JOURNAL OF QUATERNARY SCIENCE (2011) 26(6) 635–644 ISSN 0267-8179. DOI: 10.1002/jqs.1486

Chrono-stratigraphy of the Upper Pleistocene and Holocene archaeological sequence in Cova Gran (south-eastern Pre-Pyrenees, Iberian Peninsula)

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Received 7 October 2010; Revised 7 January 2011; Accepted 7 January 2011

ABSTRACT: The Cova Gran de Santa Linya (Lleida, Spain) is a recently discovered site, with a broad chrono-cultural sequence that contains archaeological levels dating to the Middle Palaeolithic, Early Upper Palaeolithic, Late Upper Palaeolithic, Neolithic and Early Bronze Age. We present the chronometric and stratigraphic context of these occupations, which were dated using ^{14}C accelerator mass spectrometry and thermoluminescence. The sequence provides important indicators that aid in the reconstruction of the history of human occupation on the southern slopes of the Spanish Pyrenees over the past 50,000 years.

KEYWORDS: Cova Gran; Iberia; radiometric dating; stratigraphy.

Introduction

Cova Gran is a large rock shelter in which archaeological excavations undertaken from 2004 onwards have revealed a broad cultural sequence covering the last 50,000 years. This shelter contains autochthonous sediments with archaeological levels from the Late Middle Palaeolithic (LMP), Early Upper Palaeolithic (EUP), Late Upper Palaeolithic (LUP), Neolithic and Early Bronze Age. Preliminary results for the MP–UP transition levels have been published recently (Martínez-Moreno *et al.*, 2010), but most of the archaeological sequence is presented here for the first time.

The main focus of this paper is the archaeo-stratigraphic sequence of this site as it is currently known with emphasis on the cultural, stratigraphic and chronometric context. We also present 36 ^{14}C accelerator mass spectrometry (AMS) and thermoluminescence (TL) dates, most of which have not previously been published. The significance of this radiometric series is analysed and discussed on the basis of its stratigraphic and archaeological consistency, acknowledging that there are differences in terms of their temporal resolution. This series of dates has implications for our perception of the technology, subsistence and organization of human populations that lived on the southern slopes of the Pyrenees during the Late Pleistocene and Holocene.

Cova Gran provides a key sequence for the analysis of the MP–UP transition, the occupation of the southern Pyrenees during and after the Late Glacial Maximum, and the appearance of a Neolithic economy in the Iberian Peninsula. In summary, Cova Gran provides unparalleled evidence in understanding the cultural processes that have occurred in the western Mediterranean over the last 50,000 years.

General setting

Cova Gran de Santa Linya (0°48′45.78″E, 41°55′37.65″N) is located in the outer Marginal Sierras of the southern slopes of the Eastern Pyrenees (Lleida, Spain; Fig. 1). The region contains thin Mesozoic layers with a Tertiary cover, overlying Triassic evaporites. The rock shelter is in the Bona Formation (Late Cretaceous), and is composed of bioclastic limestones, calcarites, sandstones and bioconstructions that were deposited on a shallow-marine carbonate platform (Simo, 2004).

This rock shelter faces south, is 92 m wide, 83 m deep and has a 25-m-high vaulted roof (Fig. 2). Cova Gran is 385 m asl at the bottom of the Sant Miquel ravine, a tributary of the Noguera Pallaresa river. This ravine forms a small V-shaped valley more than 250 m deep, with mean slopes of 17°. The valley was incised at the contact between the Bona Formation and the Upper Triassic evaporites (ICC, 2002) (Fig. 1). The displacement of this contact by faulting determines the direction of the ravine, which forms a small meander. The concave side of the meander enters the rock shelter, the walls of which show faults and fractures with areas of associated brecciation.

The sedimentary infill at Cova Gran contains clear morphological sectors (Fig. 3). On the western side, a ramp (R) has been preserved on gravitational deposits. These sediments overlie two large blocks, which cover alluvial gravels. The ramp is 9 m above the riverbed and slopes down towards the east, to a transitional (T) sector that becomes a platform (P) located +3 m above the riverbed. Recent sandy sediments cover the surface of sector P, which extends towards a lower plain (LP) affected by the current stream course. The thickness of deposits was estimated using electrical resistivity tomography, from 2.6–4.5 m near the rock shelter wall to 7–9 m in more central areas of the cavity (Martínez-Moreno *et al.*, 2008). In sector R deposits are estimated to be between 4 and 6 m thick.

Stratigraphic sequence

Fieldwork has combined test-pitting and open-area excavation undertaken in the sectors, which we refer to as ramp (R), transitional (T) and platform (P). Approximately 60 m^2 of sector R at the western end of the rock shelter and 32 m^2 of sector P, in its innermost area, have been excavated. A 4-m^2 test-pit was also dug in the transitional sector (T) (Fig. 3). The information obtained from these areas has provided an initial stratigraphic sequence, in which we have identified human occupations during the Upper Pleistocene and Holocene.

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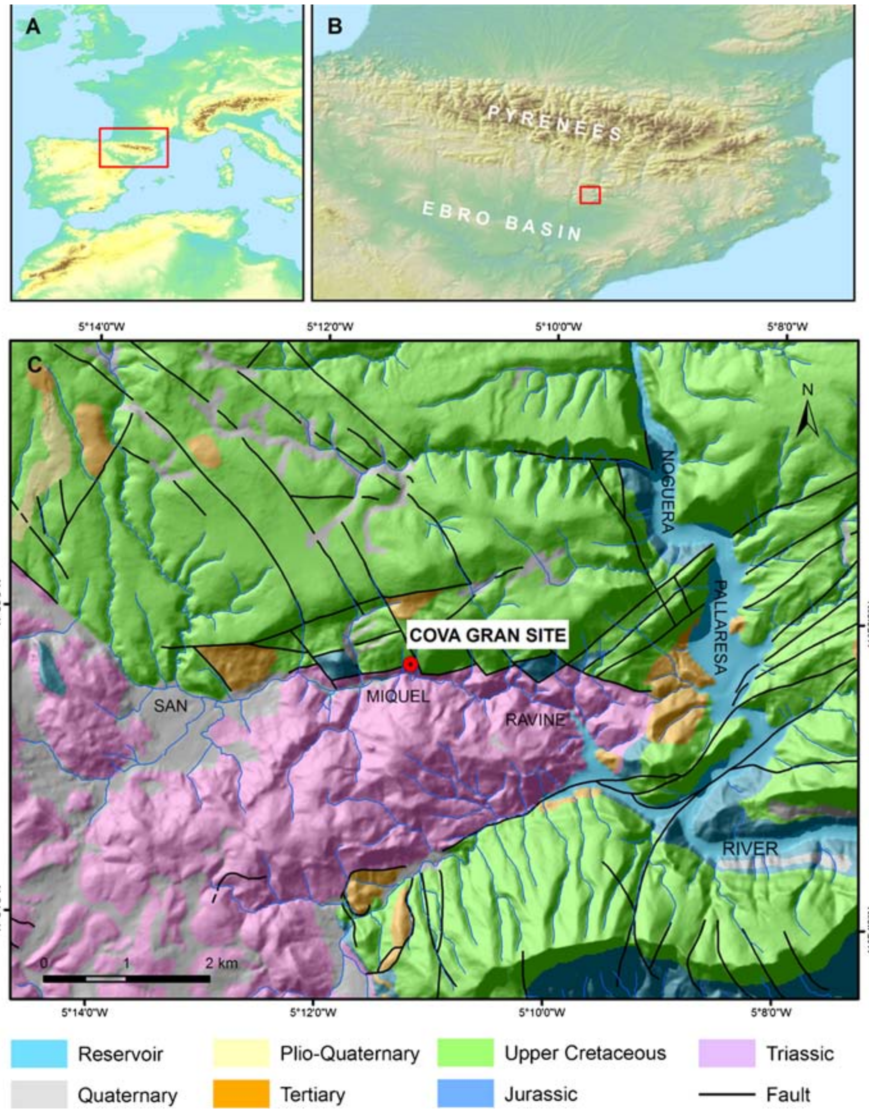

