



The palaeoecological potential of pollen records in caves: the case of Mediterranean Spain

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Abstract

Important palynological sequences are reviewed from caves with archaeological interest in Mediterranean Spain. Upper Pleistocene sites include Abric Romani and Abric de l'Arbreda in NE Spain, and in SE Spain Cueva de la Carihuela, Cova Beneito, Cueva de Perneras, Cueva del Algarrobo and the Holocene Cova de l'Or and Cova de les Cendres. Carihuela has the longest sequence, starting in the last interglacial and covering most of the last glaciation. A pre-Würm phase was followed by two glacial maxima separated by an interpleniglacial phase, and in the Lateglacial the Younger Dryas seems present. Whereas at Carihuela harsh pleniglacial conditions caused Mediterranean associations to disappear, in the milder surroundings of Beneito and Perneras these were able to survive. At Romani, pollen shows acute palaeoclimatic sensitivity, pointing to upland refuges nearby. Holocene pollen from Cova de l'Or and Cendres underlines the importance of pine in natural woodlands of mature meso and thermomediterranean taxa. Some between-site comparisons and contrasts with modern bioclimatology are interpreted in the context of the palaeoclimate history. Despite taphonomical and methodological problems of cave palynology, its future in arid regions such as SE Spain is promising. © 1999 Published by Elsevier Science Ltd. All rights reserved

1. Introduction

Cave palynology tends to arouse controversy and scepticism, especially when employed in archaeological inquiry to reconstruct the prehistoric environments (Bottema, 1975; Bottema and Woldring, 1994; Coles *et al.*, 1989; Coûteaux, 1977; Sánchez-Goñi, 1991, 1994; Turner and Hannon, 1988). This is because of

- (a) possible discontinuities in sedimentary sequences and gaps in pollen records,
- (b) differential preservation or even widespread destruction of certain palynomorphs by oxidizing agents or bacterial activity which can distort the pollen records,
- (c) pollen transport by animals, leading to over-representation of some taxa, and
- (d) vertical movement or reworking leading to contamination of sediments by younger or modern pollen.

Nevertheless, several palynologists contend that cave studies can throw some light on palaeoenvironmental conditions, provided due account is taken of those taphonomical problems (Bryant and Holloway, 1983; Dumbleby, 1985; Davis, 1990; Horowitz, 1992). We agree with this view and will show here how pollen obtained from cave sediments can provide extremely useful palaeoecological information, when studied in a multidisciplinary context. After briefly outlining several pollen records from Mediterranean Spain, some palaeoenvironmental inferences will be drawn. Results are considered in the light of the modern bioclimatological character of this region and compared with pollen records obtained from swamp or peat deposits to construct a synthetic overview.

2. Methods

Samples were taken from vertical lithological sections (Girard and Renault-Miskovsky, 1969) at intervals of between 3 and 10 cm depending on the nature of the sediment. Laboratory treatment followed either Dupré (1988), or Goëury and de Beaulieu (1979) as modified by

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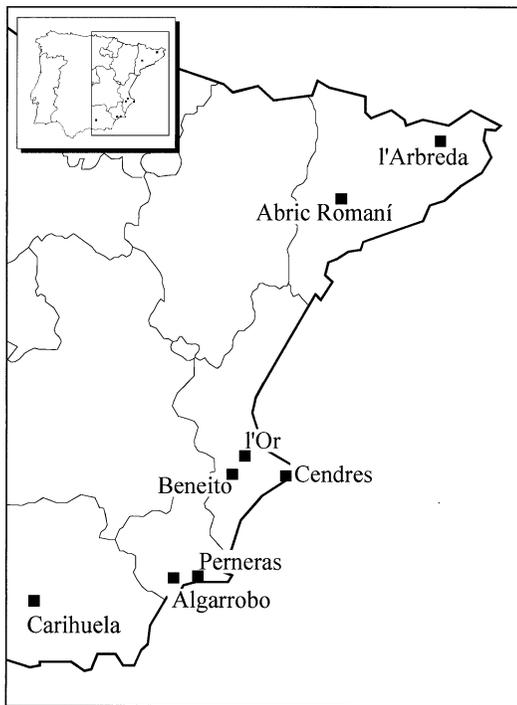


Fig. 1. Location of caves considered in Mediterranean Spain.

Burjachs (1991). Most sedimentary samples weighed over 10 g. Hydrochloric acid was used on calcrete samples, although oxidizing agents were not used. The pollen diagrams and their zonations, drawn up using *TILIA* 1.12, are fundamentally synthetic, with only selected taxa highlighted in them as guidelines. Asteraceae pollen and some cryptogam spores are excluded from pollen sums because differential transport may have accentuated these taxa (Carrión *et al.*, 1995a). Figure 1 shows locations of sites and Table 1 their geographical coordinates, altitude, and cave-mouth orientation, as well as information about mean annual temperature and precipitation, and vegetation in the areas close to each site. Some nearby sites of archaeological importance are also shown.

3. Cave pollen records: case studies with potential

3.1. Cueva de la Carihuela (Piñar, Granada)

The pollen sequence (Carrión, 1992a; Carrión, *et al.*, 1998) (Fig. 2) covers most of the last glaciation starting in the last interglacial (zone R, which has a speleothem U-Th age of $117,000 \pm 41,000$ BP), characterized both by a *Quercus-Olea* association and noteworthy pollen diversity of mesothermophilous species. Mesothermophilous taxa disappeared from zones N-M when upper pleniglacial conditions were too harsh for woodland

development. Throughout zones N-J, and again in G (Younger Dryas), extreme ice-age aridity is reflected in expansion of *Ephedra distachya*, *Artemisia*, Gramineae, Asteraceae and Chenopodiaceae, just as elsewhere in ice-age Spain (Pons and Reille, 1988; Turner and Hannon, 1988; Burjachs, 1994), Italy (Watts *et al.*, 1996) and North Africa (Le Houérou, 1992), without any sign, in what otherwise is a very complete and well-preserved sequence, of 'upper palaeolithic interstadials'.

In Carrión *et al.* (1998), the reliability of the pollen assemblages in this sequence is supported by (i) substantial pollen concentrations and taxa diversity, (ii) equivalent rises and falls in the curves of pollen concentrations and taxa diversity, (iii) relatively low frequencies of indeterminable palynomorphs, (iv) lack of any negative correlation between total pollen concentrations and indeterminable pollen percentages, (v) palynological correlation between the different sections studied, (vi) lack of pollen decay in relation to distance from entrance, (vii) ecological coherence of most pollen spectra.

