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A palaeoecological study in the western Mediterranean area. The Upper Pleistocene pollen record from Cova Beneito (Alicante, Spain)

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ABSTRACT

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Results are presented of palynological analyses of Pleistocene deposits at Cova Beneito, an archaeological site on the southern slopes of the Sierra de Benicadell, Alicante province (SE Spain), 650 m a.s.l. with a WSW orientation. The chronology is supported by radiocarbon dating, archaeological evolution, previous local sequences, and recourse to several wider correlations. For the first time in the region, a warming event is defined in the mid-last glacial stage. During this event, vegetation took on a Mediterranean character with sclerophyllous elements such as *Quercus*, *Olea*, *Phillyrea*, *Rhamnus*, *Helianthemum*, etc. The rest of the sequence shows a predominance of *Pinus* within the AP, phases of steppe-like character, and an aridity-crisis immediately after the climate improvement. Due to local conditions, forest cover was never very great.

Introduction

Palynological surveys of Quaternary sediments are scarce in the Iberian Peninsula in comparison with nearby countries. In this respect, a critical compilation has been published by Dupré (1988). For periods prior to the Late Glacial, most research has been carried out on archaeological deposits (e.g. Leroi-Gourhan, 1981; Boyer-Klein, 1984; Dupré, 1988), the analyses of peats in the tectonic Padul depression at Andalusia (Florschütz et al., 1971; Pons and Reille, 1988) being a significant exception.

This paper concentrates upon the palynological results from Pleistocene deposits at Cova Beneito (Alicante, SE Spain). The site is interesting archaeologically as it shows a cultural transition from the Middle to Upper Palaeolithic, a rare occurrence in the Iberian Mediterranean region. Palynostratigraphically, interest centres on the possibility of reconstructing considerable part of the "Interpleniglacial" (Van der Hammen et al., 1967), that is little studied in southern Europe. Any interstadial warming in the middle of the last climatic cycle has been questioned for southern Spain (Pons and Reille, 1988). Nevertheless, lithostratigraphical features suggest such a phase at the base of the Beneito sequence. This encouraged us to try to establish which of two conflicting points of view is most in accord with the vegetational development.

Perhaps archaeopalynology is not the best of method for evaluating palaeoenvironments. There are still numerous problems associated with the interpretation of cave sedimentary systems and with pollen diagram disturbance by local over-representation of some groups. However, taking into account the limitations imposed by the nature of a deposit, it can be of some palaeoecological use for areas and periods where direct access to organic sediments is lacking. In addition, it must be remembered that data distortion is hardly con-

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fined to archaeopalynology but affects also many disciplines dependent on thanatocoenoses. In this respect, Tiffney (1985) commented that innaccuracies of the fossil record lead to the accumulation of data and to the avoidance of elaborating excessive synthetic studies and theory.

Geographic location, climate and present vegetation

Cova Beneito consists of a small semi-rectangular cavity measuring 8 × 6 m on the southern slopes of the Sierra de Benicadell, in the municipality of Muro de Alcoy, Alicante province, SE Spain, at N 38° 48' 4" and W 0° 28' 19" (Fig. 1). Its mean height above sea level is 650 m and it has a WSW orientation. To the south lies the valley of the River Agres, separating the Benicadell and Mariola mountains.

The climate is typically Mediterranean with a pronounced summer dry period, two equinoctial pluviometric maxima, and mild winter temperatures. The mountainous nature of the immediate locality contributes to climatic heterogeneity. On the one hand, it has an effect of rendering the climate continental despite the closeness of the Mediterranean sea, and, on the other, it acts as a barrier against easterly winds, producing a rain-shadow effect on the southern slopes. Thus, the meteorological station at Beniatjar (396 m), to the north of Benicadell, has a mean annual rainfall of 745 mm, whereas that at Beniarrés (387 m), to the south, has only 560 mm (Dupré, 1988). The south-facing slopes lie in the bioclimatic thermomediterranean belt (17-18°C mean annual temperature, according to Rivas-Martínez, 1987).