Figure 1. General context of the Cova Gran site. Location in the European (A) and Pyrenees (B) context, and geological framework (C). This figure is available in colour online at wileyonlinelibrary.com.

Upper Pleistocene sequence

The oldest deposits documented to date are in sector R (Fig. 3), where a 3-m-thick sequence has been excavated without reaching bedrock. Two stratigraphic units (S1 and 497) have been identified in this area.

The S1 unit consists of autochthonous rockfall deposits (Figs 3C and 4), in beds in which the contact is either gradual or separated by collapsed >1-m boulders. They are angular and very angular, poorly classified sediments with medium and coarse gravel sizes. The matrix is sparse (< 20%) and consists of silty/clayey sands. The fine fraction consists mainly of calcite and dolomite, which decreases towards the roof coinciding with an increase in siliceous minerals (quartz, albite, illite and clinochlore) and gypsum (Benito-Calvo *et al.*, 2009). The basal layers excavated in the east of the ramp form a depositional slope towards the W-SW, which gradually flattens out. In the upper layers, located in the western zone of the ramp, they slope E-NE. This configuration defines two areas in which sediments originated.

Figure 2. General view of the Cova Gran de Santa Linya rock shelter. This figure is available in colour online at wileyonlinelibrary.com.

Sedimentary body 497, which slopes 12°N 70°E, rests on unit S1 (Fig. 4). Unit 497 consists of autochthonous materials that were washed downslope, characterized by fine and very fine, rounded and subrounded gravels containing an abundant matrix of lutitic sands (40%). Calcite and quartz, in equal parts, form the predominant minerals of the matrix with traces of albite, illite and clinochlore (Benito-Calvo *et al.*, 2009).

The Pleistocene sequences of sectors T and P are in a more recent stratigraphic position. Stratigraphic unit P consists of autochthonous angular and very angular clasts and large blocks, with a negligible matrix of silty–clayey sands (Fig. 6A). This unit, formed by rockfall processes, has a slope towards the south and south-east (Fig. 5).

At the base of sector T more recent Pleistocene deposits overlie a large block of limestone, which could be bedrock

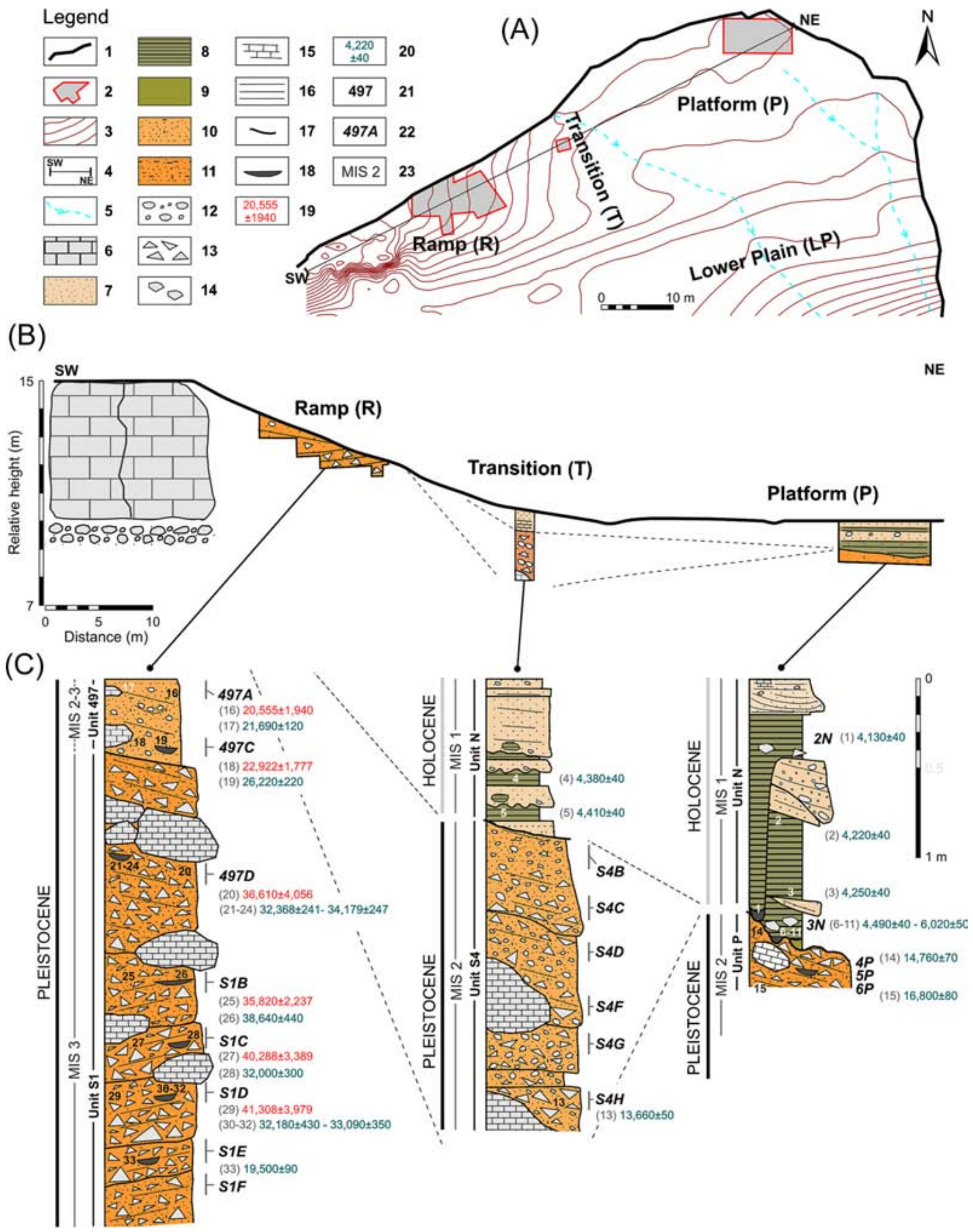

Figure 3. General stratigraphic sequence at the Cova Gran site. (A) Topography, zones and excavated areas. (B) Interior longitudinal geomorphological section. (C) Stratigraphic sequence of the excavated areas. Legend: 1, limestone bedrock; 2, excavated areas; 3, topographical contours (0.5 m); 4, geomorphological section; 5, drainage lines; 6, limestone blocks; 7, sands; 8, fumiers; 9, sand and clays; 10, clays and sands; 11, sands, clays and silts; 12, rounded and subrounded clasts; 13, angular and subangular clasts; 14, archaeological blocks; 15, carbonate concretions; 16, bedding; 17, discontinuity; 18, hearths; 19, TL data; 20, ^{14}C data; 21, stratigraphic unit; 22, archaeological level; 23, MIS. This figure is available in colour online at wileyonlinelibrary.com.