Carihuela affords satisfactory correlation between pollen zones, microfauna, and sedimentological findings (Fig. 3), provided that more weight be given to pollen-spectrum composition than to relative frequencies. Thermoclastic scree abounds in lower and upper pleniglacial zones S and N-M, respectively, which both contain the cold-adapted rodents *Allocricetus bursae* and *Microtus arvalis* (Ruiz-Bustos and García-Sánchez, 1977) and show expansion of steppe vegetation at the expense of thermophilous plants. Both the basal breccia corresponding to zone R (interglacial), and calcretes corresponding to zones W, P-O, H-I and F, were formed when thermophilous plants flourished, and micromammalian taxa imply stands of evergreen or holm-oak woodland. These findings are consistent with the regional framework that is provided by the well-known pollen sequence from Padul in Granada (Pons and Reille, 1988) which offer the most complete continuous pollen record available for the entire period and region concerned.

3.2. Cova Beneito (Muro, Alicante)

This sequence (Carrión, 1992b; Carrión and Munuera, 1997, Fig. 4) supports a view that a continent-wide interpleniglacial phase occurred in OIS 3, when thermophilous plants spread across thermomediterranean environments that showed sclerophyllous formations of *Quercus rotundifolia*, *Q. coccifera* and *Pistacia lentiscus* similar to today, alongside mesophyllous ones of *Fraxinus ornus*, *Quercus faginea*, *Acer granatense* and *Corylus avellana*. In effect, a 'Mediterraneanization' of interpleniglacial landscapes implying the presence nearby of vegetational refuges. Just as at Carihuela, evidence for 'upper palaeolithic interstadials' is absent. Instead, xerophyte expansion characterizes zones C, D, E1 and E2 over their succession of Aurignacian, Gravettian,

Table 1

Geographical coordinates, altitude, cave-mouth orientation, mean annual temperature and precipitation, surrounding vegetation, and archaeology for the sites considered at this study

Site	Location	Slope direction	Altitude (m.a.s.l.)	Climate (closest station)		Mature vegetation	Archaeology
				T (°C)	P (mm)		
Carihuela	03°25'W 37°26'N	North	1020	12.7	574	Mesic evergreen oak forest	Mousterian
Beneito	00°28'W 38°48'N	South	680	17.0	559	Xerothermic evergreen oak forest	Mousterian to Solutrian
Pernas	01°25'W 37°32'N	South	105	19.1	171	Xerothermic Ibero-Magrebian scrub	Mousterian to Upper Palaeolithic
Algarrobo	01°17'W 37°38'N	Northeast	200	17.8	213	Xerothermic scrub	Magdalenian
Romani	01°41'E 41°32'N	East	300	14.0	504	Mesic evergreen oak forest	Mousterian
Arbreda	02°44'E 42°09'N	West	200	14.8	793	Mesic evergreen oak forest	Mousterian to Post-Palaeolithic
Or	00°28'W 38°42'N	Southwest	650	17.0	559	Xerothermic evergreen oak forest	Neolithic
Cendres	00°02'E 38°43'N	Southeast	45	16.3	407	Xerothermic evergreen oak scrub	Neolithic

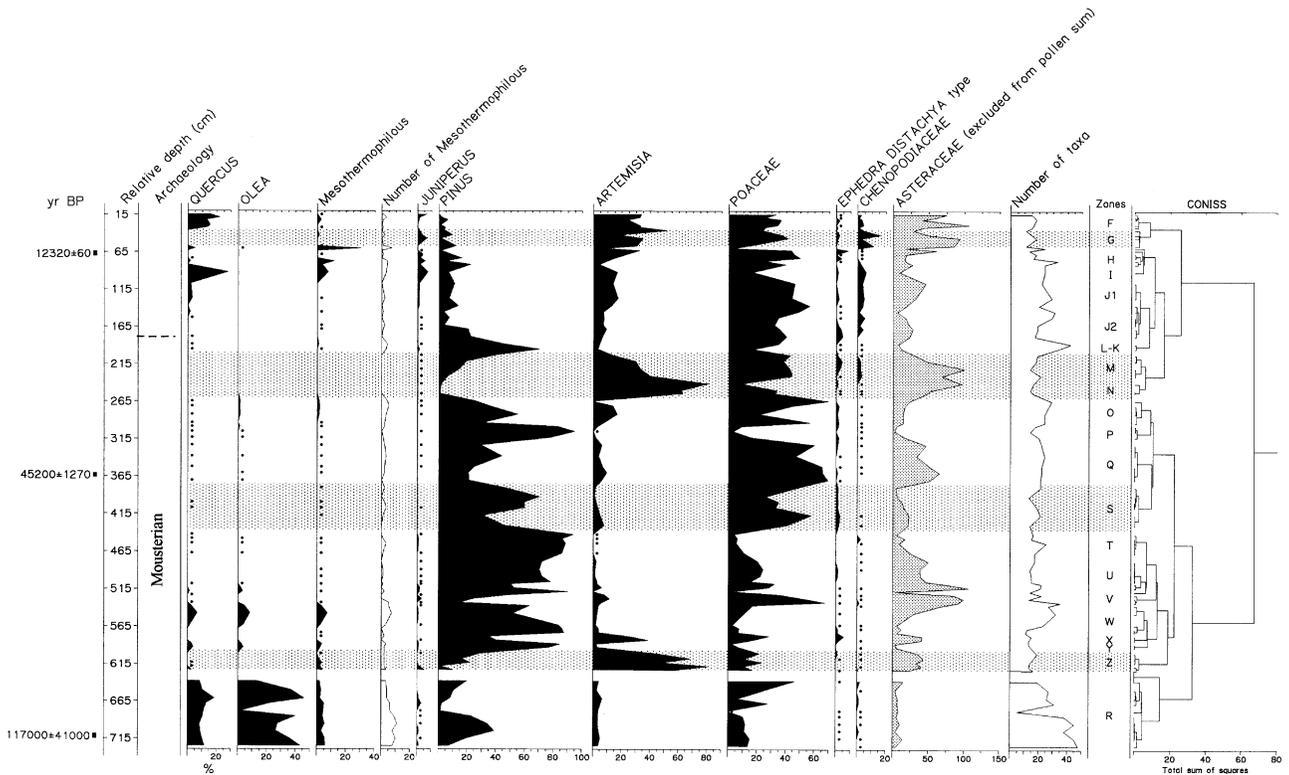


Fig. 2. Synthetic pollen diagram of Carihuela Cave (Granada). Stifle indicates zone with aridity crises.