The mature vegetation of the plains and shady hillsides comprises forests of *Quercus rotundifolia*,

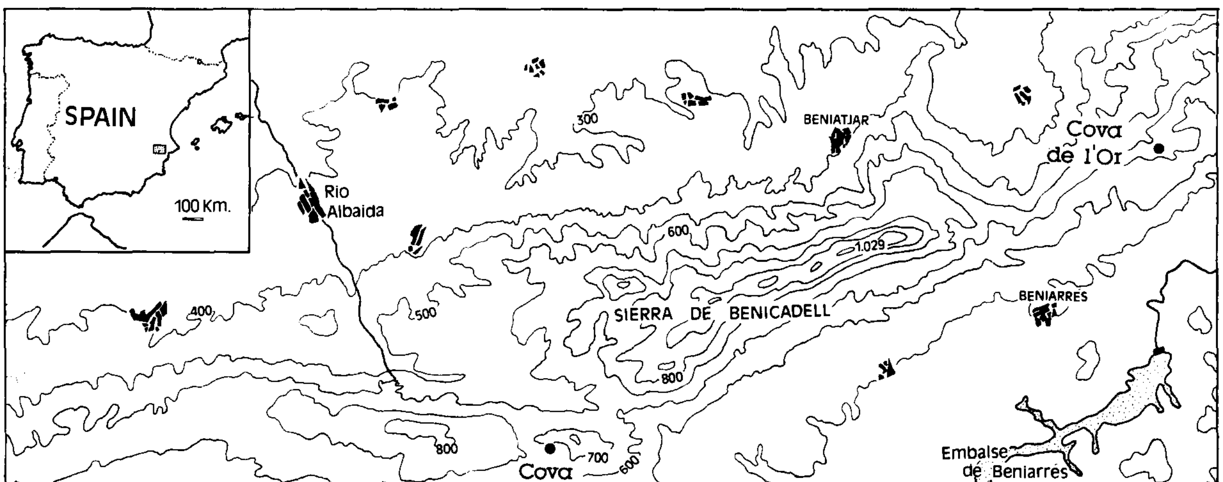

Fig. 1. Location of Cova Beneito (Alicante, Spain).

with *Quercus faginea*, *Fraxinus ornus*, and *Acer granatense* in the more humid biotopes. However, on the southern slopes of Benicadell, the poorly developed soils there are responsible for a high matorral vegetation with *Pistacia lentiscus*, *Chamaerops humilis*, *Quercus coccifera*, *Rhamnus alaternus*, *Rhamnus lycioides*, *Juniperus oxycedrus*, and *Juniperus phoenicea*. In the uppermost forest belts open stands occur, with *Pinus nigra*, *Pinus sylvestris*, and several species of *Juniperus*.

The section

Lithostratigraphy

Archaeological excavation provided a 4 m stratigraphical column, used for sedimentological studies (Fumanal and Carrión, in press). Twelve levels were established whose depth in cm and correlation with pollen samples are shown in Fig. 2. Briefly, three lithostratigraphical units are of note:

(1) The basal unit comprises levels XII and XI. The coarse fraction is chiefly pebble-type, derived from the conglomerate rockwall. The clayey-silt matrix has calcium-carbonate nodules. Chemical alteration is more in evidence than physical weathering. Fallen blocks appear, especially in the uppermost part of the unit. Contact with the overlying unit is sharp but takes place at different depths because of both the blocks and a sedimentary dip from the adjacent cave wall. (2) The following depositional phase is well defined (beds X–V). Texturally, the coarse fraction increases and is angular with surface-alteration. There is a sparse clayey-silt matrix. Some pebbles and carbonate deposits are seen in levels VIIa and VI. In general, frost action predominates in levels X, IX, VIII and V. (3) The third unit, represented by beds IV–I, follows immediately, characterised by a heavy, coarse, clastic fraction and a higher organic content. The overall sedimentological and lithostratigraphical features give a colluvial character to this depositional period.