(Fig. 3C). The deposits consist of a succession of sandy beds with rounded clasts, and medium-sized subangular and subrounded carbonated clasts in a sandy–clayey matrix. These deposits form a slope towards the east and originate from the degradation of sector R as a result of tractive processes, although subangular clasts and large blocks that have accumulated through gravitational processes can also be seen.

Holocene sequence

Sedimentary layers ascribed to the Holocene appear in sectors T and P. These sequences lie directly eroding to the Pleistocene deposits.

The Holocene sequence consists of a succession of human occupations, interspersed with tractive events represented by sand and gravel levels (Figs 3 and 5). The occupation levels are most evident in sector P (Fig. 6B), and consist mainly of fine deposits containing ashes and organic material related with *fumier*-like deposits (Angelucci *et al.*, 2009) that indicate the regular stabling of herds in the rock shelter. The occupation deposits also contain areas of angular and subangular clasts. Blocks associated with man-made structures and storage pits, which are eroding the levels beneath (Figs 3, 6 and 7), were identified.

The tractive facies are mainly fine- and medium-grained sandstones, with a level of fine and very fine gravels (Figs 3 and 5). In sector T these units slope eastwards, and in the basal zones include soft clasts originating from erosion of the *fumiers*. In sector P, however, the units slope and become thicker towards the exterior of the rock shelter (south and south-east). The basal sandstone levels are cross-stratified and laminated, associated with channels, and massive sands with superficial

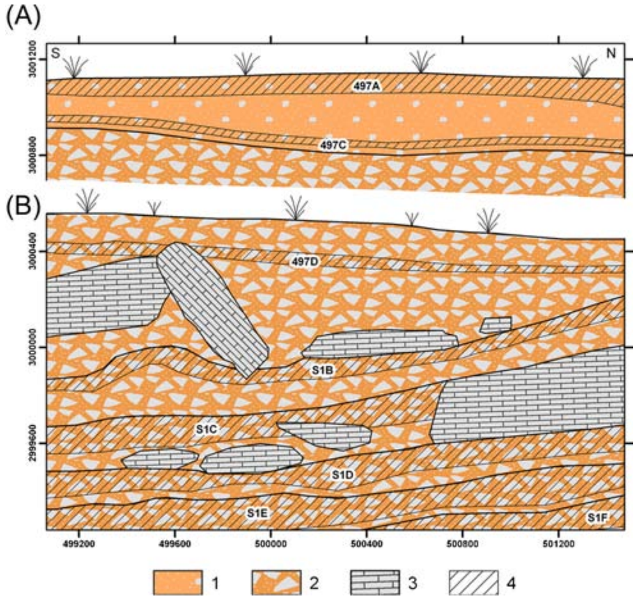

Figure 4. Stratigraphic transverse sections at ramp zone: (A) upper ramp area, (B) lower ramp area. Legend: 1, sands and clays with rounded and subrounded clasts; 2, angular clasts with matrix of sands, clays and silts; 3, limestone blocks; 4, archaeological levels. This figure is available in colour online at wileyonlinelibrary.com.

carbonation (Figs 3 and 5). To date, the structure of the levels and the direction of the sedimentary structures suggest that they are facies originating from inside the rock shelter.

Cultural sequence

The various stratigraphic units of Cova Gran contain archaeological levels corresponding to the LMP, EUP, LUP, Neolithic and Early Bronze Age.

Middle Palaeolithic

To date, five Middle Palaeolithic occupations have been excavated in sedimentary unit S1 (S1F, S1E, S1D, S1C and S1B) and above them, the level 497D, attributed to the EUP (Martínez-Moreno *et al*., 2010).

The Middle Palaeolithic levels are 10–15 cm thick and contain a high density of flint and metamorphic rock artefacts, such as hammerstones, cores, flakes and retouched tools, with characteristics that are similar to other nearby Mousterian sites with MIS3 occupations (Casanova *et al*., 2009). The fauna includes *Stephanorhinus* sp., *Bos* sp., *Equus caballus*, *Equus cfr. hydruntinus*, *Cervus elaphus* and *Capra pyrenaica*, on which diaphyses with fresh fractures can be identified, suggesting that they were processed by human. The final appearance of the Middle Palaeolithic is detected in level S1B, which includes all elements of the chaîne opératoire (hammerstones, cores, flakes, retouched pieces and microdebitage of <1.5 cm). The *Levallois* recurrent centripetal production method is abundant, although some small flint cores were flaked following a unidirectional system from orthogonal platforms.

Upper Palaeolithic

Upper Palaeolithic archaeological levels have been found in the R zone, where materials attributable to the EUP were recovered from the top of unit S1 (level 497D) and in unit 497 (levels 497A and 497C). Units S4 and P in the platform and transition zones also contain archaeological levels attributed to the LUP.

The EUP stone tools from 497D, 497C and 497A are characterized by the widespread use of blade knapping systems, although variations can be seen in the configuration of the assemblages. In level 497A the main objective was the production of bladelets, while the older levels 497D and 497C contain elongated, large, thick blades as well as bladelets. Local flint is practically the only raw material exploited. Lithic