Solutrean and Solutreo-Gravettian assemblages, just as it does at nearby Cova de les Malladetes in southern Valencia (Dupré, 1980) where there is another long upper palaeolithic sequence. Both cases exhibit the European

chronostratigraphical synthesis of Behre (1989). A climatic improvement is clearly reflected by zone B, where, moreover, chemical weathering of sedimentary particles temporarily replaced the predominantly physical

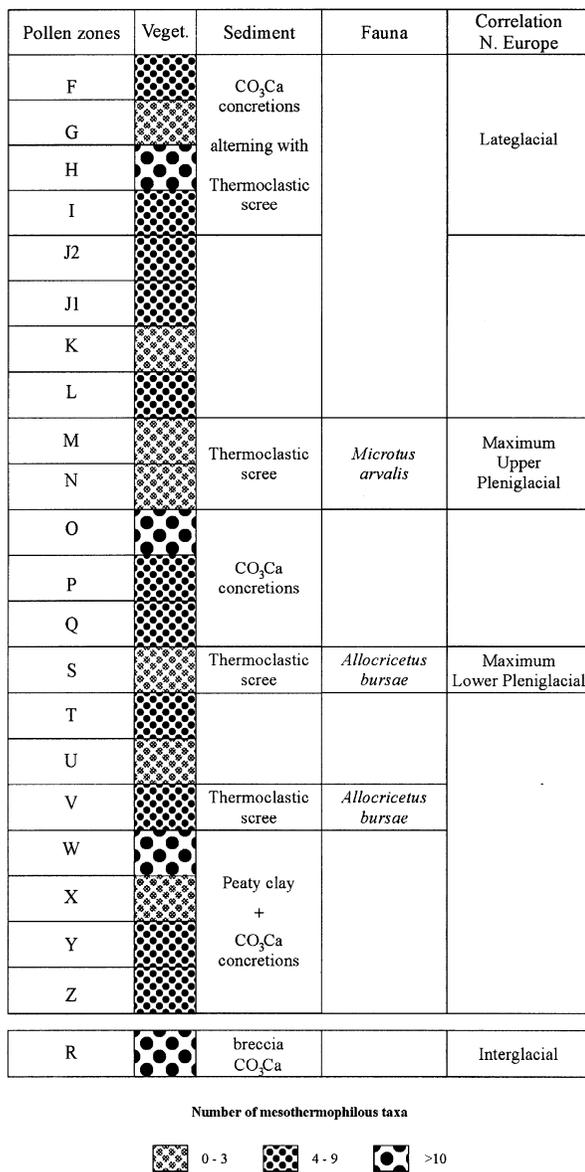


Fig. 3. Carihuela sequence. Correspondence between palynology, sediment type and fauna. Cryophilous rodents (*Microtus arvalis*, *Alloricetus bursae*) correspond with thermoclastic scree and scarcity of mesothermophilous plants.

weathering of the Benito sections. Elsewhere, these palaeoclimatic conclusions have been presented quantitatively, from considerations of pollen percentages, as indices of aridity and 'Mediterranean-ness' (Carrión and Munuera, 1997).

3.3. Cueva de Pernerás (Lorca, Murcia)

Two features stand out (Fig. 5): first, the continuous curves of *Quercus* and Oleaceae, and, secondly, taxa of thermophyllous Ibero-NW African flora such as *Periploca*, *Withania* and *Osyris* which are quite unable to withstand even one week of frost a year, unlike 'ice-age'

floras. Thus it appears the SE Spanish coastal belt could maintain significant reserves of biodiversity throughout the pleniglacial stages. No doubt, the irregular topography protected *Quercus* formations in gallery woodlands with other broad-leaved taxa (Bennett *et al.*, 1991; Willis, 1996; Bennett, 1997; Magri and Parra, 1997).

Whatever short-comings cave palynology may have for identifying ancient environments, the Ibero-NW African pollen records from this cave highlight an aspect that has signally eluded palynological studies from lacustrine, marine (boreholes 11-P off the Almerian coast, Targarona *et al.*, 1996; boreholes SU-8103 off the Murcian coast, Parra, 1994), or Almerian coastal swamps (San Rafael and Roquetas, Pantaleón Cano *et al.*, 1996). Owing their marked entomophily, such taxa as *Periploca* and *Osyris*, are not expected to be recorded in marine and lacustrine deposits. In such cases, biotic transport would still be far more of a help than a hindrance to reconstructing both microenvironments and regional palaeoenvironmental evolution. Put bluntly, qualitative cave palynology influenced by biotic transport may provide findings of fundamental importance, particularly in arid regions, that simply elude conventional quantitative lacustrine palaeopalynological methodology.

3.4. Cueva del Algarrobo (Mazarrón, Murcia)

The pollen diagram (Fig. 6) is homogenous here, as is the upper palaeolithic assemblage that points very strongly to a Lateglacial context (Martínez-Andreu, 1989; Munuera and Carrión, 1991). Chenopodiaceae, *Artemisia* and Asteraceae abound whereas arboreal pollen was sparse. The late glacial vegetation resembled that of today and doubtless responded to local soil conditions that have not favoured processes of vegetational succession. Thermophilous Mediterranean taxa were present, such as *Quercus*, *Olea*, *Phillyrea*, *Lycium*, *Pistacia*, *Buxus*, *Selaginella denticulata*, *Cosentinia vellea*, together with phreatophytes like *Betula* and *Juglans*.

3.5. Abric Romaní (Capellades, Barcelona)

Pollen analysis has been undertaken on travertines exposed in section created by excavation (Burjachs and Julià, 1994; Fig. 7). The Romaní pollen record, although unique in NE Spain, mirrors faithfully (Fig. 8) the ¹⁸O/¹⁶O palaeotemperature record of Mediterranean Sea (core KET-8004, Rossignol-Strick and Planchais, 1989) and, given a plausible correspondence between Romaní zone 5 and the Hengelo interstadial (cf. Zagwijn, 1992), can be related to the Europe-wide climatic evolution from 70,000 to 40,000 BP. Overall, however, little support is given to the recognition of pleniglacial interstadials from Mediterranean Spanish pollen sequences (e.g. Pons and Reille, 1988; Carrión and Dupré, 1996; Pérez Obiol and Julià, 1994).

