within a 15 km radius of Gibraltar (Barton, 2000). In contrast to this pattern, the shell almost certainly came from the Atlantic Ocean, which today is more than 50 km to the west. This suggests that Neanderthal mobility patterns were greater than previously thought in southern Iberia. Higueral de Valleja is also the farthest inland Middle Palaeolithic site with evidence of marine exploitation in the area (Jennings, 2006).

5.3. *Stony-silt deposits with Upper Palaeolithic evidence (Layers IV–III)*

Lithostratigraphic analysis showed that the sandy silts of layer IV may have formed over several thousand years and have undergone multiple episodes of sedimentation, erosion and mixing. This would explain the disparity in the results of the radiometric dating. The OSL date of 33 200 ± 3100 BP for the layer pre-dates the Gravettian in southern Iberia by 5000 years. The age range coincides with the Middle and early Upper Palaeolithic but no lithics belonging to either period were found in the layer. The possibility that the layer contains Solutrean lithics is strengthened considerably by the outcome of two TL dates on burnt pieces of flint. The one with the securest stratigraphic context came from the middle of the layer and had an age of 18 300 ± 4800 BP. The second piece was found at the interface of layers IV and III and was dated to 15 500 ± 3700 BP. Phytolith and small mammal evidence suggest that the climate was slightly warmer than layer V, but overall was cooler and drier than the DSm layers.

The discovery of the Gravettian style microlaminar point in layer IV is significant because it raises the possibility that modern humans occupied the cave during late MIS 3. However, it would be hasty to make such a claim until further Gravettian lithics are found. This is because the microlaminar point could be part of a late Solutrean industry known as Solutreo-Gravettian, which contains elements that resemble the Gravettian. Two bladelet cores found in the layer could equally be Gravettian or Solutrean. Given that Gravettian deposits were not recorded in the 1979–1982 test excavations, it may be that the latter explanation is most plausible.

The lack of significant change in the environmental evidence from layer IV to layer III suggests that this part of southern Iberia continued to function as a glacial refuge through the last glacial maximum. However, the similarity might also be the result of the partial mixing of the two layers as suggested by the dating results. The Solutrean occupation in layer III represents the densest occupation layer in the whole cave. This is matched by a decline in the diversity of herpetofaunal species, which would suggest a less frequent use of the cave by raptors when humans were present. As well as the increase in lithic numbers, there is a rise in the quantity of red deer remains, some of which reveal traces of human butchery cut marks. The increase in intensity of occupation at Higueral de Valleja is reflected by a concomitant increase in the number of Solutrean sites in southern Iberia, more than sixty of which are currently known.

6. Concluding remarks

A small-scale excavation was undertaken at Higueral de Valleja Cave in Cádiz Province to acquire palaeoenvironmental and dating evidence concerning the late survival and eventual extinction of the Neanderthals and the arrival of modern humans in this part of southern Iberia. The results showed that the cave does contain evidence for Neanderthal occupation during MIS 3 in the form of Middle Palaeolithic deposits dating to ca. 55 000 BP and redeposited material dating to <40 000 BP. Lithostratigraphic analysis and environmental data indicated that the depositional environment was cooler and drier during this time compared to deposits deeper in the stratigraphic sequence, which although undated may belong to MIS 5. However, despite the cooler and drier conditions, evidence emerged that a range of habitat types existed near the cave. This is significant for it raises the possibility that there may be a link between the late survival of the Neanderthals and the persistence of warm and humid environments. This will be examined in detail in the next phase of fieldwork at the cave.

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