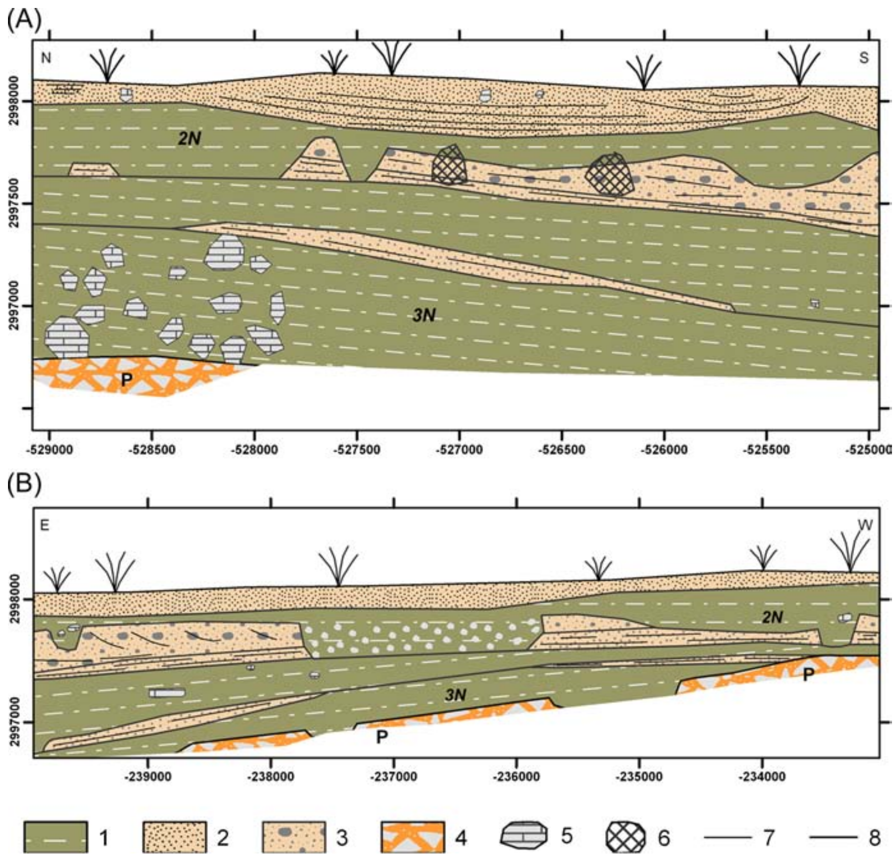

Figure 5. Stratigraphic section at platform zone: (A) N–S section, (B) E–W section. 1, fumiers; 2, sands; 3, sands and gravels; 4, angular clasts with matrix of sands, clays and silts; 5, blocks; 6, rabbit holes; 7, bedding; 8, discontinuity. Note the shape of the cuts detected in 2N, 3N and at the top of 4P which relate to intrusive pits which cut through these levels. This figure is available in colour online at wileyonlinelibrary.com.

Figure 6. General views of the excavation of sector P. (A) Contact between levels N and P in the W profile. The change between fine sediments very rich in organic material (N) and the sedimentation of angular clasts of level P can be observed. The pit-hearth H1 of level 2N is in the foreground. (B) General view of the souh-west corner of sector P. The cross-section shows the thickness of the stabling levels in this part of the excavation and various storage structures, in some cases cutting into each other. This figure is available in colour online at wileyonlinelibrary.com.

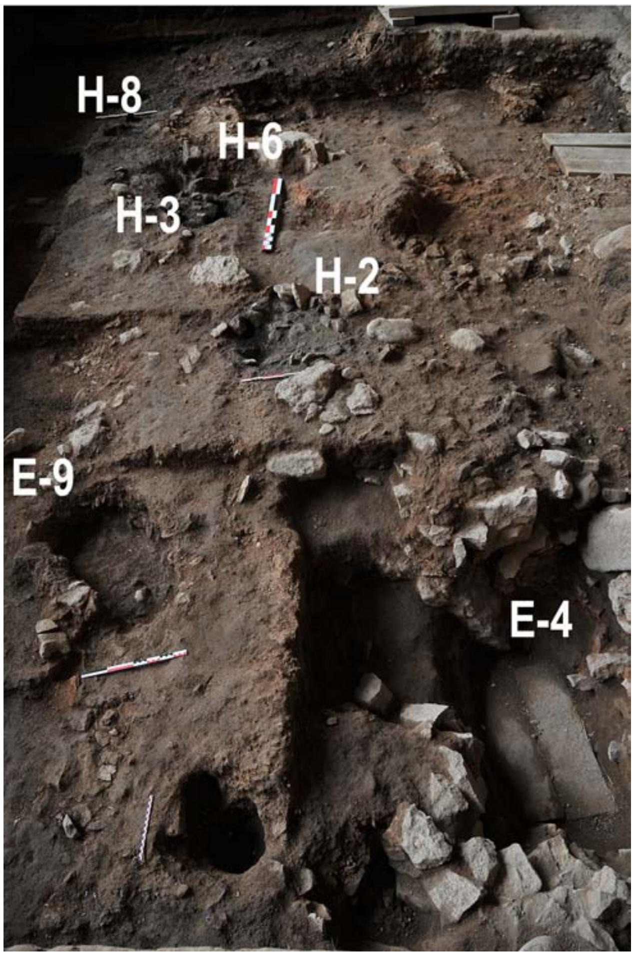

Figure 7. General view of the excavation of level 3N of sector P, showing hearths (H) and pit structures (P) dated. P-4 is a very large intrusive pit that comes from a higher level, cutting into the surface continuity of level 3N. This figure is available in colour online at wileyonlinelibrary.com.

assemblage 497D marks the first appearance of the Upper Palaeolithic in Cova Gran (Martínez-Moreno *et al.*, 2010). This assemblage contains burins, end scrapers and backed bladelets, although no index fossils or other stylistic indicators have been identified that would allow the assemblage to be ascribed to the classic cultural phyla defined for the Upper Palaeolithic of Western Europe (Demars and Laurent, 1992).

To date, no bone tools have been recovered from these levels, although fossils of *Stephanorhinus* sp., *Equus caballus*, *Cervus elaphus* and *Capra pyrenaica* have been identified in the faunal assemblage. In the three EUP levels marine shell ornaments have been recovered, including an important assemblage from level 497D in which 25 complete and 10 broken *Nassarius pygmaea* and one *Antalis* sp. have been identified. They were probably brought here from the Mediterranean, which today is more than 150 km away. The transport of marine ornaments continues to be documented in levels 497C and 497A where *Nassarius pygmaea* is still the most abundant species although *Trivia* sp. and *Columbella rustica* have also been found.

The archaeological levels attributed to the LUP are located in sector P and unit S4 (sector T) (Fig. 3). To date, three archaeological units (4P, 5P and 6P) have been documented in unit P, although bedrock has not been reached as yet. Knapping strategies are essentially aimed at the production of narrow flakes together with an important microlaminar component. Retouched pieces include an abundance of backed bladelets, burins, truncated blades and scrapers-on-blade. In level 5P three deer antler points, one broken bone eyed-needle and ornaments (carved red deer canine and marine shells) have been recovered. In chrono-cultural terms, this assemblage can be ascribed to the Magdalenian techno-complex.

A continuous archaeological record has been recovered in unit S4 of sector T, differentiating at least six archaeological levels attributable to the LUP (S4H, S4G, S4F, S4E, S4D, S4C and S4B, Fig. 3C), and ascribed to the Magdalenian. Techno-typologically these assemblages are similar to those described in unit P above, although a marked tendency towards smaller pieces is observed, and burins are more abundant than end scrapers. An important lamellar component suggests an incipient process of microlithization, a pattern characteristic of the LUP in the Iberian Peninsula (Aura, 2007).