Archaeology

Correlation between the different industries and the lithostratigraphy and pollen samples can be seen in Fig. 2. According to Iturbe and Cortell (1982, 1987) the archaeology was as follows:

(1) Superficial level: Mediaeval and Bronze Age pottery and sporadic Palaeolithic flints. (2) Upper Palaeolithic: Solutrian, Gravettian and Aurignacian industries. The latter is quite advanced in terms of the proportion of burins to scrapers (rare in the Mediterranean). (3) Mainly sterile, with two occupational levels, containing artefacts of doubtful Aurignacian classification, but otherwise poor in archaeological materials. (4) Middle Palaeolithic: there seems to be local evolution from Charentian Mousterian to final Mousterian, showing an increase in the proportion of Levallois-type flakes.

Dating

Five radiometric dates are available (Fig. 2). Stratigraphical and archaeological references are shown in Table 1. The oldest dates, from two charcoal levels, show differences of 8000 years for the same stratum. Apart from problems inherent to the radiocarbon-dating method (the dates are at the very limits of the ^{14}C time-scale), there may have been difficulty in extracting all the humic acids for the samples corresponding to 26,040 $\pm$ 890 and 30,160 $\pm$ 680 B.P. The dates are likely too young and could have been contaminated by the flux of younger organic matter (G. Delibrias, pers. comm., 1990).

Pollen analysis

Methods

Following the recommendations of Girard (1975) for archaeological deposits, 52 samples were taken for pollen analysis from the section represented in Fig. 2. The uppermost 21 samples, corresponding to the third lithostratigraphical unit and most of the Upper Palaeolithic levels, contained no palynomorphs. Identical lack of pollen was noted in samples 7 and 8. Laboratory treatment was mainly based on the procedures outlined by Girard and Renault-Miskovsky (1969) for minerogenic sediments. Routine counting was undertaken at $\times 400$ magnification, with frequent analysis at

