ISSN: 0214-1744

MICROFACIES AND STRATIGRAPHIC POSITION OF THE MIDDLE-UPPER PALAEOLITHIC BOUNDARY AT ABRIC ROMANÍ (CAPELLADES, BARCELONA, SPAIN)

Microfacies y posición estratigráfica del límite Paleolítico Medio-Superior en el Abric Romaní (Capellades, Barcelona, España).

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Abstract: The Abric Romaní rock-shelter contains a 20 meters deep sequence with abundant anthropic occupations dated to 40-70 Kyrs. The top of the sequence was first excavated and documented by Amador Romaní. The uppermost archaeological level, A. Romaní's Layer 2 (Level Aof the current stratigraphic nomenclature), contains an Upper Paleolithic assemblage.In this geoarchaeological work the stratigraphic position of Level Ais discussed, through the presentation of the NW stratigraphy and the results from micromorphological analyses. The paper also reconsiders A. Romaní's documentation. New data allow us to strengthen his hypotheses on the characterization of the Middle and Upper Paleolithic boundary. The clear chronostratigraphic framework available for level Aallows us to suggest a correlation between the continental sedimentary record of Romani site and the global chronostratigraphic and palaeoclimatic record derived from ocean and ice cores.

Key words: Oxygen Isotopic Stage 3, Dansgaard-Oeschger events and cycles, aeolian dust, micromorphology, middle-upper Paleolithic boundary, Abric Romaní.

Resumen: El Abric Romaní contiene una secuencia de 20 metros de espesor datada entre 40-70 Ka con ocupaciones antrópicas. El techo de la secuencia fue documentado y excavado por Amador Romaní. El primer nivel arqueológico, la capa 2 de A. Romaní o nivel A de la actual estratigrafía, contiene industrias del Paleolítico superior. Este trabajo de investigación geoarqueológico discute la posición estratigráfica del nivel A con la presentación de la estratigrafía de la sección NW y los análisis microscópicos de los sedimentos muestreados. Pero también se apoya en la documentación de A. Romaní donde se recogen meticulosamente diferentes aspectos de la capa 2 o nivel A. De esta forma, consideramos que sus esquemas estratigráficos perduran en la caracterización del límite Paleolítico Medio y el Superior. Finalmente, presentamos una serie de hipótesis de trabajo para caracterizar la transición entre el paleolítico Medio y el Superior en la escala del sistema deposicional y el modo de registro microestratigráfico. Esto nos lleva a la explicación de mecanismos sedimentarios registrados. Destaca la presencia de partículas eólicas, dentro de la sedimentación carbonatada dominante, en el relleno de pie de cornisa del abric Romaní. El cuadro cronoestratigráfico bien desarrollado y disponible para el nivel A ayuda a sugerir conexiones entre el registro sedimentario continental de Abric Romaní y el registro paleoclimático y cronoestratigráfico global de sondeos marinos y glaciares.

Palabras Clave: Estadio isotópico 3, eventos y ciclos Dansgaard-Oeschger, partículas eólicas, micromorfología, límite paleolítico medio y superior, Abric Romaní.

Arteaga, I., Angelucci, D. E., Carbonell, E., Courty, M. A. y Vallverdú J. (2001). Microfacies and stratigraphic position of the Middle-Upper Palaeolithic boundary at *Abric Romaní* (Capellades, Barcelona, Spain). *Rev. C. & G.*, 15 (1-2), 15-30.

1. Foreword

Abric Romaní is a large rockshelter located in the northeastern part of the Iberian Peninsula, 50 km west of Barcelona (figure 1). It forms part of the travertine cliff at the right side of the Anoia river, 310 meters above the Mediterranean sea level. The stratigraphic sequence is about 20 meters deep. The archaeological levels are found between 40-70 Kyrs within dated U/Th travertine beds (Bischoff et al., 1988; Carbonell et al., 1994). The uppermost archaeological Level A date to the early Upper Palaeolithic (UP). Level B is the most recent Mousterian Level (MP). Briophitic bioconstruction were partly responsible for the sedimentation of levels A and B near the travertine cliff. Radiocarbon analysis of charcoal remains using Accelerator Mass Spectrometry (AMS), has provided a radicarbon date for the basal Aurignacian Level of about 37 ± 2 ka (Bischoff et al., 1994). Uranium-series analysis by Alpha Spectrometry (AS) and Mass Spectrometry (MS) has provided a calendar date for the carbonates of 43 ± 1 Kyrs (Bischoff et al., 1994). MS results from the best sample above the Aurignacian bed indicate a calendar age of 42.6 ± 1.1 Kyrs (figure 2).

2. Stratigraphic overview and sampling

Much information on the MP-UP transitional boundary at *Abric Romaní* has been accumulated