Late Prehistory

Two Late Prehistoric archaeological levels have been identified so far in the sedimentary unit N (Fig. 3A,C). In this unit, anthropogenic deposits (Fig. 7) indicate the stabling of livestock in the rock shelter.

On the basis of the material recovered, archaeological levels 3N and 2N have been ascribed respectively to the Neolithic and Early Bronze Age. Nearly 30 domestic structures have been identified in level 3N (hearths, post-holes and storage pits), some of which cut into or overlap each other, indicating relative temporal positions. Pits eroding the lower levels have also been detected (Figs 6 and 7). These structures suggest that level 3N has undergone intense anthropogenic sedimentary disturbance caused by human modification of the rock shelter. Bioturbation produced by burrowing animals has also been identified. These features characterize a palimpsest with little contextual resolution.

There are few materials associated with these structures in level 3N and in stylistic terms most of the ceramic material is not diagnostic. Ceramic motifs can be attributed to the Middle/Late Neolithic, along with sherds with decorative styles characteristic of later phases (Bell-beaker and Early Bronze Age) that cover a period of more than 2000 years. These associations could have formed through disturbance caused by intrusive structures (some of which are very large) that would result in the mixing and/or redeposition of materials, giving the false appearance of synchronism.

Radiometric series

We now have 36 ^{14}C AMS and TL dates that provide varying degrees of precision of the radiometric dating of the site. The ^{14}C dates were calibrated for comparison with TL chronometric dates using the Hulu model (Weninger and Jöris, 2008). The time intervals are expressed in cal a BP with 1σ for ^{14}C dates of >26 ka BP, while ^{14}C dates of <26 ka BP are listed in cal a BP with 2σ age errors.

Pleistocene sequence

Part of the series of dates obtained places the Pleistocene stratigraphic units in zone R to Marine Isotope Stage (MIS) 3 and MIS2 (Andersen *et al.*, 2006).

Radiometric dating of the MIS3 sequence

The series of dates attributed to MIS3 is located in sedimentary body S1 (Fig. 3). As mentioned above, this unit contains level 497D, attributed to the EUP, while the levels below it (S1B, S1C, S1D, S1E, S1F) are Late Middle Palaeolithic (Martínez-Moreno *et al.*, 2010). Five new dates are presented (Table 1, see Fig. 10) that help clarify the Cova Gran sequence to between 40 and 30 ka, a period relevant to the MP/UP transition (Conard, 2006; Adler and Jöris, 2008), and in particular the debate concerning possible Neanderthal survival in the Iberian Peninsula during the MIS3/2 boundary (Straus, 2005; Finlayson *et al.*, 2006; Zilhão, 2006; Banks *et al.*, 2008).

New dates, which complement those previously presented, are from a marine ornament (*Nassarius pygmaea*) from level 497D (OxA-19520) and four TL dates. The TL series provides a consistent time sequence, although one that is characterized by greater uncertainty if we consider its time dispersion in terms of σ values (of around 10% in relation to the mean age). However, the TL date ranges for S1C and S1D place the MP in the interval 45–37 ka BP, suggesting that the ^{14}C AMS dates for levels S1C and S1D underestimate the chronometric range of these events, which could affect the ^{14}C dates in the period 40–30 ka (Pigati *et al.*, 2007).

Much of the interest in this series centres on discussion of the radiometric dating of levels S1B/497D, in which the MP/UP techno-typological change is detected. The ^{14}C AMS series of level 497D overlaps the oldest interval range suggested by the TL date, restricting this event to the period 40–36 cal ka BP (Fig. 10).

The new sample OxA-19520 (K. Douka, pers. com.) from level 497D was processed using a new decontamination protocol (CarDS) developed to reduce the effect of secondary carbonate contamination (Douka *et al.*, 2010). The date expressed in cal a BP deviates by >5 ka from the other ^{14}C AMS dates (Table 1). It is therefore possible that in this sample problems associated with the accumulation of secondary carbonate affecting this marine shell from Cova Gran have not been resolved, so it should be considered a minimum age.

Although the ^{14}C AMS sample treated with ABOX is >3 ka older than the samples treated with standard protocols, the minimum chronometric distance is around 1 ka. Radiometric deviations were identified in the same sample treated using ‘acid base acid’ (ABA) and ‘acid base oxidation’ (ABOX) protocols, and in general the dates processed with ABOX provide older chronometric ranges. This suggests that the

Table 1. Radiometric series of the archaeological levels of sedimentary body S1 in sector R, related to the MP/UP transition, obtained using ^{14}C and TL.

No.	Level	Sample	Lab. no.	Age (BP)	σ	δ^{13}C (‰)	Method	Protocol	Age (cal a BP) p (68%)	Context
Early Upper Paleolithic										
1	CG-497D	Marine shell*	OxA-19250	26340	130	–	^{14}C AMS	Car DS	31230 ± 260	Level 497D
2	CG-497D	Charcoal†	Beta-207578	32630	450	−22.7	^{14}C AMS	ABA	37020 ± 860	Level 497D
3	CG-497D	Charcoal‡	AA 68834	32368	241	–	^{14}C AMS	A	36800 ± 850	Hearth Level 497D
4	CG-497D	Charcoal‡	AA 68834	33068	261	–	^{14}C AMS	AAA	37330 ± 760	Hearth Level 497D
5	CG-497D	Charcoal‡	AA 68834	34179	247	–	^{14}C AMS	ABOX	39650 ± 900	Hearth Level 497D
6	CG-497D	Burned flint	MAD-5502BIN	36610	4056		TL		36610 ± 4056	Level 497D
Late Middle Paleolithic										
7	CG-S1B	Charcoal	Beta-224299	38640	440	−24.2	^{14}C AMS	ABA	42750 ± 400	Hearth Level S1B
8	CG-S1B	Burned flint	MAD-5580BIN	35820	2237		TL		35820 + 2237	Level S1B
9	CG-S1C	Charcoal	Beta-195430	32000	300	−23.5	^{14}C AMS	ABA	36030 ± 510	Hearth Level S1C
10	CG-S1C	Burned flint	MAD-5575BIN	40288	3389		TL		40288 + 3389	Level S1C
11	CG-S1D	Charcoal	Beta-187423	32180	430	−24.0	^{14}C AMS	ABA	36620 ± 950	Hearth Level S1D
12	CG-S1D	Charcoal	Beta-207575	32260	490	−23.0	^{14}C AMS	ABA	36710 ± 970	Hearth Level S1D
13	CG-S1D	Charcoal	Beta-195431	33090	350	−22.9	^{14}C AMS	ABA	37360 ± 810	Hearth Level S1D
14	CG-S1D	Burned flint	MAD-5574BIN	41308	3979		TL		41308 ± 3979	Level S1D
15	CG-S1E	Burnt sediment#	Beta-195429	19500	90	–	^{14}C AMS	ABA		Level S1E

The pretreatments used on the ^{14}C samples are listed. The ^{14}C series has been calibrated using the HULU model with 1σ. Observations: *K. Douka, pers. com.; †charred charcoal; ‡same sample (Pigati *et al.*, 2007); #unconformity date. Protocol: A, acid only; AAA, acid alkaline acid; ABA, acid base acid; ABOX, acid base oxidation; Car DS, carbonate density separation.

