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PALAEO

Upper Pleistocene palaeoenvironmental change in Eastern Spain: new pollen-analytical data from Cova Beneito (Alicante)

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Abstract

The results of a palynological investigation of the Upper Palaeolithic interval from the Beneito Cave (southeastern Spain) are herewith considered in the context of results from a previous report on the underlying deposits. Two new percentage and concentration pollen-diagrams with good correspondence are presented. The Upper Palaeolithic sequence is dominated by Poaceae, Chenopodiaceae and *Artemisia*, whereas arboreal pollen are less important. Mesophilous trees and Mediterranean taxa show a constant presence, but in low proportions. The new data add support to the view that interpleniglacial development of Mediterranean taxa was important in eastern Spain, while they were considerably reduced during upper pleniglacial times. Emphasis is placed on aridity as a limiting factor in influencing major vegetation changes in the area. Two additional topics are also presented: they deal with the extrapolation of north European interstadials to Mediterranean Spain and the palaeoecological value of archaeopalynological records.© 1997 Elsevier Science B.V. All rights reserved.

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1. Introduction

Excavations at the archaeological site of Cova Beneito (Muro, Alicante, eastern Spain) began in 1980 with the goal of providing insights into the poorly known Middle to Upper Palaeolithic transition. It is generally believed that the contrasts between these periods are among the most impressive to be seen in Pleistocene prehistory because they involve dramatic changes in human technology, subsistence, social organization and human cultural capacities. Furthermore, the transition roughly parallels the human fossil change in western Europe from Neanderthals to anatomically-modern humans, which adds interest to the study of palaeoenvironmental conditions under which this process took place. In this context, Beneito could well be a key site for the western Mediterranean because of its intermediate situation between the isolated Andalusian Mousterian (Vega-Toscano, 1993) in the south, and the northernmost sequences of El Castillo (Cabrera and Bischoff, 1989), L'Arbreda (Bischoff et al., 1989), and Abric Romaní (Bischoff et al., 1994) where Neanderthal was rapidly substituted by anatomically modern man not later than ca. 37,000 yr B.P.

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Palynological investigations at Cova Beneito began in 1987, initially resulting in the production of one pollen diagram mainly covering the Mousterian to Aurignacian cultural phases (Carrión, 1992a). The most striking feature of this first survey was the appearance of a Mediterranean palynozone of meso-thermophilous *Quercus*-dominated assemblages just before the archaeological transition. This event was preceded by a protophytic stage of *Juniperus* that disrupted the dominant *Pinus*-Poaceae-Chenopodiaceae assemblages. Although available datings did not permit more precise chronological control, *Quercus* could well have developed around 45,000–40,000 yr B.P. Together with the data from the southernmost Carihuela Cave (Carrión, 1992b) it was the first time that such a development of vegetation was encountered in the Iberian Peninsula during the mid-last glacial stage.

Cova Beneito has stimulated interest in its continuous record of Upper Palaeolithic industries, ranging between the late Aurignacian to the Solutrian Gravettian phases, but deposits did not provide pollen in the available sections in the cave at that time. Recent excavations have exposed new profiles which record the whole Upper Palaeolithic sequence of implements. Interestingly, these sediments yielded enough palynomorphs to undertake reliable pollen analysis, the results of which comprise the major part of this paper. It is therefore a continuation of the pollen-stratigraphical study by Carrión (1992a).

Pollen stratigraphy in caves is generally of a lower resolution than those in open, organic sites. It must be realized that one pollen spectrum can represent a considerably longer time-span and, consequently, may include pollen from several communities which dominated the past vegetation. Due to the different levels of resolution, comparison of fossil spectra from archaeological sediments to those obtained from lake and bog sequences may be over-simplistic. Before such a comparison can be made, we should know the representation of the local and regional vegetation by pollen preserved in cave sediments. Some pollen-trapping experiments (Burney and Burney, 1993; Coles and Gilbertson, 1994) suggest that pollen deposition inside caves reflect not only the vegetation near the cave but also that of a wider area beyond the site. Therefore, it could provide a reliable index of the regional and local vegetation.

2. Setting and stratigraphy

An exhaustive description including geomorphology, climate and present vegetation of the area was included in Carrión (1992a). The site is a 8 × 6 m, semi-rectangular cave (Fig. 1) lying on the southern slopes of the Sierra del Benicadell (Muro, Alicante, eastern Spain) within a montainous region with local pluviometric contrasts. The climate is typically Mediterranean, with a mean annual temperature of 17–18°C, a pronounced summer dry period and two equinoctial pluviometric maxima. The mature vegetation of the area is a *Quercus rotundifolia* forest but, locally, a garrigue of high tickets is dominant with *Q. coccifera*, *Chamaerops humilis*, *Pistacia lentiscus*, *Rhamnus alaternus*, *Olea europaea*, *Phillyrea angustifolia*, etc.

The two new sections studied (5C-3B) are situated about 1–2 m away from that considered in the first study (5D-3D) (Carrión, 1992a) and 4–6 m from the cave opening (Fig. 1). They are situated closer to the centre of the cavity. Although separated, both sections make up a stratigraphically coherent sequence (Fig. 2) including the uppermost unit 3 (layers IV–II), which was palynologically sterile in the 5D-3D profile. In addition, we have analysed again beds VIII and VIIb.