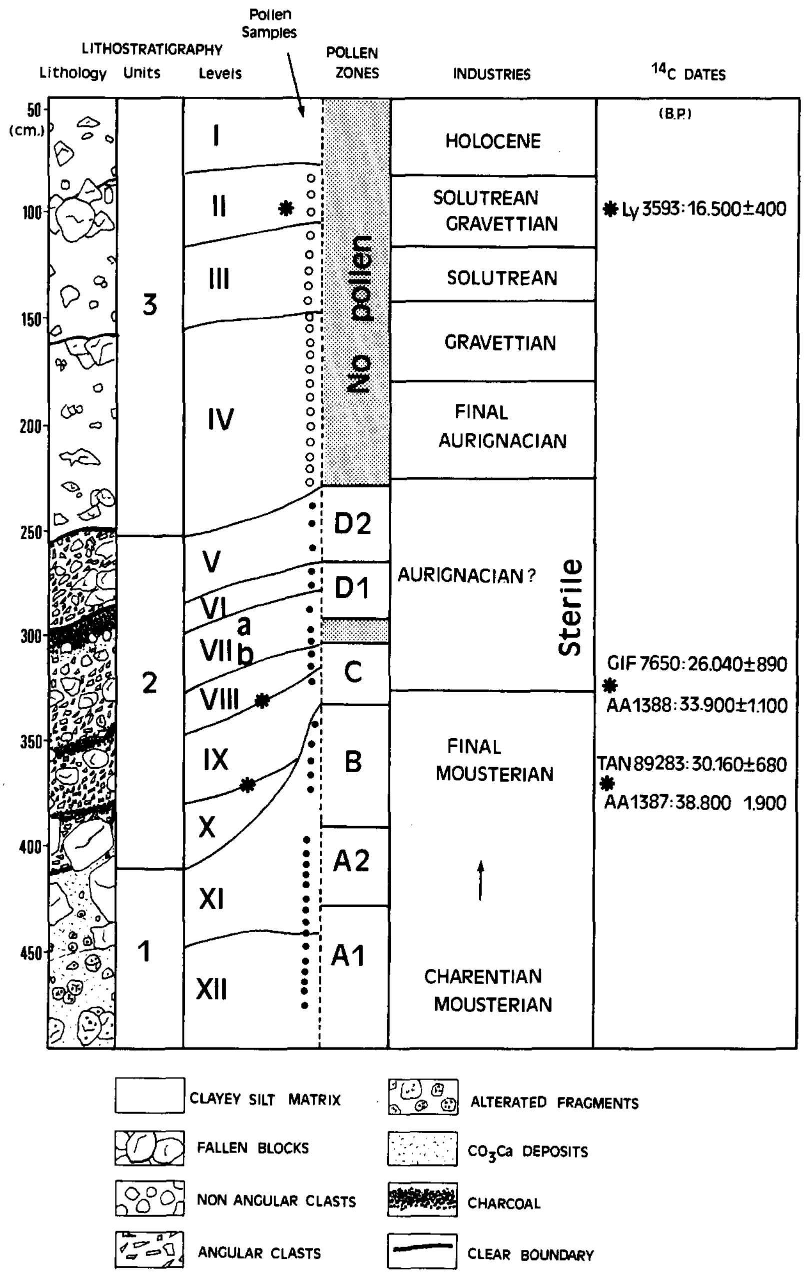

Fig. 2. Lithostratigraphical, palynological, archaeological, and radiochronological relationships at Beneito sequence.

× 1000. A total of 48 pollen types were recognized in a count of 13,806 palynomorphs, excluding unidentified pollen and non-vascular cryptogam spores. Problems of identification were the same as those already described in the surveys of Carihuela Cave (Carrión, 1992).

In the pollen diagram (Beneito 2: Fig. 3), the percentages refer to a sum which excludes pollen of Cichorioideae and Asteroideae types, a curve being established separately for these. The reason for this exclusion is connected with a supposed over-representation of these Asteraceae groups, due to possible differential preservation and to the dispersal of its pollen.

Fig. 3. Beneito 2 pollen diagram. Asteraceae pollen grains (other than *Artemisia* and *Centaurea*) were excluded from the sum. Black dots indicate percentages below 2%.

TABLE 1

Radiocarbon dates and their stratigraphical relationships

Laboratory number	Depth below surface (cm)	Estimated age (yrs B.P.)	Lithostratigraphy	Archaeology
Ly — 3593	101	16,500 ± 400	II	Solutrean Gravettian
GIF — 7650	333	26,040 ± 890	VII–IX	Sterile
AA — 1388	333	33,900 ± 1,100	VII–IX	Sterile
TAN — 89283	376	30,160 ± 680	IX–X	Mousterian
AA — 1387	376	38,800 ± 1,900	IX–X	Mousterian

Pollen zones

Local pollen zones were defined taking into account the general features of the pollen curves, but placing greater emphasis on changes in the frequency of the most common components and of tree and shrub pollen (Fig. 3). Furthermore, the curves of Asteraceae (excluded from the total) can be fitted into this palynostratigraphy. The following pollen assemblage zones are identified:

Zone A

In this zone the percentage of *Quercus ilex-coccifera* varies between 2% and 6%, whereas the curve of *Pinus* attains a value of 30–60%. Total Asteraceae pollen values are high. In the first part (A1), the pollen percentages of *Juniperus* and *Olea* are noticeable (up to 5% and 2%, respectively). On the basis of fluctuations in the curves of *Pinus* and Poaceae A1 is subdivided into A1a, A1b, A1c, and A1d. During the deposition of subzone A2 the proportion of *Pinus* pollen remains more or less constant. Values of Poaceae, *Juniperus* and *Olea* are lower than in the preceding subzone (less than 2%).

Zone B

In the course of pollen sedimentation in this zone, the percentages of *Quercus ilex-coccifera* varied between 19% and 32%, whereas a marked fall in *Pinus* frequencies occurs (to about 22%). Pollen of Cichorioideae and Asteroideae are present in low amounts. *Juniperus* is constantly present, but its values are less than 2%. Amounts of *Olea* (2–3%), *Phillyrea* (2–5%), *Rhamnus* (1–3%), *Helianthemum* (2–3%), *Cistus* (1–2%), and *Ononis* type (2–6%) are higher than in the preceding zone.