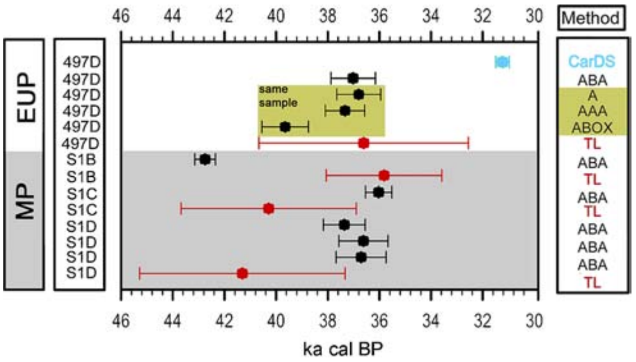

Figure 8. Calibrated radiometric results of the ^{14}C and TL dates relating to sedimentary body S1, which correspond to Middle Palaeolithic (MP) and Early Upper Palaeolithic (EUP) levels. The chronometric variations of sample AA-68834 are indicated according to the pretreatment used and the result obtained from a marine shell treated by CarDS. The ^{14}C dates are expressed as cal a BP with 1σ age ranges (see Table for details). This figure is available in colour online at wileyonlinelibrary.com.

differential preservation of the charcoal structure causes a radiometric underestimation of the dates (Higham *et al.*, 2009). Such a process could explain the asynchronies observed in dates associated with the MP/UP transition, and may be a factor explaining the phenomenon of radiometric synchrony (Martínez-Moreno *et al.*, 2010).

The ^{14}C and TL dates for S1B lack a chronometric coincidence interval and differ by C. 5 ka (Fig. 8). Accepting these limitations, the ^{14}C dates should be considered a maximum age (although possibly underestimated) for the end of the Middle Palaeolithic, tentatively suggesting that this occurred around 43 cal ka BP.

If these observations are accepted, then the earliest evidence for the Upper Palaeolithic in Cova Gran could be ^{14}C dated to around 40.5–37.5 cal ka BP, whereas the final evidence for the MP would be at around 43 cal ka BP. We propose that these temporal indicators should be considered minimum ages.

Although the chronometric ranges that we suggest for the MP/UP transition in Cova Gran do not differ substantially from those proposed in Fumane (Higham *et al.*, 2009), we consider that the uncertainties associated with the use of ^{14}C in this temporal segment make it difficult to establish temporal ranges in terms of earliest and final indicators for the MP/UP transition. The problem of treating chronometric intervals as 'precise' (Jöris and Street 2008) is that there are still substantial issues associated with the interpretation of chronometric ranges obtained using AMS dating for this period.

With such problems in mind, we have taken a 'fuzzy' perspective towards the radiometric dating of the MP/UP of Cova Gran. Improvements in the pretreatment protocols (Pigati *et al.*, 2007; Higham *et al.*, 2006; Brock *et al.*, 2010; Douka *et al.*, 2010) and the determination of isochronic markers

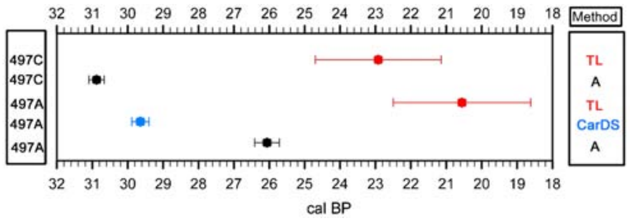

Figure 9. Calibrated radiometric results of the ^{14}C and TL dates relating to sedimentary body 497. The result of a marine shell treated with CarDS is shown (see Table 2). The ^{14}C dates are expressed as cal a BP with 1σ. This figure is available in colour online at wileyonlinelibrary.com.

(Bockley *et al.*, 2008) will probably provide new arguments to determine the reliability of the dates. Similarly, the calibration of dates, a fundamental aspect of interpreting ^{14}C, will be secondary to using dates from samples unaffected by processes of alteration, as this bias could be an active agent that conditions discussion of the MP/UP transition.

We also draw attention to the major deviations arising from dates obtained from TL and ^{14}C, which hinder effective comparison between chronometric ranges obtained by radiometric methods that are widely used to reconstruct the last 50,000 years.

Radiometric dating of the MIS2 sequence

MIS2 is represented in Cova Gran in sectors R, T and P (Fig. 3). In sector R, five dates are available for levels 497A and 497C (EUP): three on marine shells and two TL (Table 2, Fig. 9).

A considerable gap is observed between units S1 and 497, which coincides with a sedimentary change. This gap is more pronounced in the TL dates than in the ^{14}C AMS dates, where calibration reduces the temporal separation to 5 cal ka BP.

The significant deviations observed between the ^{14}C and TL dates had already been observed in unit S1. The TL dates show a consistent stratigraphic position, although with high σ values considering the percentage in relation to the mean age (Fig. 9). The samples for ^{14}C AMS analysed in the Beta laboratory are from fragments of *Nassarius pygmaea*, while a perforated example was processed in the Oxford laboratory. Calibration of these dates provides a consistent stratigraphic sequence, but with considerable deviation [> 4 cal ka BP] between the date from the standard pre-treatment (Beta-207576) and that processed using the CarDS method (OxA-19262) from level 497A (K. Douka, pers. com.). Note that the sample processed with CarDS in level 497D diverged from the chronometric tendency of the charcoal dates by around <5 cal ka BP (Table 2).

Given the disparity between TL and ^{14}C dates and the imprecise cultural ascription of these lithic assemblages, levels 497C and 497A have been provisionally assigned to an

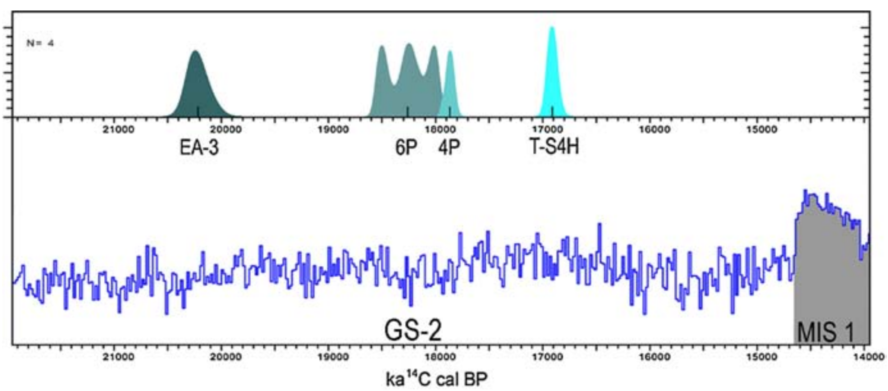

Figure 10. Calibrated radiometric results of ^{14}C dates ascribed to the Pleniglacial (see Table 3). The dates are expressed as cal a BP with 2σ. This figure is available in colour online at wileyonlinelibrary.com.