No remarkable difference was noted texturally or structurally between the sediments studied and those from the profile described in Carrión (1992a). Levels VIII and VIIb display an important coarse angular fraction within a clayey-silt matrix. Most sediments seem to be internal (unit 2). Levels IV–II pertain to a different lithostratigraphic unit characterized by higher organic matter and a lower coarse fraction, mostly a thermoclastic scree. External sedimentary input appears to have been dominant at this stage (unit 3). pH measurements were made for both the previously studied and current samples. All samples showed high values, but their variation was insignificant, ranging from 7.7 to 8.3. Notwithstanding their high pH values, pollen was relatively well preserved in

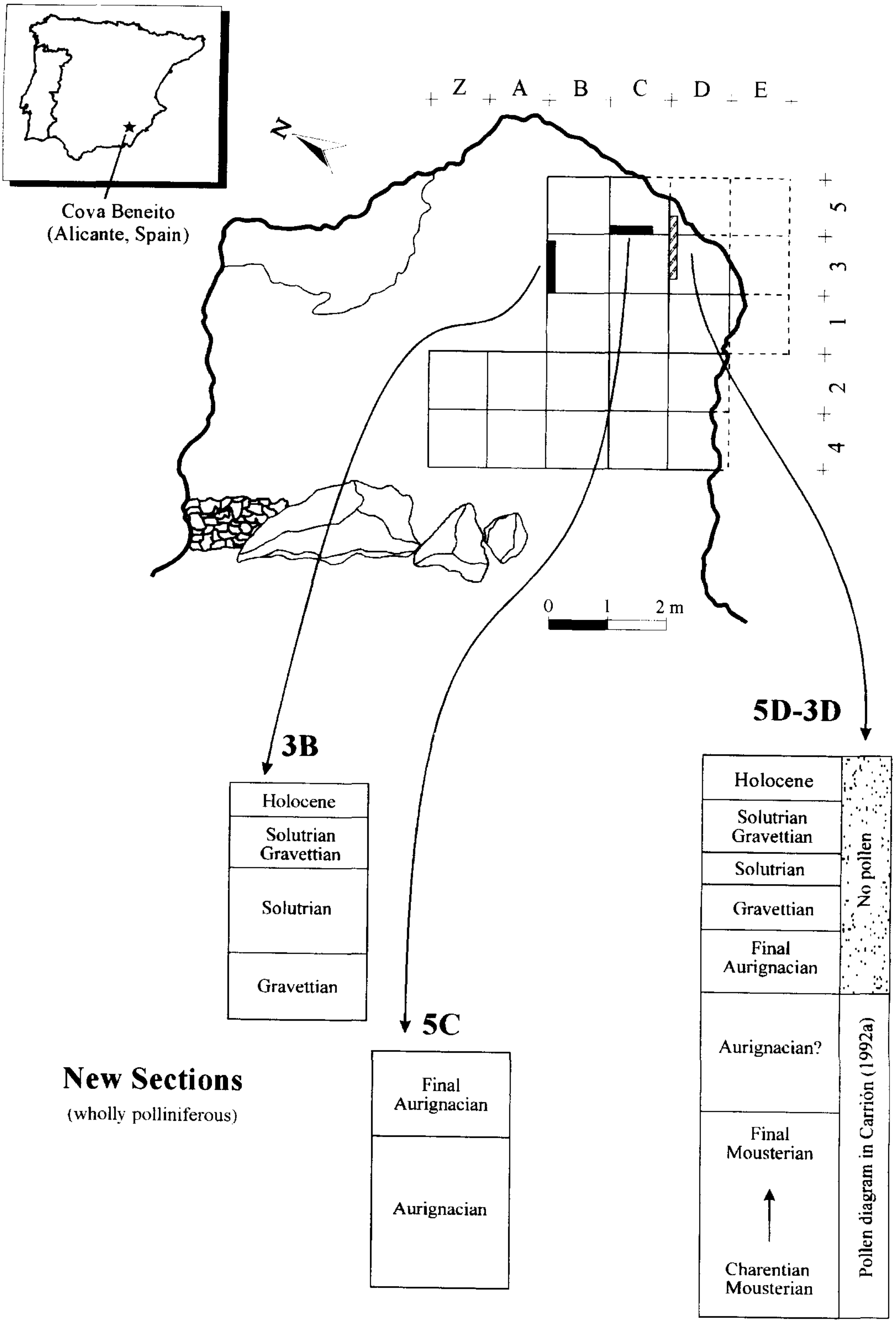


Fig. 1. Map of the excavation grid in Cova Beneito and location of the sections studied.