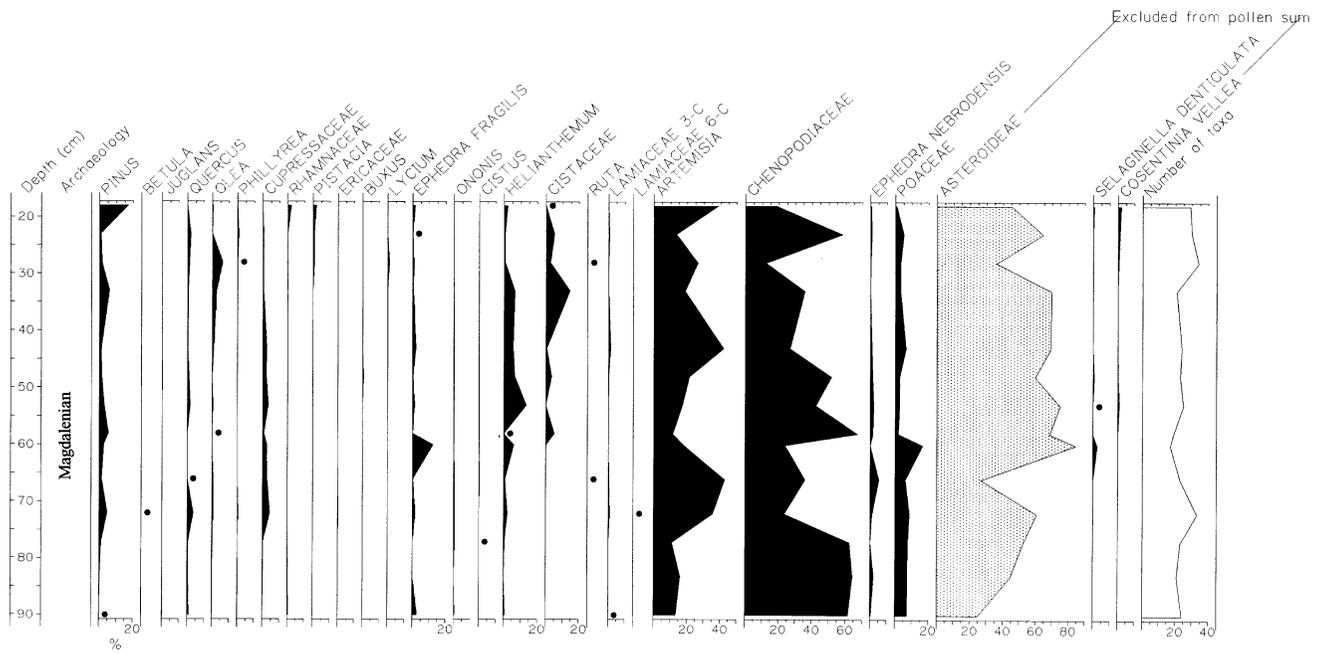


Fig. 6. Synthetic pollen diagram of Algarrobo Cave (Murcia). A Lateglacial xerophytic formation is shown with *Artemisia* and *Chenopodiaceae*.

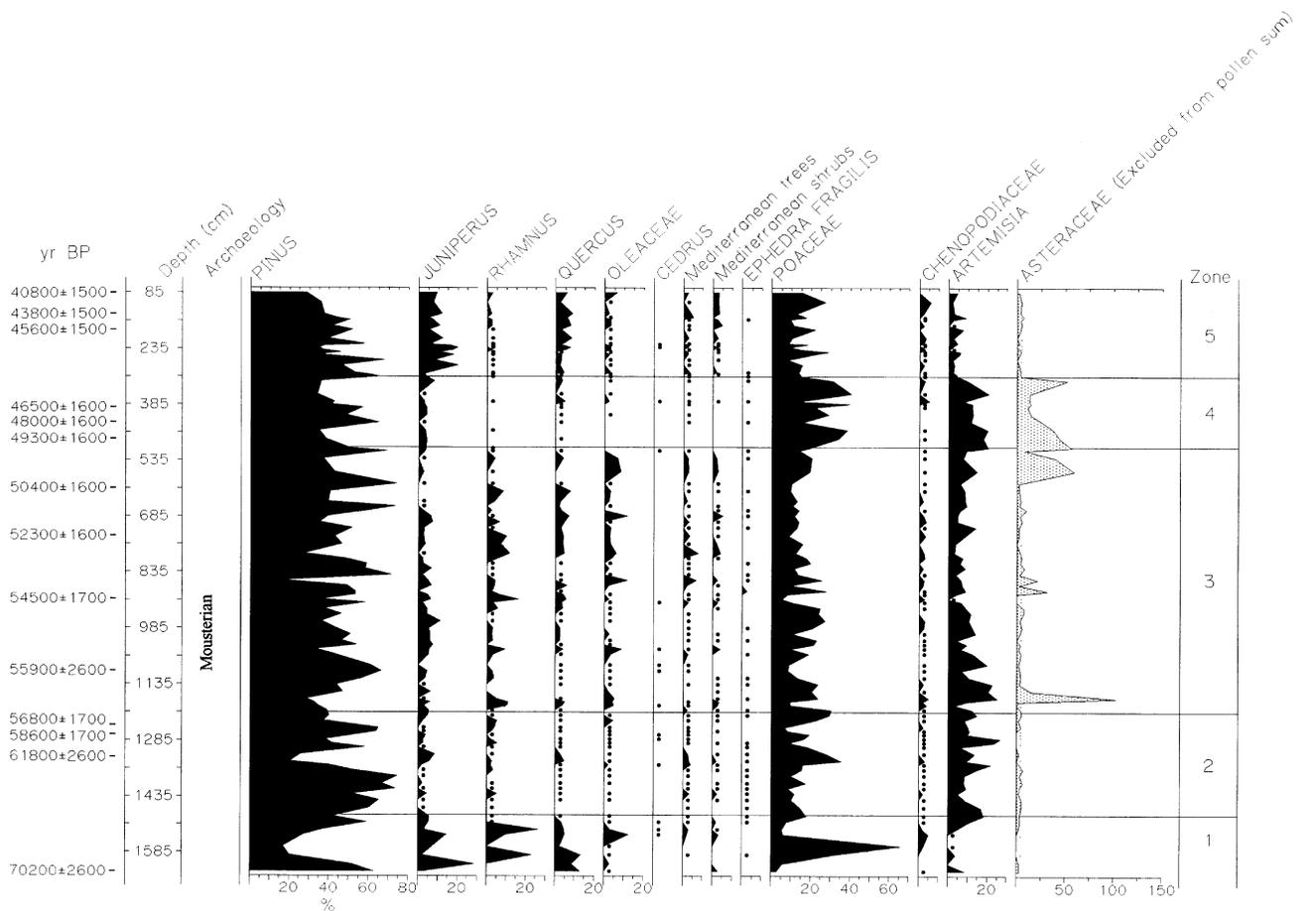


Fig. 7. Pollen diagram of Abric Romani (Barcelona). Abrupt climatic changes can be inferred from the variation of *Quercus*, *Oleaceae* and other Mediterranean taxa.