Zone C

The zone is characterized by a marked decline in the proportion of tree and shrub pollen. The percentages of *Quercus ilex-coccifera* fall to 2% and *Pinus* is again the most important component of the AP, but its values are low (15–30%). There is a significant increase in Asteraceae pollen. Chenopodiaceae and Poaceae pollen are relatively prominent, attaining, respectively, values of 36% and 28%, and there is a slight increase in the frequencies of *Juniperus* and Ericaceae.

Zone D

The zone is characterized by abundant *Pinus* and herb pollen with Poaceae and Chenopodiaceae as the main components of the NAP. Asteraceae pollen maintain relatively high values. In D1, *Pinus* pollen values attain 50–60% whereas Poaceae increase (8–14%) and Chenopodiaceae pollen frequencies decrease (19–6%). In D2, an overall decline in *Pinus* values is appreciable, attaining proportions of 35% or less. On the basis of fluctuations in the curves of *Pinus* and Poaceae D2 is subdivided into D2a, D2b, and D2c. A rise in Poaceae values is concomitant with a fall in the Chenopodiaceae curve and vice versa.

Vegetational and environmental developments

Using the pollen zonation proposed (Fig. 3), the vegetational history on the southern slopes of the Sierra de Benicadell and adjacent areas can be reconstructed. Certain environmental inferences can also be made.

During the period represented by zone A, an open vegetation develops, consisting of stands of *Pinus* (probably *P. nigra* and/or *P. sylvestris*) with a low stratum chiefly represented by Poaceae and Chenopodiaceae. In ravines and more sheltered areas of the Agres valley there may have been a fringe of evergreen *Quercus*, *Olea europaea*, and *Phillyrea* with *Quercus faginea*, *Myrtus*, and Ericaceae on the most humid and developed soils. Of note is the abundance of *Juniperus* in A1, despite its customary under-representation in modern pollen rain (Pérez-Obiol, 1987). In A1b–A1d, there is an expansion of *Olea europaea*, a genuinely thermophilous species. A *Quercus*/*Juniperus*/*Olea* association, that is not necessarily a phytosociological one, can only be explained by a climatic warmth related to a well-defined summer dry period. This is not incompatible with a relatively high annual rainfall but is characteristic of a markedly seasonal pattern.

The period covered by pollen zone B is characterized by an extension of Mediterranean floristic elements. Partial replacement of *Pinus* by *Quercus* is accompanied by the appearance of a sclerophyllous shrub layer with *Phillyrea*, *Olea europaea*, *Rhamnus*, *Myrtus*, and *Lonicera*, and tracts of matorral with *Cistus*, *Helianthemum*, *Ononis*, Lamiaceae, etc. This open plant-formation shows high heliophyte richness and may be determined by slope-geomorphology. It is clear that the abundance of thin soils was a restrictive factor in the development of a dense type of forest. The determining factor for vegetational change in zone B must be an increase in temperature. The importance of rainfall seems more doubtful. Mediterranean plant communities imply intensification of summer drought, but the greater relative frequency of *Quercus faginea*, *Fraxinus ornus*, *Myrtus*, and *Corylus*, and low values for *Juniperus* and Chenopodiaceae suggest that overall annual rainfall may have been greater.

During the following phase (zone C) there is reason to suspect xeric conditions, previously undetected. A steppic vegetation developed with abundant Chenopodiaceae and Poaceae and scattered *Pinus* and *Juniperus*. There is a likely hiatus with respect to the preceding phase. There is a reduction in the distribution of thermophilous taxa and a slight rise in *Artemisia*. It is therefore reasonable to assume a climatic crisis in which the increase of Chenopodiaceae in particular might indicate regional aridity.

In the upper part of the sequence (zone D), there is a slight re-establishment of the pine forest, but mesophilous and thermophilous shrubs and trees must have been particularly isolated. Some sclerophyllous *Quercus* may have survived in some relatively nearby refuges. Simultaneous disappearance of *Olea*, *Phillyrea* and *Corylus* suggests a harsher climate marked by a fall in temperature or by the persistence of the cold conditions of the preceding period. Whatever the case, a biostratigraphical hiatus is noted between pollen zones C and D. Concomitant increases of *Pinus* and Poaceae seem to be a strictly local phenomenon.