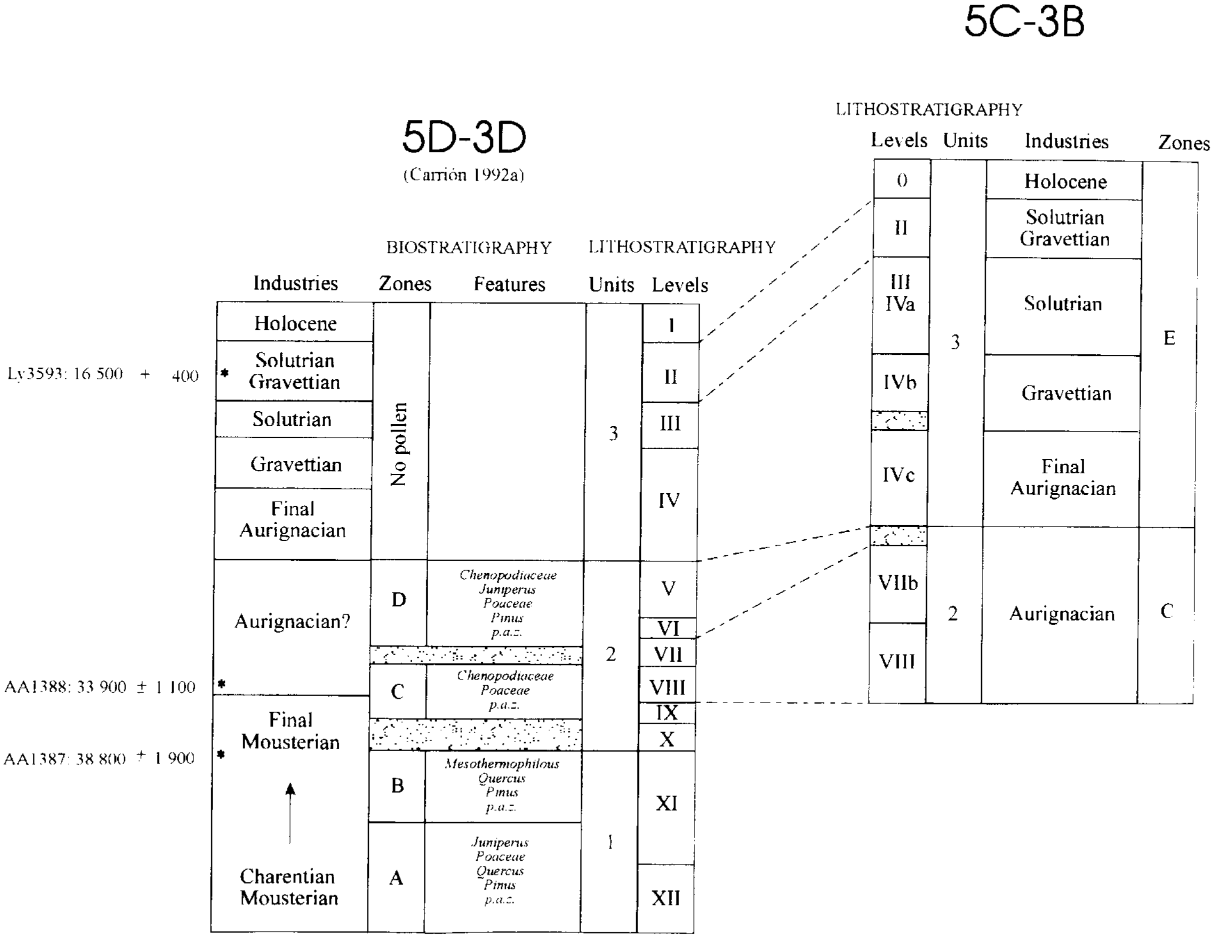


Fig. 2. Stratigraphical comparison between the previously studied section and the one presented here.

most samples. Signs of oxidation–reduction processes were not discernible.

3. Methodology and presentation of results

Most of the methods employed in the collection and analysis of material were identical to those in Carrión (1992a) and are not described again here. *Lycopodium clavatum* spores were added in order to estimate pollen and spore concentrations. Two new pollen diagrams have been drawn on a percentage (Fig. 3) and a concentration basis (Fig. 4). Pollen percentage zone boundaries were determined from the results of constrained incremental sum-of-squares cluster analysis (CONISS; Grimm, 1987), using a square-root transformation and chord-distance dissimilarity measure for the pollen taxa that occur at greater than 2% abundance (Fig. 3). A synthetic pollen percentage diagram involving selected taxa has been produced for the whole sequence (Fig. 5.). As we have repeated pollen analysis for some lithological beds, a selection of spectra was necessary to avoid overlap in the construction of the synthetic diagram. Thus, although curves in Fig. 5 seem to be continuous, one should bear in mind that hiatuses may occur at the section changes.

Palaeoecological inferences from cave deposits such as Beneito cannot be very precise because of