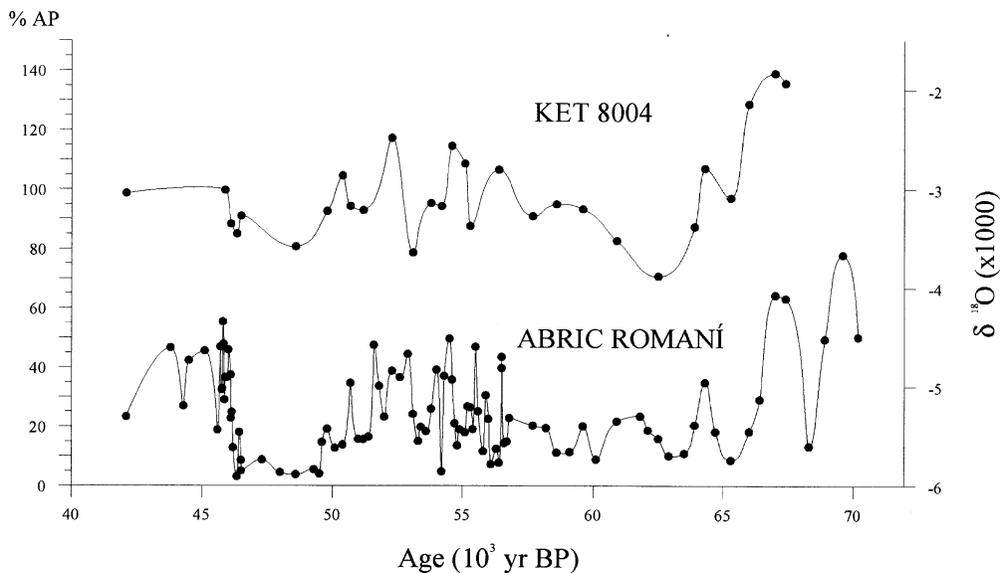


Fig. 8. Comparison between the Abric Romaní AP percentages (*Pinus* excluded) and the isotopic sequence KET 8004.

3.6. Cova de l'Arbreda (Serinyà, Gerona)

The 3 main zones of this pollen diagram (Fig. 9) are distinct in terms of the abundance of *Pinus*, *Juniperus*, *Quercus*, *Corylus* and *Artemisia*. Zone A is interpleni-glacial and shows constant appearance of evergreen *Quercus*. Subzones have been identified from oscillations within this record (Burjachs and Renault-Miskovsky, 1992; Burjachs, 1993). From a palaeoclimatological viewpoint, the sequence shows that *Artemisia* and *Ephedra* were highlights of a pleniglacial stage which was both preceded and followed by *Juniperus* and *Pinus*, with *Corylus* being post-palaeolithic (Holocene). The findings concur with those (Fig. 10) of anthracology (Ros, 1987) and micromammalian palaeontology (Alcalde, 1987). Zone A contains charcoal of mesophilous shrubs *Acer monspessulanum*, *A. opalus*, *Prunus amygdalus* and *Rhamnus cathartica*, as well as the warm-loving rodent *Pitymys*, whereas zone B has charcoal of *Pinus sylvestris* and *Betula verrucosa* indicating harsh climate and more cold-adapted rodents (*Microtus arvalis-agrestis*, *M. oeconomus*, *Citellus*), whilst Holocene zone C is characterized by warm-loving rodents (*Pitymys*, *Microtus brecciensis*).

3.7. Cova de l'Or (Beniarrés, Alicante)

This pollen diagram (Dupré, 1987, Fig. 11) shows abundant Poaceae and mesothermophilous shrubs but few trees. In zone B *Pinus* and *Quercus* curves are reciprocal, suggesting local competition (Badal et al., 1994); similar to that in swamp peat from the Valencian Navarrés basin (Carrión and Dupré, 1996) where, Holocene *Quercus* recolonization was absent, and *Quercus* began

replacing *Pinus* after ca. 5500 BP when neolithic settlement first began. *Quercus* spreading at the expense of pre-existing *Pinus* woodland calls into question Costa's (1987) phytosociological advocacy of a regional climax based on *Quercus rotundifolia*. The finding that *Pinus* woodland was important in the neolithic (as it still is today) is of major palaeoecological significance, and is supported by the pollen evidence from Navarrés.

3.8. Cova de les Cendres (Teulada, Alicante)

The coastal position of the site makes for an interesting pollen record with *Pinus*, *Quercus* and Ericaceae oscillations defining the zonation (Fig. 12). The mid-Holocene landscape seems to have been open with a wide range of mesothermophilous taxa, though Cendres has more arboreal pollen than Cova de l'Or and, here again, *Pinus* was important during early neolithic times until engaged in competition by *Quercus*. Moreover, these findings are corroborated by anthracology, down to the level of oscillations of *Pinus*, *Quercus*, the Ericaceae and even *Pistacia* (Badal et al., 1994). Due allowance must be made for some differences in relative proportions as must be expected in charcoal deposited after anthropogenic transport, but the results point to local growth of *Olea europaea* in particular along with *Quercus faginea*, *Arbutus unedo*, *Pistacia lentiscus*, *P. terebinthus* and *Erica multiflora*. *Pinus halepensis* was the commonest pine and the sclerophyllous *Quercus* was identified as *ilex-coccifera*. The local presence near the coast of *Q. faginea* in a thermomediterranean context indicates that it has retreated only recently, as seems to have been the case of several deciduous species in southern Mediterranean Spain. Indeed, at Navarrés *Q. faginea* reaches its