Discussion

Palaeoecological remarks

With regard to the vegetational development described above, some general observations can be made.

(1) Data presented here display some problems when attempting to relate pollen to past vegetation. Taphonomy of the pollen assemblages is hard to define since there are no experimental studies evaluating the bias that phenomena such as human activities or animal transport may have introduced to the pollen record. For instance, little is known about the AP/NAP percentage limit from which either closed forest or an open canopy can be claimed to have become established in the area. Certainly, a number of plausible circumstances may be invoked to explain the changes of the *Pinus* and Poaceae curves in the Beneito diagram (Fig. 3). Both taxa are heavy pollen producers, thus their growing nearby might easily result in over-representation. A further possibility is that their peaks in the diagram could be an artefact of the proportional method of calculation, thus resulting in a distortion of the pattern of vegetational development. Even bearing the above considerations in mind, they must remain rather speculative, provided that in the absence of contrary evidence a more suitable and simpler explana-

tion may be put forward: changes in the pollen record reflect approximately the main changes in the local vegetation. It should be pointed out that once the Asteraceae pollen have been excluded from the sum, modern equivalents for subsequent, hypothetical vegetation can be proposed. Thus, the Pino-Juniperetea communities (Rivas-Martinez, 1964) may be the closest equivalent in the present vegetation to the *Pinus–Juniperus*/Poaceae assemblages at Beneito, whereas the higher pollen abundances of Mediterranean evergreen elements may be related to the present-day Quercetea ilicis (Braun-Blanquet, 1947).

(2) A subject of dispute arises associated with the possibility of pollen spectra not being contemporaneous with the sediments from which they were achieved. This has been stressed by Turner and Hannon (1988), who suggested that, in most cave and rockshelter records, a mixture of pollen grains of different ages constitutes the major source of pollen assemblages. Such a fact would lead to erroneous interpretation of the pattern of vegetational development, but one must consider what is pertinent to the present paper. Can the pollen stratigraphy of Beneito can be taken as indicative of the establishment (zone A), spreading (zone B), and regression (zones C and D) of Mediterranean evergreen communities during the Middle Würm of the area, or conversely, can warm pollen have reached their present-day strata by percolation down through overlying, coarse sediments.

There is no categorical refutation of the second possibility, and some chronological overlap of pollen spectra must be assumed to have happened. However, in my opinion, neither the overall geometrical and lithological features of the profile, nor the behaviour of the thermophilous taxa in the diagram support such a hypothesis. First, pollen percolation would have had to take place over up to 2 m, a fact which is inconceivable because of the massive structure and fine texture of the sedimentary matrix between the clasts. Second, the pollen grains in question would have to be recent because no overlying bed containing them exists today. This is unlikely since neither acetolysis was employed in the laboratory nor differential susceptibility to stain was observed under the microscope. Moreover, preservation of the palynomorphs within each sample was virtually identical. Thirdly, sedimentological analysis (Fumanal and Carrión, in press) does not reveal substantial differences in the matrix and organic content of the two lithological units in consideration. The supposed displacement and subsequent settling of pollen grains such as *Quercus* and *Olea* would be hard to explain. Finally, the danger of contamination by recent pollen has been minimized by choosing those parts of the profile where erosional channels or crevices were imperceptible. In addition, no signs of bioturbation (insect holes, rodent burrows, dung layers, etc) were noticed. Perhaps other researchers studying the Beneito diagram will take dissenting views. It is a matter of subjective judgement, of course, whether these arguments add sufficient weight to justify the assumptions underlying this paper.