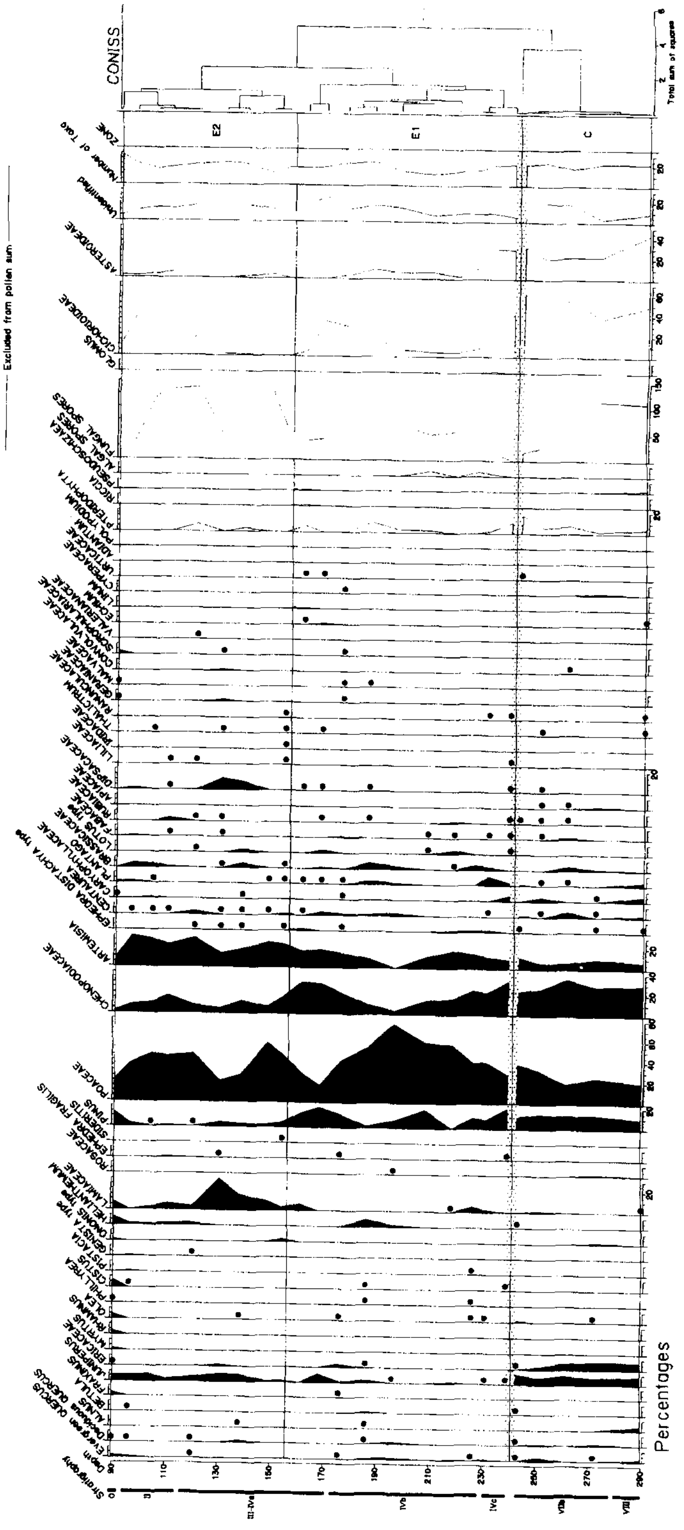


Fig. 3. Percentage pollen diagram and CONISS zonation.

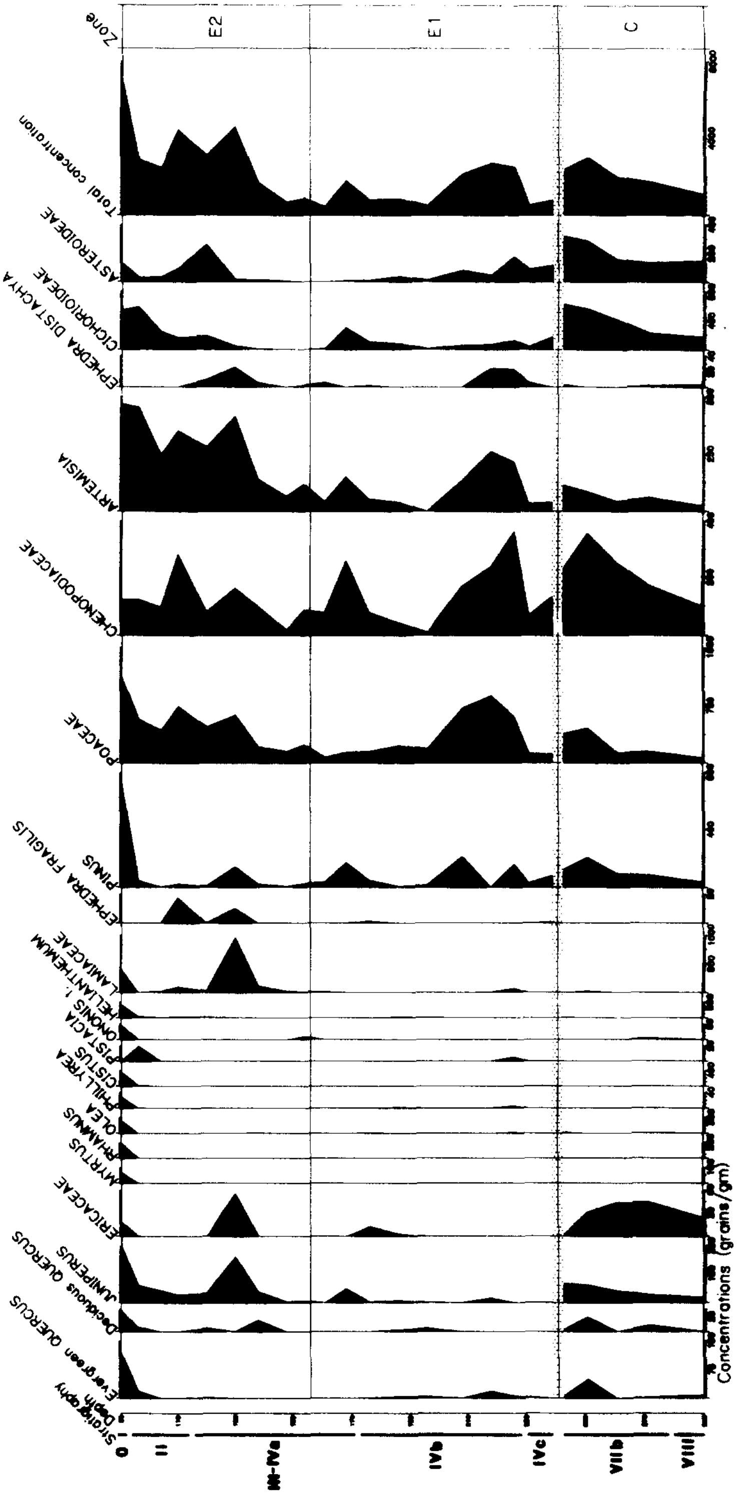


Fig. 4. Concentration pollen diagram of selected taxa.