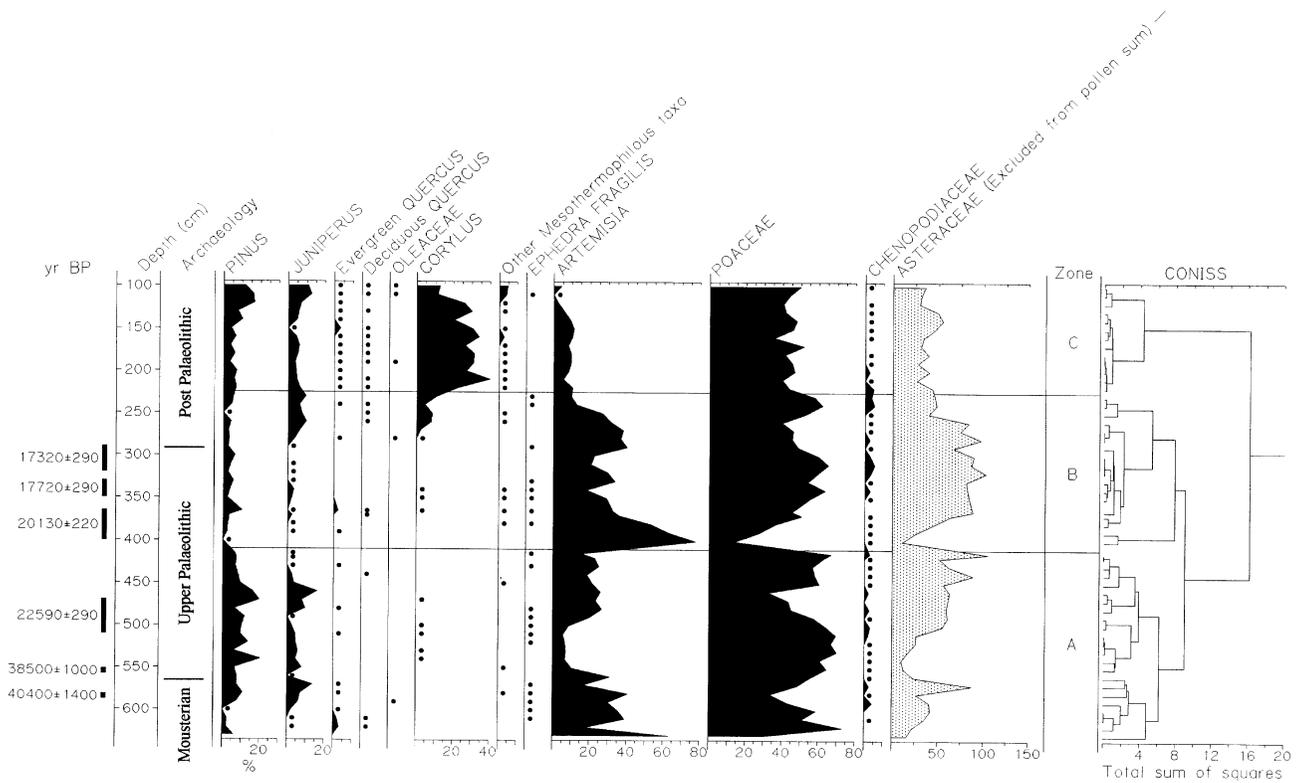


Fig. 9. Synthetic pollen diagram of Cova de l'Arbreda (Gerona). The curve of *Corylus* marks the onset of the Holocene.

	Pollen zones	Microfauna	Charcoal	
C	<i>Corylus</i> - Poaceae <i>Pinus</i> - <i>Juniperus</i> ↑ Thermophilous	<i>Pitymys</i> <i>Microtus brecciansis</i>		HOLOCENE
B	<i>Artemisia</i> - Poaceae Asteraceae Thermophilous	<i>Microtus arvalis-agrestis</i> <i>Microtus aconomus</i> <i>Citellus</i>	<i>Pinus sylvestris</i> <i>Betula verrucosa</i>	LAST GLACIAL MAXIMUM
A	Poaceae - <i>Artemisia</i> <i>Pinus</i> - <i>Juniperus</i> Thermophilous	<i>Microtus arvalis-agrestis</i> <i>Pitymys</i>	<i>Pinus sylvestris</i> <i>Acer monspessulanum</i> <i>Acer opalus</i> <i>Prunus amygdalus</i> <i>Rhamnus cathartica</i>	

Fig. 10. Arbreda sequence. Correspondence between palynology, microfauna and charcoal analyses.

maximum expansion even later than at Cendres (Carrión and Dupré, 1996). It is not known how far the retreat of mesophytes was due to climatic change, anthropic activity, or both in varying degrees at different times.

4. Palaeoclimatological comparisons

Carihuela has the longest sequence, covering most of the last glaciation including the Interglacial. There are hiatuses (Campy and Chaline, 1993), but a temporal control is provided by the three dates shown in the pollen

diagram (Fig. 2) and further fifty thermoluminescence dates. These cover the period 82,500–13,400 BP for zones Z-H. During the interpleniglacial in upland Carihuela, only mesophytes were present, while at Beneito, relatively near the Alicante coast, a full sclerophyllous *Quercus* woodland of shrubs, creepers and deciduous trees existed (Fig. 4). Harsh pleniglacial conditions at Carihuela caused Mediterranean associations to disappear, whereas in the milder surroundings of Beneito (Table 1) they persisted, albeit in small proportions. In comparison with Carihuela and Beneito, the Pernerás (Fig. 5) and Algarrobo (Fig. 6) sequences show a clear rise in

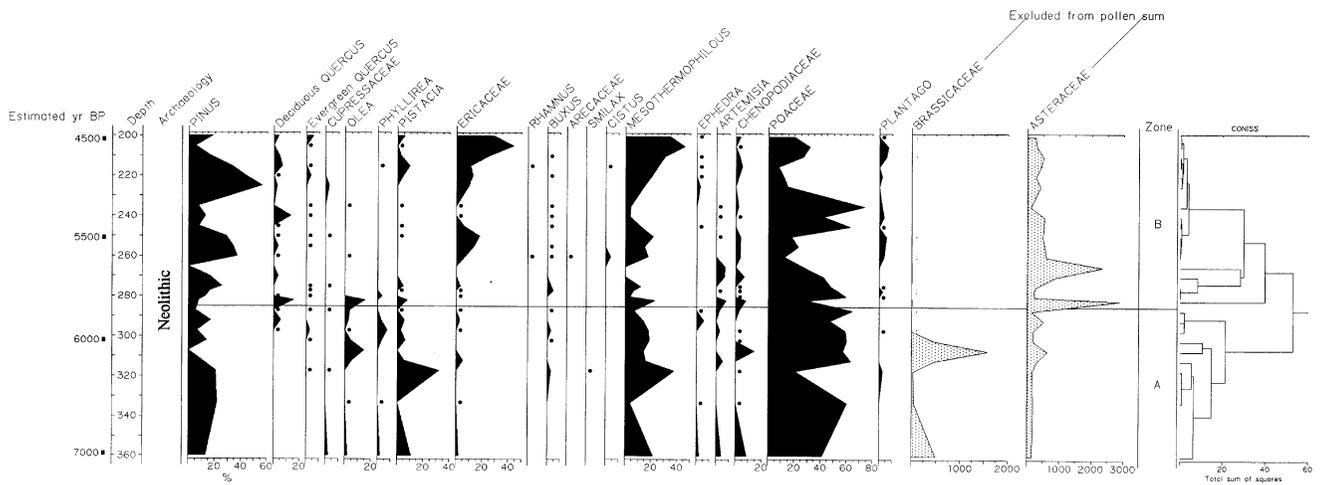


Fig. 11. Synthetic pollen diagram of Cova de l'Or (Alicante). Note the reciprocity of *Pinus* and *Quercus* curves.