Table 2. Radiometric series for levels 497A and 497C of sedimentary body 497 of sector R obtained using ^{14}C and TL.

No.	Level	Sample*	Lab. no.	Age (BP)	σ	$\delta^{13}C$ (‰)	Method	Protocol	Radiometric age (cal a BP) p (68%)	Context
1	CG-497A	Marine shell	Beta-207576	21690	120	1.0	^{14}C AMS	A	26066 ± 349	Level 497A
2	CG-497A	Marine shell†	OxA-19262	24600	110	–	^{14}C AMS	Car DS	29643 ± 244	Level 497A
3	CG-497A	Burned flint	MAD-5569BIN	20555	1940		TL		20555 ± 1940	Level 497A
4	CG-497C	Marine shell	Beta-207577	26220	220	2.0	^{14}C AMS	A	30881 ± 216	Level 497C
5	CG-497C	Burned flint	MAD-5570BIN	22922	1777		TL		22922 ± 1777	Level 497C

The pre-treatments used on the ^{14}C samples are listed. The ^{14}C series was calibrated using the HULU model with 1σ.
*All five samples were attributed to Early Upper Paleolithic. †K. Douka (pers. com.).

indeterminate EUP on the MIS3/2 boundary. On the basis of the ^{14}C dates, these levels lie in the interval 31–26 cal a BP, while the TL data place them in a more recent time frame, 25–18 ka BP.

Human presence in Cova Gran during MIS2 is also documented in sectors T and P, and levels excavated so far post-date the Maximum Late Glacial (Rasmussen *et al.*, 2008). The four dates of unit P are from archaeological levels 4P, 5P and 6P. The dates from these levels (Table 3, Fig. 10) are consistent with their stratigraphic position, between 18.5 and 18 cal ka BP.

There is only one date in sector T, with a range of 16,990–16,830 cal a BP (Table 3, Fig. 10). This is consistent with the associated Magdalenian archaeological record. The date of this level complements the sequence of levels from sector P. The archaeological levels situated stratigraphically above it are more recent, probably belonging to the end of the Pleniglacial and Late Glacial.

Holocene sequence

The third block of dates presented here belongs to the Holocene and they are from unit N. The domestic structures from levels 2N and 3N constitute a palimpsest, although a number of inferences can be made about the duration of human occupation on the basis of ^{14}C. The 12 ^{14}C AMS dates are consistent with the stratigraphy and the archaeological record attributed to the Neolithic and Early Bronze Age (Table 4, Fig. 11). The only date obtained from level 2N is more recent, and its chronometric distribution is excluded from the level 3N series of dates.

The dates obtained from the top and bottom of the animal pen in sector P (Beta 262454 and Beta 260860) show practically identical chronometric intervals (Table 4, Fig. 11), although in some cases the excavated deposits are nearly 0.5 m thick (Fig. 6). Similarly, the rates of accretion of the animal pen in sector T are very fast. This suggests that these

Table 3. Radiometric series for the levels attributed to the end of MIS2 in sectors P and T.

No.	Sector	Lab. no. (Beta-)*	Level	Age (BP)	σ	$\delta^{13}C$ (‰)	Radiometric age (cal a BP) p (95%)	Cultural attribution
1	T	187424	S4H	13660	50	−24,1	16990–16830	Middle Magdalenian
2	P	259273	4P	14760	70	−23,2	17950–17790	Early/Middle Magdalenian
3	P	265984	6P	15120	70	−23,1	18700–17820	Early Magdalenian
4	P	233606	EA-3	16800	80	−22	20420–20020	Early Magdalenian

The ^{14}C series was calibrated using the HULU model with 2σ. *All charcoal samples, ABA protocol, charred charcoal context.

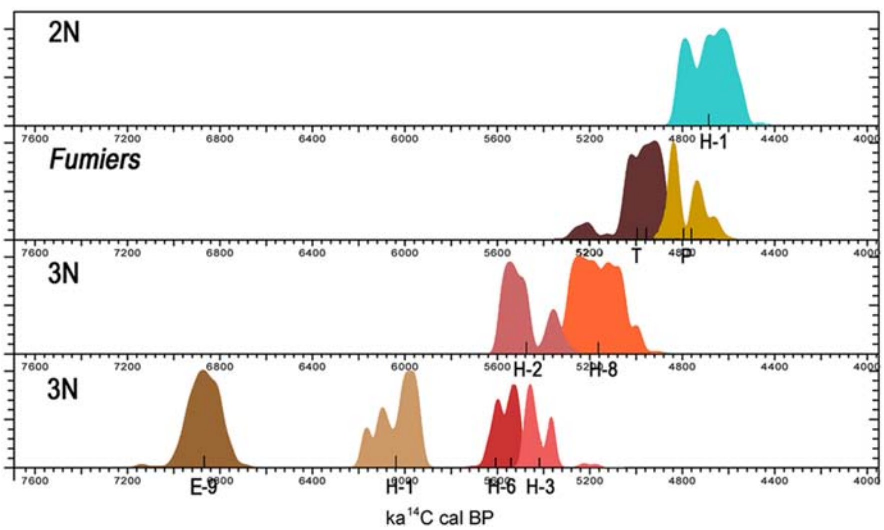

Figure 11. Calibrated radiometric results of ^{14}C dates ascribed to recent Prehistory and which relate to levels 2N and 3N. The chronometric position of the livestock stabling deposits (*fumier*) detected in sectors T and P are indicated. The dates are expressed as cal a BP with 2σ (see Table 4). This figure is available in colour online at wileyonlinelibrary.com.

Table 4. Radiometric series for the recent Prehistoric levels of sectors P and T.

No.	Sector	Sample	Lab. no. (Beta-)	Level	Age (BP)	1σ	$\delta^{13}C$ (‰)	Protocol	Radiometric age (cal a BP) p (95%)	Context	Cultural attribution
1	P	C	261424	2N	4130	40	−24,6	ABA	4890–4490	Hearth H-1	LN
2	P	OS	262454	F-P	4220	40	−25,4	A wash	4920–4600	*Fumier* P-Top	
3	P	OS	260860	F-P	4250	40	–	A wash	4920–4680	*Fumier* P-Base	
4	T	OS	262455	F-T	4410	40	−25,3	A wash	5160–4840	*Fumier* T-Top	
5	T	OS	262456	F-T	4380	40	−25,5	A wash	5070–4830	*Fumier* T-Base	
6	P	C	260862	3N	4490	40	−24,5	ABA	5340–4980	Hearth H-8	MN
7	P	C	260863	3N	4750	40	−23,9	ABA	5650–5290	Hearth H-2	MN
8	P	C	262453	3N	4620	40	−21,4	ABA	5500–5260	Hearth H-3	MN
9	P	C	259272	3N	4780	40	−24,7	ABA	5630–5430	Hearth H-6	MN
10	P	C	261425	3N	4860	40	−21,5	ABA	5680–5520	Hearth H-6	MN
11	P	C	233605	3N	5250	40	−25,7	ABA	6200–5880	EA-2/Hearth H-1	MN
12	P	QS	265982	3N	6020	50	−21,1	ABA	7010–6730	Pitt E9	EN

The original contexts of the samples are listed (see Fig. 7). The ^{14}C series has been calibrated using the HULU model with 2σ.
C, charcoal; OS, organic sediment; QS, *Quercus* seed;LN, Late Neolithic; MN, Middle Neolithic;EN, Early Neolithic.

anthropogenic deposits developed vertically very quickly and could have been formed in less than 300 years. Such high rates of sedimentation would explain why the chronometric intervals of dates from the top and bottom are so similar.