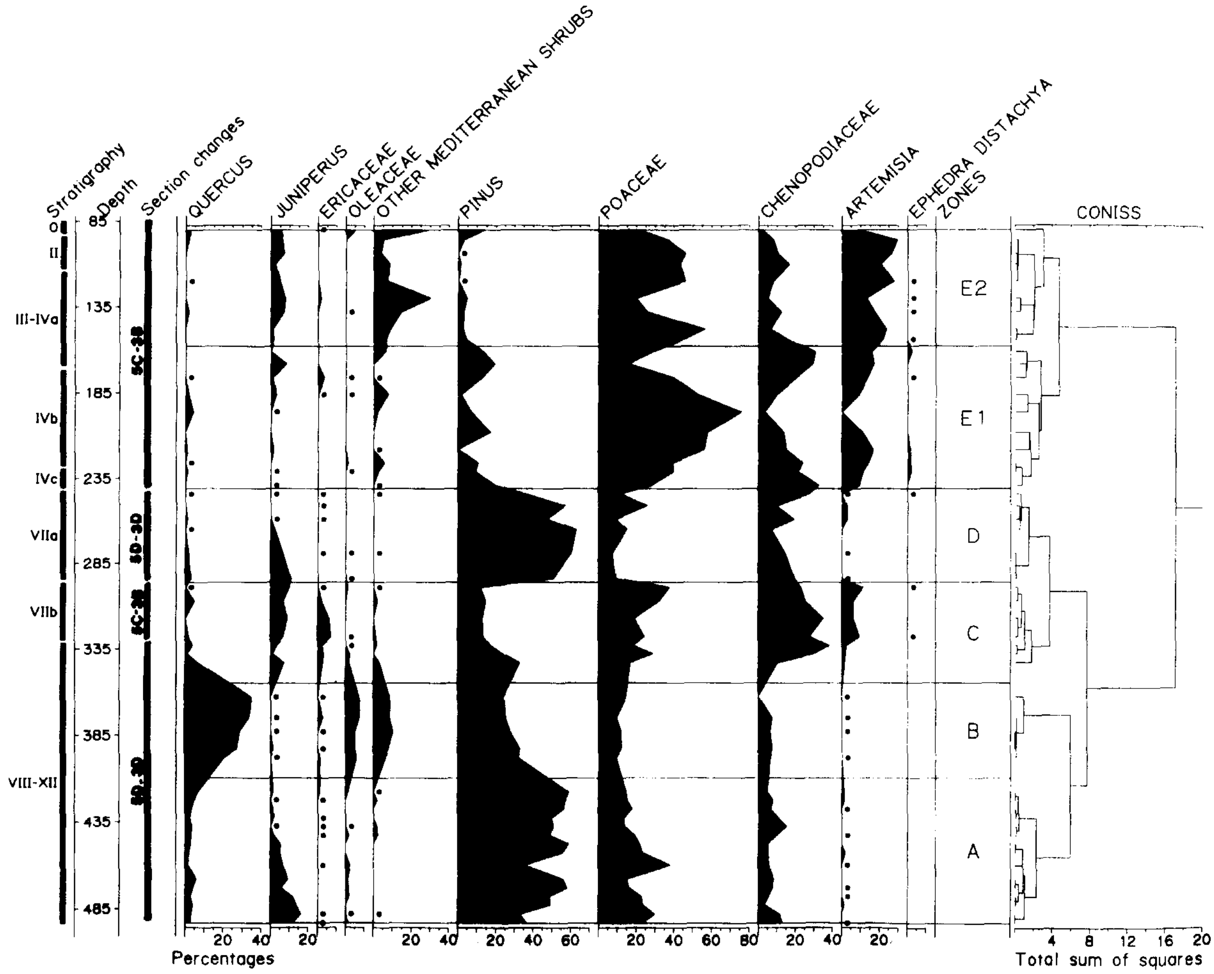


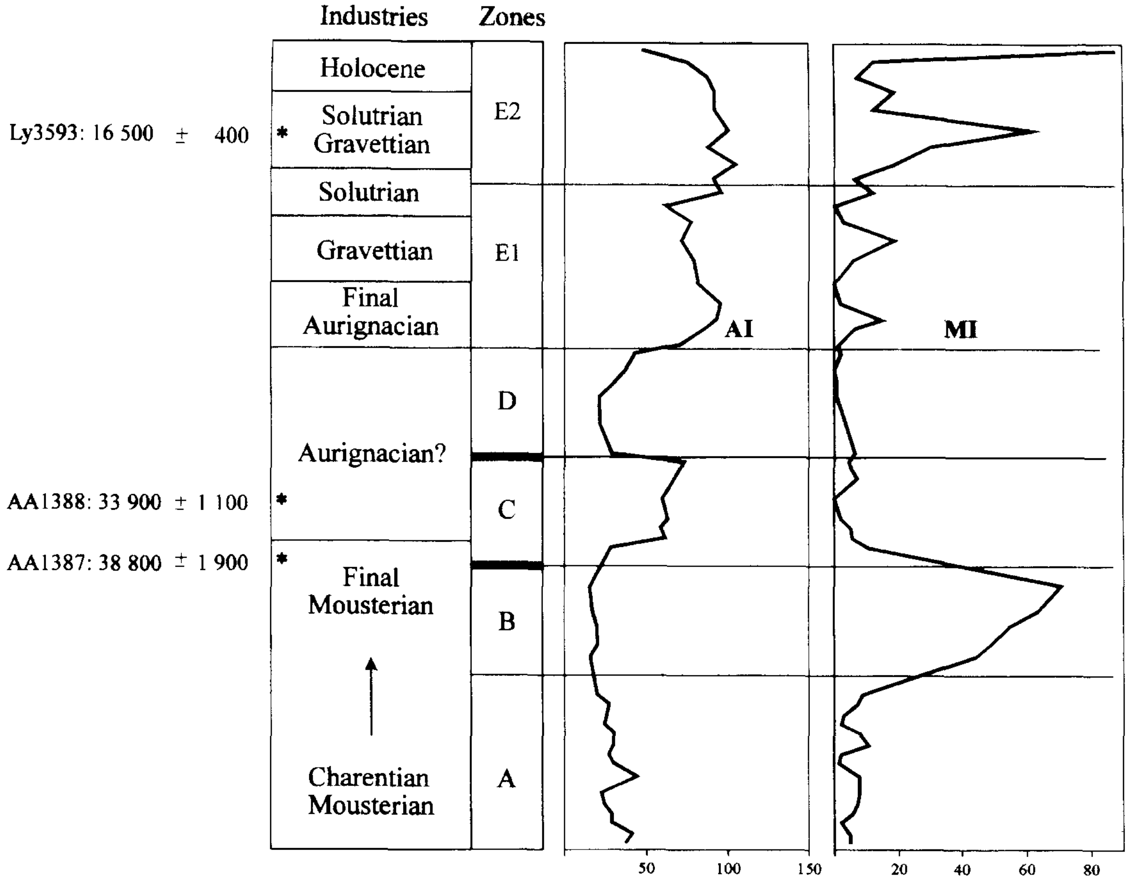
Fig. 5. Synthetic pollen diagram from beds XII–II from Beneito.

several factors, e.g. the lack of modern analogues, limited chronological control, vague knowledge about pollen deposition in cave sediments, possibilities of undetected erosive processes and past bioturbation, etc. Consequently, one should not expect to provide palaeoecological information from each positive or negative peak in the pollen curves. Consideration of broad trends appears to be more realistic. Fig. 5 must be viewed from this perspective.