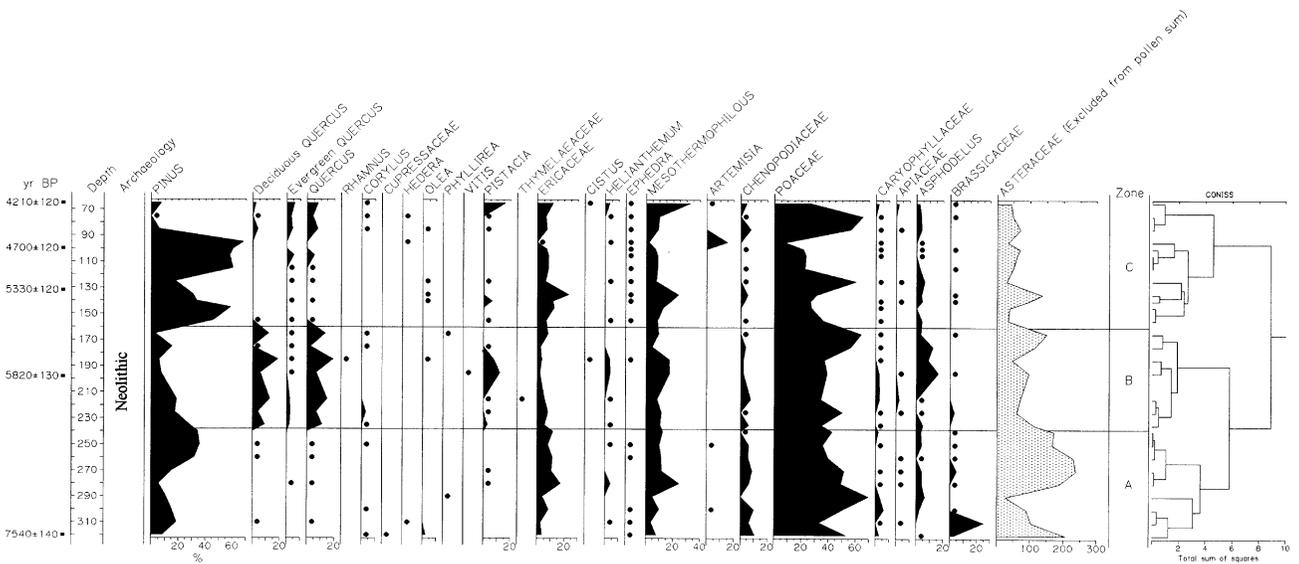


Fig. 12. Pollen diagram of Cova de les Cendres (Alicante). Note the importance of *Pinus* during Neolithic times.

Chenopodiaceae, *Artemisia* and *Ephedra* during the last glacial period, although mild conditions near Perneras, where a thermomediterranean flora survived during the coldest part of the last ice age, highlight the important part played by SE Spanish refuges. The Catalan Romani (Fig. 7) and Arbreda (Fig. 9) sequences fit into the Carihuela record. Romani pollen shows acute palaeoclimatic sensitivity which points to upland ice-age refuges nearby. Holocene pollen from Cova de l'Or (Fig. 11) and Cendres (Fig. 12) indicates Mediterranean matorral associations and underline the importance of pine in natural woodlands of mature meso and thermomediterranean taxa.

Some correspondences can be discerned between inter-site climatic differences today (Table 1) and those which

existed during contemporaneous prehistoric phases (Fig. 13). Thus, from Carihuela in Andalusia, through Beneito in Alicante, to Perneras and Algarrobo on the Murcian coast (Fig. 1), there is evidence for increasing environmental dryness and an increase in mean annual temperature. During cold episodes the coastal sites showed relative increase in thermophilous Mediterranean taxa and xerophytes such as Chenopodiaceae. Similarly, northwards from Carihuela, through Alicante, to Catalonia, a trend exists towards higher temperature and/or precipitation (Table 1) which is reflected in palaeolithic sequences showing greater abundances of thermophilous plants and deciduous trees. Comparison between Holocene sites in Alicante and Gerona shows a rise in woodland species further north. On the Murcian