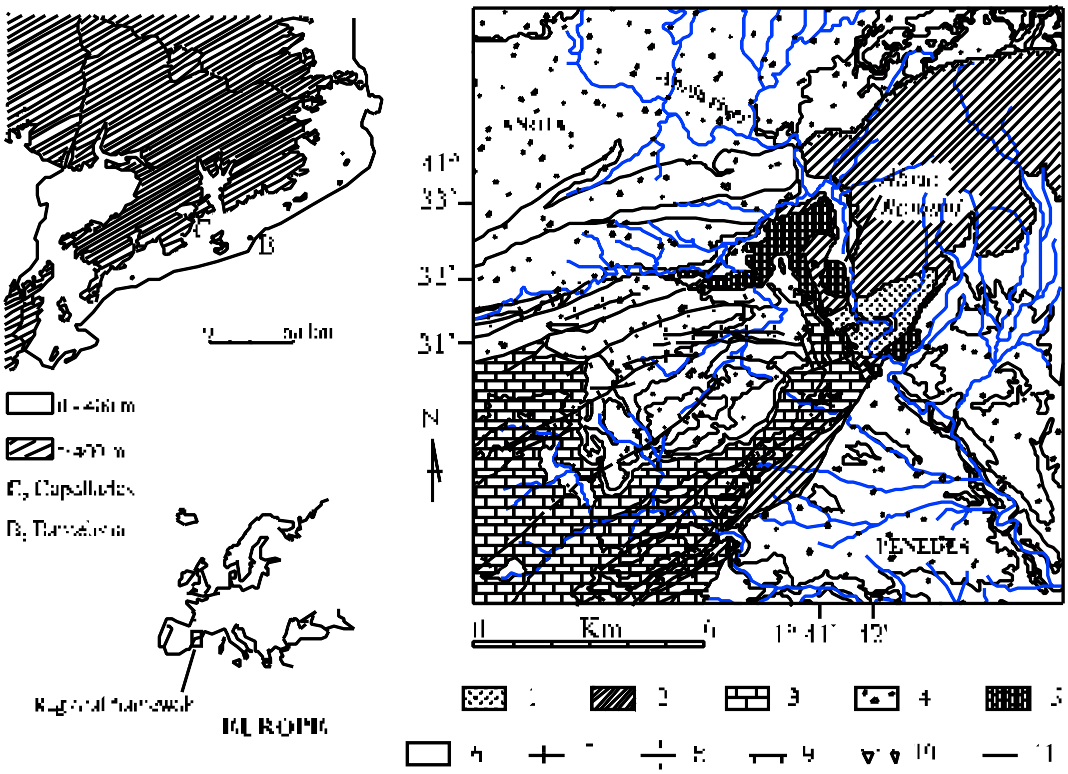

Figure 1. Geographic and geologic location of the *Abric Romaní* (Capellades, Anoia, Barcelona) in the NE of the Iberian Peninsula. Legend of the geological framework of the Capellades area (Benzaquen et al. 1973; Peón et al., 1975). 1, Plutonic Rock. 2, Palæozoic. 3, Mesozoic. 4, Cœoenozoic. 5, Quaternary travertine. 6, Quaternary undifferentiated. 7, anticline. 8, syncline. 9, thrust fault. 10, reverse fault (?). 11, fault.

Figura 1. Situación geográfica y geológica del Abric Romaní (Capellades, Anoia, Barcelona) en el NE de la Península Ibérica. Leyenda del contexto geológico de la región de Capellades (Benzaquen et al. 1973; Peón et al., 1975). 1, rocas plutónicas. 2, Paleozoico. 3, Mesozoico. 4, Cenozoico. 5, travertinos cuaternarios. 6, Cuaternario indiferenciado. 7, anticlinal. 8, sinclinal. 9, enca - balgamiento. 10, falla inversa. 11, falla.