Further, many doubts prevail concerning the palaeoenvironmental value of some taxa, mainly due to an insufficiently precise level of identification. For instance, we were not able to realistically relate variations of *Pinus*, Poaceae or even *Quercus* with a precipitation factor. Other taxa, such as *Juniperus*, indicate colonizing phases of uncertain nature because we do not know which species are involved. *J. oxycedrus* and *J. phoenicea* would for instance, suggest sclerophyllous scrub but others such as *J. thurifera* would indicate cold continental conditions. On the other hand, we are confident that Pleistocene increases of Chenopodiaceae–*Artemisia*–*Ephedra* assemblages point to high aridity. Likewise, there is no doubt that such genera such as *Pistacia*, *Olea*, *Phillyrea*, *Cistus*, etc, denote Mediterranean climates with a characteristic summer drought. Taking into account these considerations, we have used two indices in order to estimate palaeoenvironmental development of the sequence: AI (aridity index), and MI (mediterranean index). Fig. 6 shows both the method of calculation of the indices and the application to the Beneito pollen record. Formulas for the two types of climatic indices (AI, MI) presented in Fig. 6 are based on the totals of pollen percentages of various indicators for either aridity or Mediterranean conditions. In order to present the index curves on comparable scales and to enhance the effects of important, but under-represented indicators, some values were multiplied by factors of either 2 or 4, following the same mathematical principles of Kukla et al. (1981) and Rousseau et al. (1995).

4. The pollen record

The sequence (Fig. 3) is clearly dominated by Poaceae, Chenopodiaceae, and *Artemisia* while



MI = sQ + 2 (Ol + He + Lm + Rh) + 4 (Ph + Ef + Pi + Ci + My)

AI = Ar + Ch + Po + 2 Lm + 4 Ed

Fig. 6. Curves of variation of the Aridity index (*AI*) and Mediterranean index (*MI*) indices covering the whole sequence of Beneito and the formulae for their calculation. *sQ* = sclerophyllous *Quercus*; *Ol* = *Olea*; *He* = *Helianthemum*; *Lm* = Lamiaceae; *Rh* = *Rhamnus*; *Ph* = *Phillyrea*; *Ef* = *Ephedra fragilis*; *Pi* = *Pistacia*; *My* = *Myrtus*; *Ar* = *Artemisia*; *Ch* = Chenopodiaceae; *Po* = Poaceae; *Ed* = *Ephedra distachya*.

arboreal pollen appears in low proportions. Mesophilous trees (e.g. *Alnus*, *Betula*, *Fraxinus*, deciduous *Quercus*) and Mediterranean taxa (e.g., evergreen *Quercus*, *Olea*, *Myrtus*, *Cistus*, *Pistacia*, etc) are diverse but they appear in low percentages. In general terms, concentration curves (Fig. 4) correspond well with percentage ones (Fig. 3) which, without underestimating uncertainties intrinsic to the type of deposit, suggest that deposition was not erratic, and that reliable palaeoecological interpretations can be based on this record.

The following pollen-assemblage zones have been established in the new upper Pleniglacial pollen diagram of Cova Beneito (Fig. 3):

Zone C: It compares relatively well with the homologous zone in the 5D-3D section (Carrión, 1992a). If Asteraceae are excluded from the total pollen sum, both diagrams shows Poaceae and Chenopodiaceae percentages of around 20–30%, *Pinus* below 15%, a continuous curve for *Juniperus* of 3–7%, and the nearly constant presence of Ericaceae and *Quercus*. *Artemisia* is somewhat more abundant here (5–10%), but differences are not higher than 5%. Other Asteraceae pollen is abundant (Cichorioideae 39–58%, Asteroideae 21–46% out of total) but its high numbers are neither related to particular pollen preservation (as can be seen in the curve of unidentified palynomorphs) nor with diversity of taxa. No relationship can be found with low total pollen concentration, which varies between 1200 and 2800 grains/g in this zone. It is, however, worth mentioning that Asteraceae pollen was more frequent in the zone C of the 5D-3D section (Carrión, 1992a) where both Cichorioideae and Asteroideae reached percentages higher than 120%. Correlation is therefore only acceptable between the 5D-3D and 5C-3B sections if Asteraceae are excluded from the sum. This partially reinforces our initial view that Asteraceae appears to be over-represented. Unfortunately, quantitative data on pollen concentrations and preservation for the 5D-3D diagram are not available.

Zone E: Overall increases are noticed in Poaceae, *Artemisia*, and *Ephedra distachya*. Curves of Chenopodiaceae and *Pinus* show higher oscillations with a general trend to diminish towards the top. Ericaceae rarely surpass 2%. Cichorioideae and Asteroideae decline although they episodically rise up to 20–30%. E1 displays 16–57% Poaceae, 4–31% Chenopodiaceae, 9–15% *Artemisia*, 7–20% *Pinus*, while Lamiaceae and *Juniperus* at no time exceeds 3%. *Ephedra fragilis* is absent. Total pollen concentration is 510–2600 grains/g, mostly below 2000 grains/g. E2 shows 18–45% Poaceae, 2–16% Chenopodiaceae, 9–30% *Artemisia*, and *Pinus* 1–13%. Lamiaceae and *Juniperus* show continuous curves reaching up to 29% and 8%, respectively. *Ephedra fragilis* is frequent as a minor constituent. In the uppermost sample (Holocene surface sediments) some taxa such as *Quercus*, *Fraxinus*, *Myrtus*, *Rhamnus*, *Olea*, and *Helianthemum* appear with values higher than 2%. Total pollen concentration is 1000–7100 grains/g mostly above 3500 grains/g. The highest value corresponds to the uppermost sample.