However, the animal pen in sector P is more recent than that in sector T, which suggests the existence of a fairly large herd of livestock which were regularly stabled in large parts of the rock shelter between 5200 and 4600 cal a BP.

The dates from units 3N and 2N of sector P come from excavated pit-hearths, except for a burnt *Quercus* seed recovered from a pit (P-9) (Fig. 7). Acorn seed is an example of a short-life sample recovered from a context that, in principle, implies short-term use.

This set of dates from precise stratigraphic and archaeological contexts shows that level 3N is an accumulation of at least four distinct occupations over two millennia, between approximately 7000 and 5100 cal a BP. Although this area seems to have been reused intensively between 5600 and 5300 cal a BP, as indicated by the dates from hearths H-2, H-6 and H-3, hearth H-8 represents a more recent occupation (Fig. 7). Before that period, two other occupation events are detected; the first around 7000–6800 cal a BP, the date obtained from pit P-9, and the second between 6200 and 5900 cal a BP, which comes from a hearth that could not be correlated with those excavated in level 3N.

Subsequently, a substantial level of stabling is detected in fumier P between approximately 4900 and 4600 cal a BP, which coincides virtually with the calibrated date range for level 2N of 4900–4500 cal a BP. The temporal range for fumier P suggests that the date for this deposit is 4900–4700 cal a BP, while that in level 2N is more recent, between 4700 and 4500 cal a BP.

Conclusions

Excavations undertaken in Cova Gran de Santa Linya have revealed an archaeological sequence that includes the Pleistocene and Holocene. The Pleistocene sedimentary units, accumulated as a result of rock-fall processes, probably related to cold periods and tractive processes, associated with wet episodes. Currently the area excavated does not permit the physical connection of some of the Pleistocene units, in which we have detected sedimentary discontinuities. At the top of the Pleistocene sediments, discordancy with palaeo-relief is observed. In the subsequent Holocene sequence, tractive events also appear, interspersed between sedimentary accumulations in which the stabling of livestock is an important site formation agent.

Despite the presence of sedimentary breaks, Cova Gran contains an impressive cultural sequence with levels attributed to the Middle Palaeolithic, MP/UP transition, EUP, LUP, Neolithic and Early Bronze Age.

From the series of ^{14}C AMS and TL dates obtained in Cova Gran, and discussed on the basis of their stratigraphic position and cultural context, it is tentatively proposed that at this site the final Late Middle Palaeolithic level is not more recent than 43 cal ka BP, while the EUP appears in the interval 40.5–37.5 cal ka BP. These dates introduce new elements of discussion concerning the MP/UP transition in the Iberian Peninsula, which has received much attention in recent years with regards to the extinction of the last Neanderthals (Zilhão, 2006; Adler and Jöris, 2008; Martínez-Moreno *et al.*, 2010).

The chronometric dating of sedimentary body 497, which contains levels 497C and 497A, shows major discrepancies depending on the dating method employed (^{14}C or TL). Furthermore, the archaeological record of these levels does yet not permit a definitive chrono-cultural attribution. These results should form the basis for future investigation on the chrono-cultural position of assemblages at the MIS3/2 boundary and at MIS2, which are very poorly known in the southern Pyrenees.

The series of ^{14}C AMS dates attributed to the LUP indicates re-occupation of the site beginning at around 20 cal ka BP. On the basis of the date from the base of the sector T test-pit, the rock shelter was occupied repeatedly from 17 cal ka BP onwards throughout the end of the Glacial and Late Glacial. To evaluate this hypothesis, more dates are required. Cova Gran provides a key cultural sequence to characterize the Magdalenian techno-complex and its evolution with regard to the impact of the Bolling/Allerod warming period and the Younger Dryas event. Although better known than earlier Upper Palaeolithic periods, the Magdalenian of the Iberian Eastern Pyrenees is still poorly understood (Utrilla and Montes, 2007). Therefore, Cova Gran will become a basic reference for the study of the Pleniglacial and Late Glacial human occupation of the southern Pyrenees.

Between 7000 and 4500 cal a BP, Cova Gran saw consecutive occupation of farming–herding groups. The sectors excavated show that the rock shelter was inhabited, as indicated by the large number of domestic structures (hearths, pits), but this space was also used to stable livestock, as shown by the interstratification of fumiers between archaeological units 2N and 3N. Thus, Cova Gran can also contribute to discussions on the appearance of production economies in the

Iberian Peninsula, a topic that has attracted great interest in recent years (Zapata *et al.*, 2004).

Lastly, it is important to note that the chrono-cultural sequence presented here is preliminary: bedrock has not been reached in any of the zones excavated. However, these provisional data demonstrate the pivotal role for Cova Gran in our understanding of several Palaeolithic and post-Palaeolithic periods, and the radiometric series presented in this paper are fundamental in the context of the Prehistory of the Iberian Peninsula. Excavations at Cova Gran will contribute to a more precise characterization of human settlement during the Pleistocene and Holocene in the western Mediterranean.

Acknowledgements. We thank the two anonymous reviewers and Antony Long for their valuable comments. Katarina Douka kindly allowed us to use her dates on marine shells from levels 497A and 497D. We thank Andreu Rivadulla for his support and comments. The fieldwork in Cova Gran is authorized by the Societat de Munts de Santa Linya. Since 2004, fieldwork has been supported by the Servei d'Arqueologia i Paleontologia-Generalitat de Catalunya. Cova Gran is part of the project 'Human settlement during the Upper Pleistocene and Holocene in the South-eastern Pyrenees' (HAR2010–15002). This is a contribution to research group 2009SGR-0729. R.M. acknowledges an ICREA-Academia award.

Abbreviations. ABA, acid base acid (protocol); ABOX, acid base oxidation (protocol); AMS, accelerator mass spectrometry; EUP, Early Upper Palaeolithic; LMP, Late Middle Palaeolithic; LUP, Late Upper Palaeolithic; MIS, Marine Isotope Stage; TL, thermoluminescence.

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