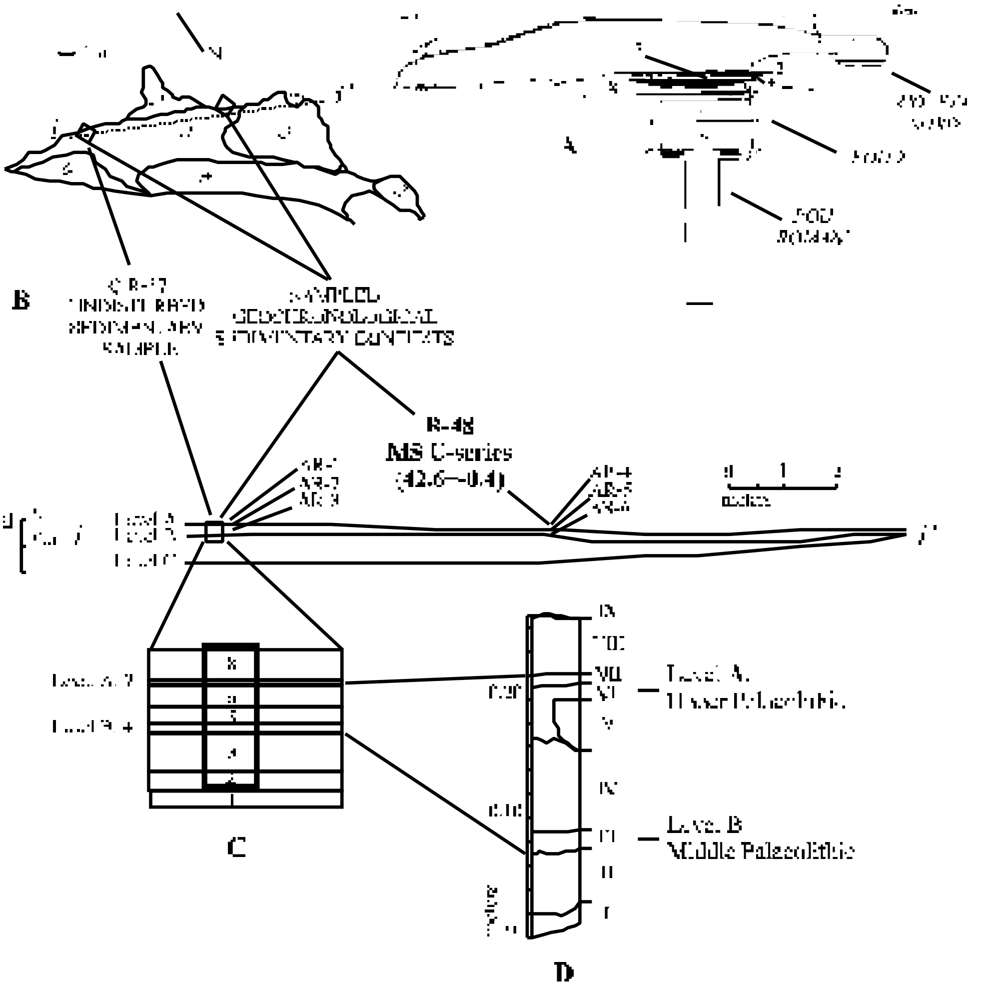

Figure 2. Location of sedimentary samples in square Q/R57 and chronological framework.
A. Cross section drawn by A. Romaní at central zone and *Coveta Nord*, including archaelogical levels (Bartrolí et al., 1995). Note the well excavated by A. Romaní (*pou Romaní*) and the topographic variation between *Coveta Nord* and the central zone.
B. Simplified topographic cross section at south and central zone (*i-i'*) of sampled and dated context for the Mousterian-Aurignacian boundary in *Abric Romaní* (Levels A and B). AR-1 to AR-6 are the positions of geochronological samples (Bischoff et al., 1994). Best chronological U/Th date: 42.6±0.4 for travertine bed atop Level A (Bischoff et al., 1994).
C. Field sketch and description in square Q/R57, in the Intern Dripping depositional system of centimetric or flat puddles, near the wall shelter. 1, microkarstified and cemented fine and coarse clastic sediment. 2, bryophyte bioconstruction. 3, cemented fine clastic sediment. 4, cemented sand and gravel. Level B. 5, microkarstified and cemented fine and coarse clastic sediment. 6, two bryophitic bioconstructions separated by a sandy scar. 7, cemented sandy-silt. Level A. 8, two bryophitic bioconstructions separated by a silt scar.
D. Microstratigraphic units identified in a thin section continuum of Q/R57 core-log (see table 1).
Figura 2. Situación de las muestras del cuadro Q/R57 y marco cronoestratigráfico.
***A**. Sección dibujada por Romaní en la zona central y en la coveta norte. Emplazamiento de los niveles arqueológicos con la nomenclatura de Romaní. Destaca la referencia del pozo Romaní y la posición topográfica distinta de la coveta norte y la zona central.*
***B**. Sección topográfica de la zona simplificada en la zona sur y central (i-i') del límite Paleolítico medio - Paleolítico superior (niveles A y B) y su detallado contexto geocronológico. AR-1 a AR-6 indican la posición de las muestras datadas (Bischoff et al., 1994).*
***C**. Descripción de campo en el cuadro en Q/R57, en el sistema de deposición de goteo interno con charcos centimétricos. 1, clastos finos y gruesos cementados y microcarstificados. 2, bioconstrucción de musgos. 3, clastos finos cementados. 4, Arenas y gravas cementadas. Nivel B. 5, clastos finos y gruesos cementados y microcarstificados. 6, dos bioconstrucciones de musgos separadas por una cicatriz de arenas. 7, limoarena cementados. Nivel A. 8, dos bioconstrucciones de musgos separadas por una cicatriz de limos.*
***D.** Unidades microestratigráficas (UM) establecidas en láminas delgadas en continuo del muestreo en Q/R57.*

through the years. This boundary was first noted and studied at the beginning of the 20th century by Amador Romaní (Bartrolí et al., 1995). With time, the accumulation of data on the MP-UP limit yielded diverging views according to the different phases of archaeological investigation in the site (Campillo et al., 1999; Giralt & Julià 1996; Mora 1988; Ripol & Lumley 1965; Vaquero 1992; Vidal 1911).

During 1997, due to the expansion of the excavation area along the NW section, a deposit laying above the stalagmitic floor was found near the travertine wall in P41 square (figure 3 A). The discovery of this remnant of the stratigraphy linked with abundant sedimentary data from these levels allowed one of us (I. Arteaga) to begin a graduate thesis project. In 1998, field description and sampling of the sediments in squares Q/R57 (figure 2) and P41 on the NW section (figure 3) were performed.

The present stratigraphic study of the MP-UP transition at *Abric Romaní* starts from spatial distribution related issues in those areas where the sedimentation processes enabled clear definition of the UP record (Q/R57), versus other areas where stratigraphic distinction was less clear (P41). Moreover, the stratigraphic study attempts to establish a dynamic geoarchaeological research framework for the *Abric Romaní* sediments based on continuous feedback between microscopic sedimentary analysis and field description. Nine large format thin sections (13 x 5 cm) were prepared at the Soil Science laboratories of the University of Lleida; description was done according to the terminology established by Bullock et al., (1985).

3. Results

3.1 Stratigraphic sequence of MPand UP boundary

New data derived from better stratigraphic profiles, NW section in figure 3, together with previously available information allows us to look deeper into the geoarchaeological nature of the MP-UP transition at the *Abric Romani.* In this way, we have identified two different depositional systems at the top of the *Abric Romaní* sequence (figure 3 C): an Internal Dripping depositional system (ID) and an External Filling depositional system (EF). The latter is characterized by a dominant presence of Mixed Siliciclastic and Carbonated Silt (MSCS). In the ID depositional system, pure carbonate materials prevails and, for this reason, the detection of MSCS material is relatively easy.

The ID depositional system is formed by stromatolite domes with decimeter deep puddles near the drip line impact zone. During the formation of Levels A and B, these deep drip line puddles were filled with clastic sedimentary facies (figure 3 C). The cultural remains are accumulated onto a palimpsest context. Towards the wall of the travertine cliff, the dome formation mentioned above shapes flat surfaces composed of shallow centimetric puddles, which contain Mousterian and Aurignacian occupations clearly separated by non-anthropic layers (figure 3B). This zone of the ID environment is characterized by an imbrication of bioconstructions and clastic sediments, including rare to occasional Mixed Siliciclastic and Carbonatic Silt (MSCS). It is worth noting the occurrence of anthropogenic materials during the clastic sedimentary phases. The bioconstructions are the main component of the non-anthropic sedimentary layers delimiting the human occupations of this zone, and thus providing a good distinction of MP and UP boundary.

3.2 Microstratigraphy of the MP-UP transition at Abric Romaní

Extensive sampling of Levels A and B in square Q/R57 was carried out in order to correlate a profile displaying clear stratigraphic differentiation with another profile, in P41, in which differentiation was difficult. Initially, the P41 log posed a sedimentary problem similar to the excavation of M39 square, in which it was not possible to locate neither Romaní’s layer 2 nor Level A of the current stratigraphy (Vaquero 1992). This problem was already mentioned by Amador Romaní in his work at *Coveta Nord*, where he documented a low number of Aurignacian finds (Bartrolí et al., 1995). Romaní proposed two possible classifications for Layer 2 at the *Coveta Nord*: Aurignacian or Magdalenian (Bartrolí et al., 1995). Moreover, he indicated the presence of significant anthropogenic and paleobiological transformations at the EF contact or layer 1: one human remain in association