The synthetic pollen diagram (Fig. 5) shows the significance of the new data presented herein. The CONISS zonation fits relatively well to scheme in Carrión (1992a) if variations in the main pollen producers are considered. The following features are worth mentioning:

(1) The *Quercus* curve is continuous in zone A, and shows its maximum in zone B. It declines progressively through the upper Pleniglacial zones C-E2. A similar curve is noted for Oleaceae. The climatic optimum of the sequence appears therefore to be located in the interpleniglacial zone B which is chronologically just before ca. 38,800 yr B.P. (Fig. 6), corresponding to a Mousterian culture at Beneito site. It remains uncertain whether the local landscape was a mixed *Quercus–Pinus* forest with Mediterranean shrubs growing in favourable situations, or if it was a shrubby *Quercus*-dominated formation including thermophilous elements.

(2) Apart from *Olea*, the expansion of Mediterranean shrubs occurs simultaneously with *Quercus* in zone B, but it is not discernible in zone E2. It must be taken into account, however, that what determines major percentages of "Other Mediterranean shrubs" (Fig. 5) for both zones is not exactly the same. In zone E2, the group includes mostly heliophytic chamaephytes which are frequent on eroded soils, whereas in zone B the most important constituents are *Phillyrea*,

Myrtus, *Rhamnus*, *Lonicera*, and Fabaceae. This adds support to the view that Mediterranean elements in zone E2 are related to water stress whereas changes in zone B are mainly determined by a temperature increase. This seems to be supported by variations in the MI and AI indices (Fig. 6). A lower MI peak coincides with low values of AI (zone B) whereas the uppermost increases of MI are coincident with high AI values (zone E2).

(3) *Juniperus* displays three stages of maximum development. At the bottom of zone A it appears as fore-runner to the development of *Pinus* and later *Quercus*. In zone C it also precedes an important *Pinus* expansion. *Juniperus* could therefore represent an only partially wooded landscape. Nowadays, such a situation is common on the Mediterranean highlands. Such species as *J. thurifera*, *J. sabina*, and, to a lesser extent, *J. phoenicea* are involved. During E2 *Juniperus* variations parallel those of Mediterranean chamaephytes (e.g. Lamiaceae, *Helianthemum* type) and other heliophytes. Furthermore, zone E2 shows a maximum decline in tree pollen. Chronological control in this zone (ca. 16,500 yr B.P., Solutrian–Gravettian) together with the changes in *Juniperus* support the view that this taxon was preceding forest development. *Quercus* colonization ca. 14,000–13,000 yr B.P. is characteristic of thermic situations in southern Spain (e.g. Pons and Reille, 1988), although this early colonization cannot be ruled out (Carrión and Dupré, in press). *Pinus* may also have been important.

(4) *Pinus* has its minimum pollen representation during zones C, E1, and E2. This coincides with relatively important proportions of Chenopodiaceae, *Artemisia*, and *Ephedra distachya* type. Moreover, *Pinus* pollen is particularly scanty in E2, just when Lamiaceae and chamaephytic Cistaceae reach their maxima. The *Pinus* declines could be therefore linked with aridity changes. Similarly, Poaceae pollen could be mostly interpreted as a steppic influence because it is more abundant during the C and E stages, although its peak is not coincident with Chenopodiaceae and *Artemisia* (e.g. 190–200 cm, zone E1). The interpretation of a Pleniglacial increase in aridity is supported further by the AI index (Fig. 6).

5. Discussion

Taphonomic research is required to understand why these new sections contained relatively well-preserved pollen while the 5D-3D section yielded no pollen. The possibility of recent pollen degradation by atmosphere exposure in the 5D-3D section can be excluded, because this section was not exposed for a long time before sampling. Fresh sections of cave deposits are much better than old exposures which are likely to have been degraded or contaminated (Scott, 1982, 1995) because the infill has been subject to intense excavation. It is risky to consider the surface sediments of Beneito cave as recent. Such an investigation is in progress from other similar, but less altered caves in south-eastern Spain. Preliminary observations from these studies suggest that deterioration of pollen could occur particularly in situations on the sides of the cave. One might speculate therefore that seepage close to the cave walls occurred over a long time period, creating cycles of sediment hydration–dehydration that lead to the complete destruction of all fossil record from the 5D-3D profile. It is, however necessary to explain why pollen numbers increase significantly over such a short lateral distance.

In view of these considerations, the palaeoecological interest of the Beneito pollen record becomes clearer. If, in the context of regional studies, the whole sequence (Fig. 5) reinforces the view that interpleniglacial episodes of expansion of meso-thermophilous vegetation were common, the new pollen record adds support to the view that interstadials were absent during the Upper Pleniglacial. For a long time, the possible existence of last-glacial warm oscillations in Europe has been questioned since they were apparently not reflected in the major pollen records. This is the case especially with interstadials suggested during the Upper Pleniglacial. For the Middle Würm, the situation remains unclear, although the Spanish sequence of Padul (Pons and Reille, 1988) appeared to doubt that any important climatic amelioration occurred after the Pre-Würm warm phases. It has already been mentioned that Cova Beneito showed a meso-thermophilous vegetation development at this time (Carrión, 1992a). In Carihuela Cave (Granada), such a expansion was even stronger but more complex (Carrión, 1992b). In the coastal site of Perneras Cave (Murcia), at the semi-arid southeastern Spain, the thermophilous scrub including north-African elements, appears not to have been disrupted during the Upper Pleistocene (Carrión and Dupré, 1994; Carrión et al., 1995). However, the subject of dispute is not whether Mediterranean vegetation appeared as a consequence of interpleniglacial climatic change, but whether the particular assemblages are synchronous with the Palaeolithic industries described for that age or, alternatively, if they were derived from such processes as percolation, sedimentary disturbance, reworking, etc.