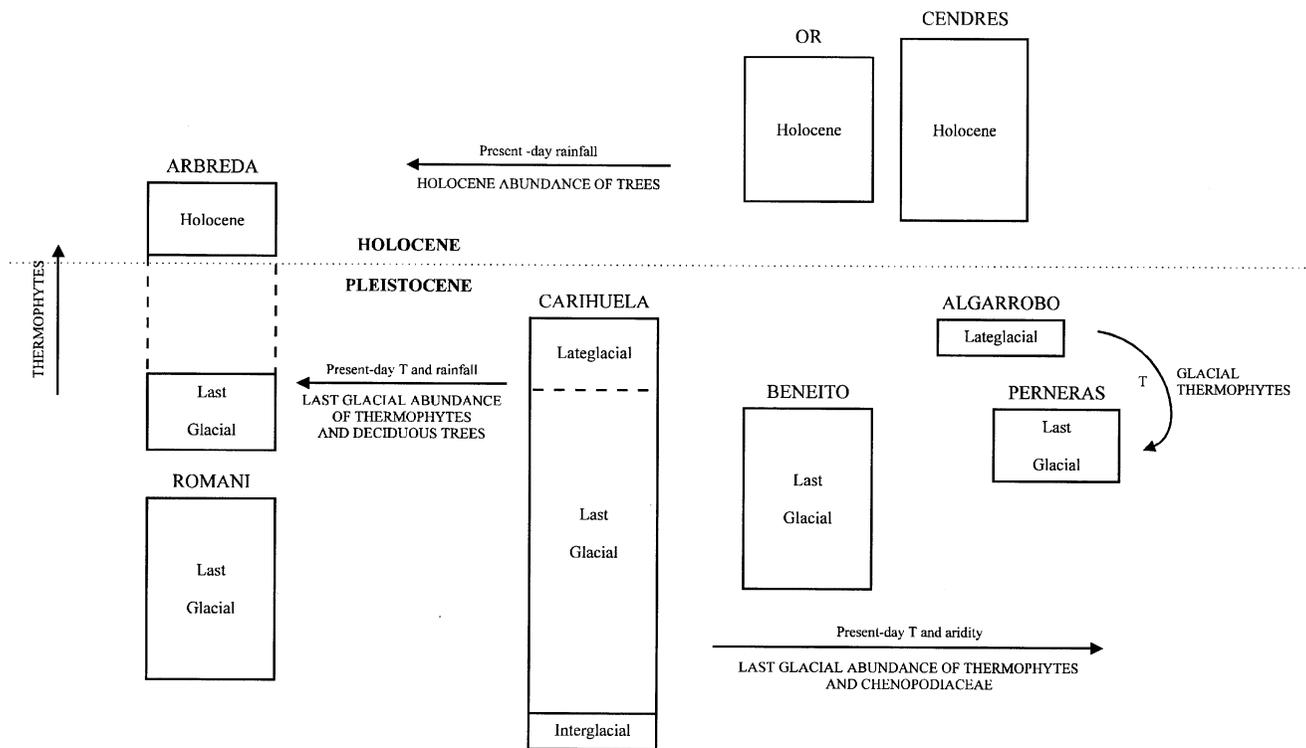


Fig. 13. Interpretation of palynological differences between the sequences studied in terms of present-day climate. Arrows indicate increases.

coast, south-facing Pernerás had relatively more thermophilous species than northeast-facing Algarrobo, perhaps reflecting a thermal gradient still present today, although aspect may also have been influential (cf. Weinstein-Evron, 1981). The more numerous thermophytes at pleniglacial Romani, when compared with Arbreda, appears to be related to the fact that the pollen sequence represents a lower part of the pleniglacial than the Arbreda sequence.

5. Suggested criteria for overcoming some methodological problems of pollen studies in caves

Although palynological research has problems caused by sedimentary discontinuities, selective preservation, preferential transport, and contamination, cave palynology in particular has suffered from a dearth of experimental data capable of determining the effectiveness of cave pollen spectra in representing source vegetation. In effect, this science is at the stage that open-site palynology was before pollen-vegetation transfer functions were first developed.

The great challenge before cave palynology is to decide how far vegetational cover contributed to each pollen spectrum with respect to local taphonomic or depositional processes. Some recent research into the representativeness of cave pollen spectra, using Cour filters (Burjachs, 1991), glycerine-impregnated microscope

slides (Coles and Gilbertson, 1994), and Tauber traps (Burney and Burney, 1993), implies that cave interiors reflect local and regional floras quite well.

The interpretative potential assigned here to cave palynology is based on, and limited by, a working hypothesis that cave pollen spectra can represent local vegetation to a variable degree and on occasions may even represent the regional flora. This is corroborated by the coincidence of cave spectra with well-established regional pollen records from open sites such as Padul (Pons and Reille, 1988) or Navarrés (Carrión and Dupré, 1996). Likewise, palaeoclimatological inferences from cave sequences presented here are also constrained by sedimentological, paleontological, and anthracological inferences at the sites (Fig. 13).

Our pollen records form only a small part of a large Mediterranean Spanish data-set (cf. Davis and Mariscal, 1994; Dupré, 1988; López García, 1978, 1986; López García and López Sáez, 1994). This is because very few cave deposits are suitable for pollen analysis due to (1) clear-cut evidence of contaminants or percolating water, (2) too few palynomorphs, or (3) destruction of all pollen. For these reasons, pollen was absent from middle palaeolithic sites at Cueva de los Aviones and Cueva Negra del Estrecho del Quípar de La Encarnación in Murcia, Cova del Salt in Alicante, Cova Negra in Valencia, Cueva de la Higuera in Murcia, and Abrigo del Molino in Albacete.

From our experience, a reliable pollen record from cave sediments is dependent upon the following (a) a taxo-

onomic diversity of around 30 taxa per sample and certainly above 15, (b) pollen counts of more than 200 grains per sample with Asteraceae excluded, (c) pollen concentrations of around 10,000 grains per g^{-1} and certainly not much less than 4000 (Burjachs and Julià, 1994; Carrión and Munuera, 1997; Carrión et al., 1998), (d) a percentage of less than 20% of indeterminable pollen, (e) in some cases, calcification of sediments, (f) samples should be taken from central areas of cave galleries, (g) there should be ecological coherence of pollen spectra after excluding the Asteraceae, (h) availability for sampling of multiple excavated sections (especially helpful at Carihuela and Beneito), and (i) a joint inter-disciplinary approach to palaeoecological interpretation.

Even if these conditions are fulfilled, the success or failure of palaeopalynological sampling depends also on the quality of laboratory treatment of the samples. Sometimes, as at Cueva Beneito, sections barely a metre apart show striking differences (Carrión and Munuera, 1997) and recently-exposed sections may give better results than those left open at old excavations (Scott, 1982, 1995).

Some longstanding problems can be addressed such as the question of whether humid organic samples in cave sites retain well-preserved pollen. Evidence from Carihuela suggests that this is not necessarily the case. Here, least pollen is found in layers that looked 'peaty', and it is considered that degradation of pollen, as of other organic remains, is a function of repeated wetting and drying rather than prolonged dryness (Davis, 1990). This appears to apply even though aridity may well have brought about rapid mummification of those spores and pollen grains preserved in calcrete or breccia in Middle Pleistocene deposits at Cueva de Atapuerca in Burgos (García Antón and Sáinz Ollero, 1991), in middle palaeolithic deposits at Abric Romaní in Catalonia, and Cueva Pernerías in Murcia, or in the lower and upper parts of the sequence at Cueva de la Carihuela in Andalusia.

Historically the science of archaeopalynology has debased by jumping to unwarranted conclusions with hasty palaeoclimatological inferences drawn from flimsy data (López-García et al. 1991). Nevertheless, there is a need to depend upon cave sediments in arid or semi-arid areas where conventional open pollen-rich deposits are rare and colluvial fills may be the only alternative sites. The accumulation of speleothems (Brook et al., 1990), coprolites (Scott, 1987), bat droppings (Dimbleby, 1985), middens of *Procyon*, *Petromus* (Scott and Cooremans, 1992) or *Neotoma* (Davis and Anderson, 1987) in cave sediments enhance the potential of cave pollen to describe the environmental palaeorecord.

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