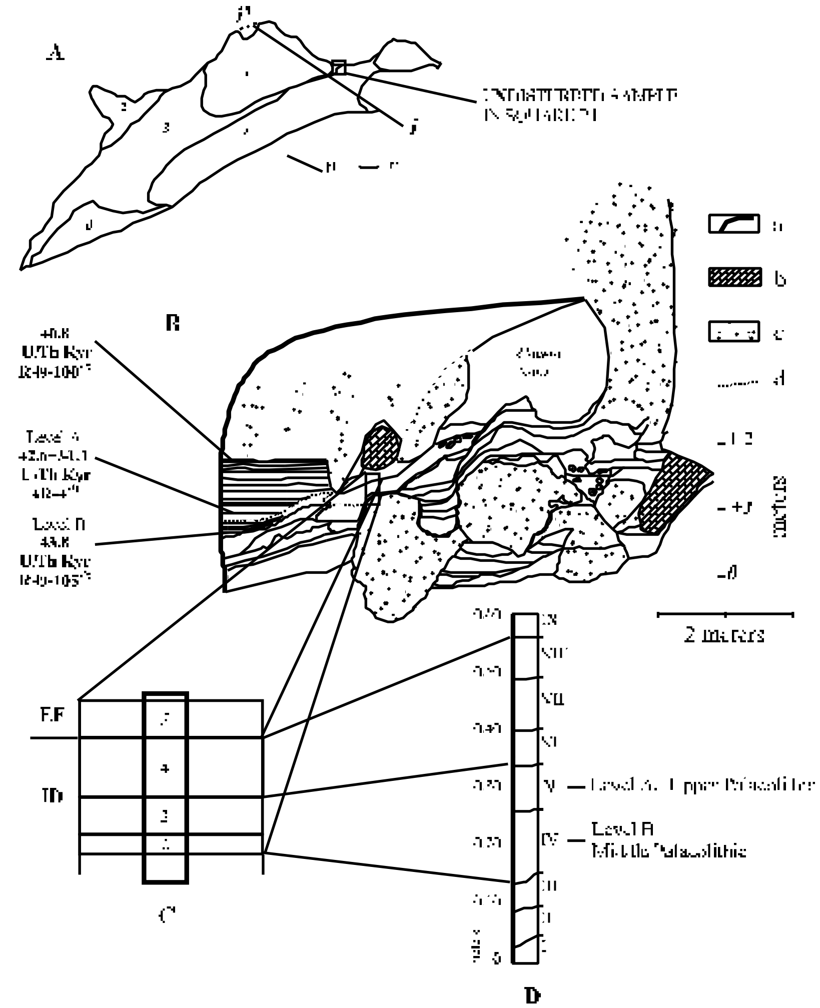

Figure 3. Location of sedimentary samples in square P41 and chronological and stratigraphic framework.
A, current profile (i'-i) upper NW section, in **B**, within the planigraphic context of Amador Romaní's Level 2 (Bartroli, et al., 1995) and position of the sampled sedimentary context.
B, current upper NW section of Abric Romaní. **a**, travertine wall and roof. **b**, travertine boulders. **c**, stalagmite-stalagtite (flowstone) formation. **d**, main contact of MP-UPsedimentary contexts in well defined-zone. Selected dates: Level A [(1)] after Bischof et al., (1994), and Level B[(2)] after Bischoff et al., (1988).
C. Field sketch and description in square P41. ID, Internal Dripping depositional system of deeper or decimetic puddles in drop zone. EF, External Filling. 1, stromatolite bioconstruction. 2, red sand and gravel, with charcoal fragments, lithic and faunal remains. 3, red sandy silt with lithic and faunal remains. 4, red coarse silty sand with few anthropic remains. 5, red clayey silt with recent bioturbation.
D. Microstratigraphics units identified in a thin section continuum of P41 core-log (see table 2).
Figura 3. Situación de las muestras sedimentarias en el cuadro P41 y su contexto cronológico y estratigráfico
***A.** Situación del perfil estratigráfico (i'-i) de la sección NW, en B, dentro de la representación planigráfica del nivel 2 de A. Romaní (Bartrolí et al., 1995).*
***B**. Parte actual superior de la sección NW del Abric Romaní. Leyenda: **a**, travertino de la cornisa del abrigo; **b**, bloques de travertino de cornisa; **c**, estalagminta-estalactita; **d**, contacto sedimentario entre el nivel del Paleolítico medio y el Paleolítico superior en la zona bien diferenciada del Abric Romaní.*
***C**. Descripción de campo en el cuadro P41. ID, sistema de deposición de goteo interno en charcos profundos. EF, sistema de deposición de relleno externo. Leyenda: 1, bioconstrucción estromatolítica; 2, arena grava roja, con carbones, industria lítica y restos faunísticos; 3, limoarena roja con industria lítica y restos faunísticos; 4, arena gruesa y limos con pocos fósiles; 5, limoarcilla roja con bioturbaciones recientes. .*
***D**. Unidades microestratigraficas (UM) establecidas en laminas delgadas en continuo (enlaza con tabla 2).*

Table 1. Synthetic micromorphological description of the Microstratigraphic Units (MU) QR57 samples, with depositional characterisation and palaeoenvironemental interpretation.
Tabla 1. Resumen de las unidades microestratigráficas de las muestras de QR57. Caracterización del depósito y su interpretación ambiental.

MU	THICK (cm)	MICROFACIES CHARACTERS	DEPOSITIONAL CONDITIONS	ENVIRONMENTAL IMPLICATIONS
I	2	Strongly cemented sand by hyaline biocementation	Regular biocementation Physico-chemical precipitation	Moderate cold Humid seasonal contrast with lower evapotranspiration
II	8	Highly porous spongy [illegible] microsparitic hyaline biocementation	Regular biocementation Strong biochemical weathering	Warmer humid Increased evapotranspiration
III	3	Discontinuous silty sand with fine silicate Fresh bryophytic biocementation	Archaeological level B Moderate aeolian input Periodic biocementation No freezing	Moderately cold Seasonal contrast of the humidity Episodic wind action
IV	6	Highly porous microspongy and sparse bryophytic biocementation	Regular biocementation Weak biochemical weathering	Moderately cold Humid and medium evapotranspiration
V	2	Sporadic fossil bryophytic biocementation	Regular biocementation Physico-chemical precipitation Frost fragmentation	Increased cold Humidity with low evapotranspiration
VI	1	Gravel size [illegible] sand-sized strongly cemented Platy microstructure	Archaeological Level A Frost fragmentation Weak biochemical weathering	Cold and dry with high evapotranspiration
VII	0.5	Occasional silicate silt Discontinuous [illegible] layer Platy microaggregate	Aeolian input Superficial freezing	Short cold Dry pulse
VIII	2	Strongly cemented sand by hyaline biocementation	Regular biocementation Physico-chemical precipitation	Moderate cold Humid seasonal contrast with lower evapotranspiration
IX	0.5	Discontinuous sandy silt [illegible] layer Platy microaggregates	Strong aeolian input Freezing	Short cold Dry pulse

with pierced malacofauna (filled with Layer 1 sediment or MSCS of EF depositional system), pigments, and Upper and Middle Palaeolithic industry. To this list, we must add the presence of carnivore activity evidenced by hyena coprolites.