In dealing with the question of mid-last glacial Mediterranean expansions, some recent data support the previously mentioned Mousterian findings in southeastern Spain and, therefore, the view that these developments are of relatively general nature in southwestern Europe. Burjachs and Julià (1994) show a number of abrupt vegetation variations during the last glaciation at the travertine rockshelter of Abric Romaní (Barcelona, northeastern Spain). Following a *Juniperus–Pinus* colonization, a warm-climate event is suggested for the period between 46,200–40,800 yr B.P., characterized by a *Quercus* expansion with Oleaceae, *Rhamnus*, Fabaceae, *Erica*, Cistaceae, and mesic taxa. Even if the unaccuracies of the available dates are considered, this coincides strongly with the results from Beneito. For a later period within the confines of isotope stage 3, a similar conclusion can be drawn from the paper by Pérez-Obiol and Julià (1994) for the lacustrine site of Banyoles (Girona, northeastern Spain). Their suggested interstadial event is now Th–U dated between 30,000 and 27,000 yr B.P., and it is characterized by *Pinus*, *Juniperus*, and constant minor frequencies of *Quercus*, *Acer*, *Corylus*, *Tilia*, etc.

Hitherto, there has been much emphasis on treating these vegetation changes as climatic stages. It is debatable if changes in the dominant vegetation types are representative of major climatic events. More and more interpleniglacial pollen sequences show thermophilous vegetation phases in southwestern Europe, although their chronology is not always contemporaneous. Some of them are now also available from long lacustrine sequences (Pérez-Obiol and Julià, 1994) or some show a palaeoecologically coherent vegetational development, even in an archaeological context (Carrión, 1992a; Burjachs and Julià, 1994). Based on these observations, a hypothesis can be outlined, namely that vegetation has changed as a result of slight climatic ameliorations in stage 3 but that they were locally very variable both in time of response and establishment of the spatial organization of communities. No doubt, conditions as reconstructed from the pollen record, were not fully pleniglacial in Mediterranean-influenced areas between 50,000 and 30,000 yr B.P., but they can also not be compared with those of an interglacial phase. Interpleniglacial climate improvements would create opportunities for discrete, not necessarily coeval, spreading of mesic and thermic taxa in continental situations while they were able to persist for longer in the most favourable stations. There is no reason why mosaic phenomena could not have intervened in the past. Interstades are reported from northernmost sites where vegetation cover is generally more uniform and, therefore, their extrapolation to the biogeographically complex Mediterranean Spain, often become simplistic.

Turner and Hannon (1988) and, more exhaustively, Sánchez-Goñi (1994) criticize the identification of European Upper Palaeolithic interstadials through a detailed analysis of each stratotype. The latter finds enough objections to maintain a sceptical viewpoint towards the Les Cottés, Arcy, Tursac, Laugerie, Lascaux, Angles-sur-l'Anglin and Pre-Bölling interstadials (a synthesis of which can be found in, for instance, the paper by Cattani and Renault-Miskovsky, 1989). As a first step, a new study of the stratotypes involved would be of the utmost importance because most interstadials were defined from only one profile. However, we are not ready to establish statistical and ecological criteria to validate or reject pollen spectra recovered at archaeological sites and we emphasize that further research should be done.

The one regional pollen record from the archaeological site covering Upper Palaeolithic cultures is that of Malladetes cave (Barx, Valencia) (Dupré, 1980, 1988). In comparison with results presented here, the Malladetes sequence shows generally higher pine pollen values and lower numbers for *Artemisia*, Chenopodiaceae, and Poaceae. Likewise, mesothermophilous assemblages are constant although in low frequencies. Hypothetically, present-day climate gradients could have existed in the past and therefore the highest *Pinus* representation at Malladetes would be a result of higher precipitation. Other northernmost sequences such as L'Arbreda (Burjachs, 1987) and Banyoles (Pérez-Obiol and Julià, 1994) show Chenopodiaceae–*Artemisia*–*Ephedra*–Poaceae pollen assemblages typical of pleni-Würm European times. Similar findings are shown in the southernmost site of Padul (Florschütz et al., 1971; Pons and Reille, 1988). Palaeoanthracological data (Badal and Roiron, 1995) suggest that both mesophytes and sclerophyllous scrub were present in Mediterranean Spain during the last cold stage but their presence would have been limited to mountainous refugia and coastally-influenced environments. These studies also report the gradually increasing importance of several pine species (*Pinus nigra*, *P. halepensis*, *P. pinea*).

From a palaeoclimatological perspective, much effort is still needed before we are able to interpret accurately such results as those presented in this paper. One can suggest with a certain degree of confidence that, for example, zone B represents a thermic optimum since the occurrence of typically thermophilous species is concentrated there. Moreover, the overall sequence is within a glacial phase and this zone fits into isotope stage 3. However, some Chenopodiaceae, Poaceae and *Artemisia* species growing in the semi-arid parts of southeastern Spain can be also considered as thermophilous indicators. Without ignoring possible temperature changes, it can still be questioned if the most constraining factor for major vegetational changes in the area during Quaternary was not precipitation or, more precisely, hydric stress, which is strongly related to the persistence of drought conditions.

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