Despite the evidence above, microscopic analysis of the P41 samples has not provided any sign of anthropization at the contact with Layer 1. Thus, the P41 sample is relatively independent from the anthropic and palaeobiological evidence at the *Coveta Nord* described by Romaní (Bartrolí et al., 1995). We interpret this observation as these loci sharing the same palaeotopographical setting within the cavity (figure 2 A). In this way, we have traced a clear correlation between P41 and Q/R57 in terms of anthropic impact on the sediment, palaeoenvironment and depositional sedimentary conditions. This correlation, which is outlined below, indicates that the anthropic record, formalised by Levels A and B, is located within the ID depositional system.

In order to illustrate the microstratigraphic analysis, we have displayed the Microstratigraphic Units (MU) in figures 2 D and 3 D, and structured a general approximation of the study in tables 1, for the Q/R-57 sequence, and table 2, for the P41 sampled sequence. The analysis of microfacies features and depositional characters (including postdepositional modifications) allow us to infer, for particular archaeological levels, environmental implications previously observed in the field and from the analysis of large format thin sections.

Table 2. Synthetic micromorphological description of the Microstratigraphic Units (MU) P41 samples, with depositional characterisation and palaeoenvironmental interpretation.
Tabla 2. Resumen de las unidades microestratigráficas de las muestras de P41. Caracterización del depósito y su interpretación ambiental.

MU	THICK (cm)	MICROFACIES CHARACTERS	DEPOSITIONAL CONDITIONS	ENVIRONMENTAL IMPLICATIONS
I	5	Regular stromatolithic bioconstruction Alternated micritic-sparitic laminae	No freezing Accretion by regular dripping	Humid fresh Weak seasonal contrast
II	4	Weakly cemented coarse sand Unweathered rounded travertine fragments Rare silicated silt Rare sand-sized anthropic remains	Archaeological level C Periodic episode of frost-fragmentation of travertine cliff	Short cold pulses Drier Stratified freezing Strong winds Higher evaporation
III	4	Irregularly layered bioconstruction Strongly cemented complex crystalline fabric Sparitic cementation of micritic sand-sized aggregates	Seasonal accretion by water dripping Moderate freezing	Slightly cold Humid Increased seasonal contrast
IV	12	Loosely packed microaggregate silty sand Discontinuous compact layers Unweathered gravels Abundant burnt bones, charred remains and organic staining	Archaeological level B Periodic (?) fragmentation of the travertine cliff strong human action (trampling, [illegible]) Aeolian input	Slightly cold - fresh and drying
V	8	Strongly packed coarse sand and coarse sandy silt Platy structure Abundant sand-sized anthropic remains Discontinuous compact layers	Archaeological level A Intense frost fragmentation of the travertine cliff Increased aeolian input Strong human action	Cold Increased drying Increased wind regime
VI	5	Loosely packed coarse and rounded sand Rare silicates Weathered travertine fragments Dusty coatings	Intense fragmentation of the travertine cliff Mineralisation Partial percolation	Strongly cold Humid
VII	9	Massive [illegible] in platy microstructure silty sand and rare silicates Weathering of abundant coarse rounded fragments	Intense frost fragmentation Partial Percolation	Cold Slightly humid
VIII	7	Massive platy sandy silt Abundant silicates Rare strongly weathered coarse fragments Silty clay intercalations and dusty capping	Partial percolation Water dripping Seasonal collapse Increased aeolian input	Cold and drying Stratified freezing
IX	-	Massive silt Platy structure Unweathered carbonated silt Abundant silicates [illegible]	Aeolian sedimentation Dominant [illegible] freezing	Increased cold and drying Strong wind

3.2.1 Level C

Level C, centimetric Microstratigraphic Unit II (MU II) at the log sampled in P41 (table 2 and figure 3 D) lies in unconformity between two stromatolithic bioconstructions. These bioconstructions, MU I and III (figure 3 D) indicate moisture in the cavity (Kahle 1977) (table 2). The sparitic cementation of bioconstruction layer overlying Level C (MU III in table 2 and microphoto 1 in figure 4), represents a slightly colder and humid episode (Vogt 1974) (table 2). However, anthropization in Level C is linked to a drier, colder episode, as indicated by the presence of surface frost and by fragmentation of the bioconstructions, as well as by the rare to occasional presence of external MSCS input (MU II in table 2 and microphoto 2 in figure 4).

3.2.2 Level B

Level B, centrimetric Microstratigraphic Unit III on the Q/R57 log is constituted by cemented sand and silt, with weakly weathered bryophyte bioconstruction (MU III, table 1 and figure 2 D). Fragmentation of the wall is documented in field descriptions with the presence of fine gravel (figure 2 C, in 4). Although there are no traces of frost on the surface, cliff humidity recorded in the clastic weathered sedimentation indicates seasonal humidity variation. There are signs of aeolian activity, but with rare siliciclastic components and a few, weakly corroded carbonated silts. The basal Microstratigraphic Unit II is highly porous, associated with strong endolithic weathering, and it indicates a warmer, more humid phase (Courty 1986) (table 1, MU II). Microstratigraphic Unit IV, overlying Level B, comprises an increase in humidity, which entails limited mecanical fragmentation. This, added to a lack of micritization leads us to interpret a hydric circulation model with colder temperatures (table 1, MU IV) (Courty et al., 1994).

In the P41 decimetric Microstratigraphic Unit IV (table 2), there is a strong anthropic impact limiting its microstratigraphic correlation with unit III from Q/R57. This unit displays a significant sedimentary record featuring anthropogenic processes (figure 4, microphoto 3). Regarding the use of space, a diachronic formation of anthropogenic facies was found evidenced by a displacement of sediments overlain by sediment modification due to trampling. The environmental and depositional interpretation for microstratigraphic correlation of the units is hampered by the anthropic modification of the natural sedimentary processes, especially among the anthropic facies indicating sediment displacement. In any case, the sedimentary constituents composed by gravel and sand indicate fragmentation processes during relatively dry conditions by seasonal contrast. Such conditions are also recorded in the sediments through a slight increase of siliciclastic materials and occasional microaggregated carbonated silt. Nevertheless, there is no evidence of transformation by surface frost as in unit IV from Q/R57, in which Level B has been clearly delimited.

3.2.3 Level A.

Level A in Q/R57 is characterised by centimetric Microstratigraphics Units VI and VII (table 1 and figure 2 D). Presence of gravel and sandy silt and a well-developed laminar microstructure (table 1, MU VI) register a strong fragmentation of the cliff. Mixed Siliciclastic and Carbonatic Silt materials (MSCS), forming well-developed laminar microstructure, with frequent to common non-weathered carbonated silt are occasionally present (table 1, MU VII). Therefore Level A registers features reflecting an increase in cold environmental conditions, which are responsible for the fragmentation and postdepositional evolution of the micro-laminar structure (Vliet-Lanoë et al., 1984). These environmental patterns are complemented by an increase in dry conditions, favouring fragmentation in the form of carbonated silts, as well as in an increase in the input of MSCS materials.

In the P41 sequence, Microstratigraphic Unit V is centimetric and registers noticeable anthropic modifications, though not interfering significantly with the natural processes (MU V, table 2). This unit directly overlies the anthropic facies of MU IV, Level B, though there is an important change in the nature of the sedimentary facies (table 2). It is composed of small gravel with abundant slightly weathered carbonated silts and occasional siliciclastic silts (figure 4 microphotos 4 and 5). Moreover, the postdepositional transformations of these constituents register a significant frost activity. Microlaminar structure is well developed here (figure 4, microphoto 4). Thus, unit Vexhibits the same textural and postdepositional features observed for MU VI and VII in Q/R57 (table 1). These features allow us to follow a sequence of increasingly colder and drier environmental conditions.

3.2.4 The microstratigraphic record between the Internal Dripping (ID) and the External Filling (EF) sedimentary contact

The transition of the depositional system rupture is represented by Microstratigraphic Units VI, VII, VIII in the P41 log (figure 3 C and D and table 2). Units VI, VII and VIII represent the end of the ID environment. These units are characterized by sedimentation of weathered sand and small gravel from the cornice wall. Shattering is limited due to the shortening of the wet/dry cycles caused by the high humidity of the cliff. Similarly, an increase of humidity favours the increase of bioconstructions on the cornice. Thus, we propose that this coarse sand is the by-product of disaggregation caused by the growth of bioconstructions on the cornice. The sedimentation of this coarse sand along the basal stretch of unit VI is rapid, since the fine fraction is practically absent. This humid phase, featuring sedimentation of coarse sand, allow us to note that laterally, towards the wall, the sedimentary processes comprise bioconstructions. Thus, it is possible to propose the microstratigraphic correlation of this unit VI of P41 with MU VIII from the Q/R57 samples. The latter features a bryophyte bioconstruction with a strong sparite cementation (see MU VIII in table 1).

In microstratigraphical units (MU) VII and VIII from P41, the cornice coarse sand deposition slowed down, a process which is also manifested by the presence of well-developed postdepositional transformations (table 2). These units contain MSCS with abundant carbonated silts, suggesting slightly drier conditions and an increase in cold temperatures. The increase of colder temperatures at the top of the ID depositional system is recorded with the variation of spongy microstructures that shift vertically towards microlaminar structure (figure 4, microphotos 6 and 7; and table 2, MU VII to VIII). We interpret the presence of features indicating rapid percolation and creeping in MU VIII as a sign of important postdepositional transformation by processes of freeze/thaw and structural collapse (table 2) (Vliet-Lanoë 1985). In this way, MU VIII yielded a low sedimentation rate in the cave filling rather than sedimentary input from the cliff and cave wall. We propose this VII and VIII UM a posterior sedimentary record that the last near wall dated bioconstructions of Romani sequence. The evolution towards poor drainage conditions, which exaggerates the humidity factor in the sampled zone, mask the dry conditions of sedimentary formation process. Such an evolution indicates that the decimetric puddles formed during the ID sytem were filling. This is clearly seen in their stratigraphic position according to field descriptions.

Microstratigraphic Unit IX contains the sedimentary facies corresponding to the EF depositional system (figure 3C), with very dominant MSCS material. These facies indicate that the input from the cave cornice is limited by the presence of dry environmental conditions. However, the presence of water is recorded through intercalations (microphoto 8 in figure 4) and microlaminar structure, indicating superficial frost activity (microphoto 9 in figure 5) (Vliet-Lanoë et al., 1984). The sedimentary components composed of dominant MSCS show the prevalence of aeolian sedimentation generated by strong winds that accumulate many siliciclastic silts containing rare to occasional heavy minerals.

3.3 Nature of the Mixed Siliciclastic and Carbonatic silts (MSCS)

Two groups of MSCS materials are recognizable in the stratigraphic record. Those materials related to the EF depositional system is coarser, with a less carbonatic content, and a many silicate minerals and heavy minerals (figure 4, microphoto 8). The ID sedimentary depositional system, MSCS materials are richer in weakly weathered carbonates (figure 4, microphoto 5). The origin of the silty components identified in the *Abric* Romani sequence is poorly known. However it is probably associated with Pleistocene glacial morphogenetic land processes in the Anoia valley (Gallart 1981; Gallart 1991). In the ID sedimentary sequence, MSCS silts are associated with frost features (mainly ice lensing) and particularly with shattered bioconstructions (table 1, in microestratigraphic units V, VI or Level A). This fragmentation to silt particle sizes suggests a probable local source for the carbonatic silts.

The two groups mentioned could be related to two different sources: a local one, in the surroundings of the travertine cliff, which would provide the aeolian inputs of the ID system, and a more hypothetical distant source that would form the EF depositional system.

The origin of MSCS materials in the EF depositional system is more problematic and requires more detailed analysis. The entrance of the cave is oriented towards the Penedès Basin. We might suggest that the Penedès depression is the source area of the aeolian input identified in the sequence, although it does not conform to eastern dominant winds (Gallart 1981). Studies on loess sediments in the NE of the Iberian Peninsula suggest that aeolian deposition played a role during the Late Pleistocene in coastal depressions and littoral ranges in the Mediterranean (Solé Benet et al., 1988; Solé 1961; Solé et al., 1957; Virgili 1960). Recent investigations in the Ter Valley (Girona) show the occurrence and significance of loess formations that were differentially reworked after deposition (Mücher et al., 1991). The weak representation of loess sediments in the Pleistocene stratigraphy and in the geologic maps of the region was strongly debated during the 1960s, especially for the littoral and pre-littoral continental Quaternary formations (Virgili 1960; Butzer 1964). Finally, aeolian materials recorded in lakes during the last glacial cycle in Central Italy have shown a North African origin (Narcisi 2000).

The location of the Capellades travertine cliff at the contact between the Ebro Basin and the Prelittoral Range, suggests that geographic relationships have a more continental trend than a littoral or pre-littoral one. In this way, the aeolian record at top of Romani sequence is hardly comparable by its geographical position with the mentioned littoral and pre-littoral models of loess sedimentation.

3.3.1 Environmental interpretation of MSCS

The depositional system of the EF has been palaeoclimatically and depositionally interpreted in different ways (Bischoff et al., 1988; Carbonell et al., 1994; Mora 1988; Ripoll & Lumley 1965). The microscopic evidence from the P41 core-log, together with complementary evidence from square S45 (not included in this data presentation), have shown a dominant MSCS components. The palaeoclimatic interpretation is also clear, given the existence of well developed frost transformations (figure 4, microphotograph 9). The observed features, such as absence of the coarse components derived from cliff fragmentation, lead us to suggest that this sedimentary record represents a cold, dry climatic episode (table 2, in microstratigraphical unit IX). On the other hand, the low degree of weathering of the carbonate fraction indicates rapid burial, which is characteristic of a high sedimentation rate, at least for the sampled parts of EF depositional system or MU IX (figure 3 C).

4. Discussion

The identification of the ID depositional system in Level A was one of the results of integrating fieldwork and sedimentary microscopic analysis. It relies on the good resolution obtained on samples collected from the sedimentary context of sector QR/57. Observation of the spatial distribution at the sampled filling suggests that the P41 sector represents the same depositional system as Q/R-57 square-sector (figure 2 A). Thus, we think that the anthropic record of the *Coveta Nord*, where anthropic and carnivorous activities were found in an EF context (Bartrolí et al., 1995), is part of human occupations younger than thoses of Level A. Therefore, we think that only one UP archaeological levels is present in the current preserved sedimentary record of Abric Romaní. Microstratigraphic characterisation of the UP at *Abric Romaní* in the ID context, which is consistent with the geochronological datum (Bischoff et al., 1994), is an indicator of the ancient age of Layer 2, or Level A.

Sudden changes of sedimentary facies, which we explain as corresponding to some of the abrupt climatic changes within OIS 3, were observed in the sampled microstratigraphic sequences. The results, as well as the types of depositional systems recognised, may refer the evidence to two different scales of palaeoclimatic record.

4.1 Palaeoclimatic significance of the imbrication between bioconstructions and clastic sediments with MSCS components in the ID depositional system.

The interpretation of microfacies sequence has critical restrictions, being a qualitative approach to palaeoenvironmental studies. Nevertheless, it is possible to sketch a working hypothesis for explaining the imbrication of bioconstructions and clastic sediments with MSCS materials in the ID environment. We may refer to the literature on Greenland ice cores and North Atlantic deep sea cores (Bond et al., 1993; Bond & Lotti 1995; Dansgaard et al., 1993; Voelker et al., 1998), which can help us to explain the moisture fluctuations recorded in the depositional sedimentary cycle of Levels C, B and A at Abric Romaní. On these lines, Burjachs & Julià (1994) interpreted pollen data of mainly part of the stratigraphic sequence as abrupt climatic change.

OIS 3 was characterised by abrupt climatic events, which are recorded in both ocean and ice cores (Handel, 1997). Abrupt climatic changes are represented by cold and by dry events (Dansgaard-Oeschger events), with a duration in the order of hundreds to thousands f years, and temperate events (Dansgaard-Oeschger cycles), spanning from one to three millennia. Dry events modulate the record of the cold phases just before glacial increase. In our hypothesis, we correlate the imbrication of bioconstructions and clastic with MSCS components of the ID environment with the abrupt climatic changes evidenced by Dansgaard-Oeschger cycles and events. We explain the increase of MSCS components as dry events preceding cold events. Cold events are represented by clastic sedimentation from cliff fragmentation as well as by postdepositional modifications of the deposit caused by frost action.

4.2 Climatic change between the Internal Dripping and the External Filling depositional system

The environmental features of the ID system, between Levels A and B at *Abric Romaní*, are known in detail thanks to palynological studies (Burjachs & Julià 1996). Pollen data obtained for the transitional zone between the Mousterian and Aurignacian attributed this sequence when favourable environmental conditions began to be harsh (Burjachs & Julià 1996). U/Th dating of the top (calendar 42.6 ± 1.1 Kyrs of MS in Bischoff et al., 1994) and of the bottom of Level A (calendar 43.8 ± 1.5 Kyrs, sample 105, Bischoff, et al., 1988) has provided a date for the unit towards the middle of the Dansgaard-Oeschger cycle 12 (Bond et al., 1993). The last phases of the ID depositional system in *Abric Romaní* are dated at an average in calendar age of 40.8 ± 1.5 Kyrs U/Th (sample 100, in Bischoff et al., 1988; Burjachs & Julià, 1994) which would correspond to the end Dansgaard-Oeschger event 12 (Bond et al., 1993).

Units VI, VII y VIII do not show any evidence of the depositional cycle of moisture variation recognised in the sector Q/R57 sampling. Particularly, unit VI is characterised by the input of loosely packed sand coming from the shelter wall. Units VII and VIII from sample P41 are noteworthy for the development of postdepositional modifications due to frost action and rapid water percolation, which denote moisture increase in the local depositional setting of the sampled area. The increase of MSCS inputs in Microstratigraphic Units VII and VIII is not very high, but the contrast between a significant micritisation and the enrichment of unweathered, well-sorted carbonate silt in these facies is outstanding. The data allow us to determine that burial processes were slow. There is evidence of redistribution by water of the travertine sand fallen from the roof, during humid phases of the depositional cycle, and of the carbonate silt of the cave filling during the dry and cold phase of the cycle. The formation process observed in these MU VII and VIII may be caused by the intense frost shattering of bioconstructions and indicate, as a working hypothesis, their correlation with the posterior uppermost bioconstructions dated of the stratigraphic sequence.

The evidence of wetting and drying represented by gravel formation from the cliff, is absent in the upper part of the P41 ID sequence. This suggests that the wetting and drying of the wall is low, with a higher stability of the cliff. This may be explained either as an effect of the higher duration of dry conditions, or as an absence of water, or else as an increase of freezing. The latter is also evident from the observation of postdepositional modifications of the microstratigraphic units. Temperature decrease modifies the depositional cycle, forming abundant autochthonous carbonate silt that is easily redistributed by creeping and percolation during thawing. Microstratigraphic units of the upper part of the ID environment may be interpreted as an increase of dry environmental conditions because of temperature decrease indicated by laminar microstructure in UM VIII

The absence of chronometric dating and pollen analysis for the EF depositional system limits the interpretation of the uppermost portion of the stratigraphy. According to our hypothesis, that is that Microstratigraphic Units VII and VIII may be posterior to a most dated recent bioconstructions in the end of Dansgaard-Oeschger cycle 12. The discontinuity inside Microstratigraphic Unit IX, in the

P41 samples, is not known, as no dating is available for this part of the sequence.

But, the three Microstratigraphic Units containing MSCS materials have been observed in the P41 sedimentary record. MSCS with rare to occasional siliciclastic material while carbonate silts dominant are in the two lower nits, namely Level A (UM V) and MU VIII (table 2 and microphoto 4 and 7 in figure 4). The third unit, MU IX in the EF depositional system which contains many siliciclastic material.

In the North Atlantic ocean core Dansgaard-Oeschger events corresponds to a peak (or subpeak) in the quantity of lithic input (Bond & Lotti, 1995). On this line our hypothesis, which correlates global phenomena with the regional atmospheric circulation, may also be interesting for the understanding of the OIS 3 palaeoclimatology and aeolian activity in continental sedimentary records.

Consequently, we propose a hypothesis which starts with the chronostratigraphy of the upper part of the *Abric Romaní* sequence. We relate the Dansgaard-Oeschger events, associated with Bond's peaks and subpeaks, to those Microstratigraphic Units containing significant quantities of MSCS.

Calendar ages from U-series dates of Abric Romani and age layer counting in Kyrs (GISP2) correlated with marine ^{14}C ages of the North Atlantic cores (Bond & Lotti, 1995; Voelker et al., 1998) show that Level Aand bioconstructions at top of Romani sequence dated in 40.8 ± 1.5 Kyrs limit the boudary of DO cycle 11-10. In this case, the sedimentary record of units VII and VIII from P41 core log would represent a DO event 10-9 record (figure 4 C). The aeolian sedimentation in unit IX would also be related to the lithic peak corresponding to the Heinrich event 4 or interstadial 9-8.

We may observe that the climatostratigraphic hypotheses suggest that the Heinrich event 4 and the shift from the ID to the EF environment may to be broadly contemporaneous. As already stated by Giralt & Julià (1996) the end of dripping depositional system suggests an important opening of the landscape caused by a marked hydrological regime of the travertine cliff in the Capellades area. Therefore, the EF environment may be interpreted as the climax of the long term cooling cycle spanning between the Dansgaard-Oeschger cycles 12 to 8 (Bond et al., 1993). In the end of this cycle a significant lowering of the sea level took place, with subsequent variation of hydrological systems. Cacho et al., (1999) have detected the Heinrich event 4 in the Alboran Sea with an radiocarbon age model around 39 Kyrs. BP. Voelker et al. (1998) correlated the marine radiocarbon ages of the Heinrich event 4 in the Nordic Sea with the GISP2 calendar age isotope record in chronological interval of 38-39 Kyrs BP

5. Final remarks

The present geoarchaeological study has been developed in order to articulate the sedimentary context of the human impacts related to the MP-UP boundary at *Abric Romaní* and to suggest a hypothetical palaeoenvironmental model for the lithological interpretation of this part of the sequence.

One of the results, which had already been established thanks to the dedicated research conducted at *Abric Romaní* in previous years, is the antiquity of the UP documented by Amador Romaní (Straus et al., 1993; Straus 1996; Carbonell & Vaquero 1996; Zilhao 2000). The Aurignacian of the Romani sequence, Level A of the current nomenclature, is placed in the context of an Internal Dripping depositional system, before the onset of a main phase of loess deposition, during the cool an dry External Filling system. The chronological and lithological data for the Aurignacian of Romani sequence show the Upper paleolithic occupation during a cooling maximum of the 12 interstadial (Voelker et al., 1998). The occurrence of this climatic degradation is generalized for the Early Aurignacian in caves of SW of France (Lévêque 1997). Loess deposits characterize the depositional system of early UP findings in Italy (Cremaschi 1990). This interpretation is supported by a number of interdisciplinary data: U/Th and ^{14}C dating (Bischoff et al., 1988; Bischoff et al., 1994), palaeoenvironmental studies (Burjachs & Julià 1994; Burjachs & Julià 1996, Giralt & Julià 1996) and archaeology (Carbonell et al., 1996; Vaquero 1992).

Microfacies analysis permits us to develop a hypothetical model of lithological interpretation, than can be related to the global climatic record. Hence we can suggest that the *Abric Romaní* sequence is composed of continental sediments whose features link the record of the site to global phenomena and climatic changes know from oceanic and ice cores. Nevertheless, we are aware of the restrictions linked to the interpretation of natural and anthropic sedimentary formation processes in continental environments and, more so, in archaeological sites. We think that *Abric Romaní* may constitute a good case study for analysing the paleoenvironmental evolution in the Mediterranean region (Burjachs & Julià 1994). We have tried to characterize the palaeoenvironmental significance by imbrication of bioconstructions and clastic sediments with Mixed Siliciclastic and Carbonatic Silts in the ID depositional system, and of the MSCS in the External Filling environment. At a microstratigraphical level, we propose that these mix aeolian components and clastic sediments may relate to the Dansgaard-Oeschger events, which correspond to subpeaks in the Bond framework. At general stratigraphic level, we also propose a chronostratigraphic correlation between the Heinrich 4 and the onset of the Externally Filling depositional system.

The chronostratigraphy of the aeolian activity recorded in the *Abric Romaní* sequence can be useful for the establishment of a general chronology of the Pleistocene aeolian morphogenetic processes in the Anoia valley and NE of the Iberian Peninsula (Gallart 1981, 1991; Mir & Salas 1979; Solé 1961; Solé et al., 1957; Solé Benet et al., 1988; Virgili 1960). Layer A suggest high diversity of thermal habitats exploited by anatomically modern humans during the Early Upper Paleolithic (42.6 Kyrs) in NE of the Iberian Peninsula close to «so called» Ebro Frontier (Vega 1990; Villaverde, V. & Fumanal, P. 1990; Zilhao 2000)

6. Acknowledgements

This work is dedicated to the Arteaga-Egiluz family.

We also thank P. G. Silva, editor of Q&G, for his suggestions and thorough revision of the initial manuscript. This paper was translated into english with the help of C. Mallol. Finally we are thankful to the institutions, Generalitat de Catalunya, Empreses Gràfiques Romanyà-Valls, and the archaeologists that are responsible for the research at *Abric Romaní.*

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Recibido el 20 de julio de 200
Aceptado el 16 de febrero de 2001