(3) Insufficient precision of taxonomic identification hinders palaeoecological characterization of *Juniperus*. In the Iberian Peninsula, some species grow into large trees (*J. thurifera*), whereas others remain only dwarf-sized or normal-sized shrubs (*J. oxycedrus*, *J. phoenicea*) or creeping phanerophytes (*J. sabina*, *J. communis* ssp. *nana*). The percentages found indicate that the species was plentiful near the cave. Charcoal-analysis (Bazile-Robert et al., 1980) suggests that *Juniperus* was relatively abundant in Spain after the conventional Würm II stage. Likewise, we have not been able to differentiate palynologically between *Pinus nigra* and *P. sylvestris* and so a phytogeographical question of great interest in the study area remains unanswered, precisely because in mountains of the Iberic System there is contact between *P. sylvestris* and the southern morphotype *P. nigra* ssp. *clusiana*. Some results of regional charcoal-analysis have shown the dominance of *P. nigra* during this period (Badal, 1984), which, together with the relatively Mediterranean character of the area, suggests it was the most abundant species. In zone B, *P. halepensis* appears to have been present, a species much better adapted to summer drought. In palynological studies at Carihuela Cave (Carrión, 1992) the association of *P. halepensis* with the development of sclerophyllous formations is clear.

(4) Palaeoecology of herbaceous vegetation is open to different interpretations, especially for Poaceae, where identification of the pollen below family level is impossible at this stage, and where

a great number of taxa may be involved with diverse ecological tolerances. Besides, it is possible that some variations in the Poaceae may be unrelated to the locally predominant past vegetation. With regard to Asteraceae, it is suggested that differential degradation of pollen cannot be considered the only reason for the high Asteroideae and Cichorioideae pollen percentages recovered from Beneito. No quantitative assessment of deterioration was made, but the general state of preservation was no worse in those spectra where Asteraceae pollen occurred in abundance.

(5) Given differences of exposure to the sun and the contrast that exists today between the north- and the south-faces of the Benicadell mountain, it is reasonable to assume that the northern slopes, during the period under study, had a greater degree of tree-cover. This hypothesis is supported by Weinstein-Evron (1981) in Israel, who pointed to the importance of aspect on surface-pollen spectra. Furthermore, palaeontological studies (Martí et al., 1980) and charcoal analysis (Vernet et al., 1987) suggest the existence of extensive woodland in the area.

(6) During the Upper Pleistocene, climatic fluctuations influenced changes in the predominance of some floristic elements; during the Holocene, sclerophyllous vegetation stabilized, so that human impact must have occurred early. This has been deduced from the studies of Dupré (1988) on postglacial deposits at Cova de l'Or, situated further west on the southern face of the same mountain (see Fig. 1).

(7) Greater convergence between sedimentological and palynological data exists in the characterization of the climatic optimum of the sequence, namely in a period before deposition of the second lithostratigraphic unit (levels X–V), i.e. in pollen zone B. There is also some concordance in the palaeoclimatic interpretation of sedimentary beds X–V: the processes responsible for this part of the section seem to have been resulted from a cold, dry climate, with a probable slight intensification of interstitial hydric circulation in levels VIIa and VI (pollen zone D1). The lowermost part (levels XII and XI, pollen zone A) is hard to evaluate; it may have been deposited under quite mild climatic conditions. This hypothesis is in fact supported by both lithological features and the appearance of *Quercus*, *Olea*, *Phillyrea*, and *Myrtus* in the pollen spectra. Moreover, the latter evidence strengthens the suggestion that Mediterranean communities were widespread in the region at this time. A more complex question is to estimate the palaeotemperatures involved. Perhaps vegetation responded enormously to little temperature increases. Bioclimatic characteristics of the equivalent present-day communities can not be extrapolated here backwards in time to this situation.

Chronological interpretation

Several difficulties are encountered when trying to draw up a chronostratigraphical outline for the Beneito sequence.

First, any similarity between Pleniglacial episodes in the northern and southern hemispheres with dry periods in subtropical zones, remains to be demonstrated; it only seems to be valid during periods of major climatic deterioration (Talbot, 1984). In this attempt, the metachronous character of vegetational and climatic variations is considerably accentuated. Moreover, a profound revision of the stratotypes involved is necessary within the major European geochronological systems. Second, no firm chronology is available for the main cultural events at Cova Beneito. Dating of hearths between levels X, IX and VIII (Table 1) must be treated with caution. To the evident imprecision of the first (AA-1387: 38,800 ± 1900 B.P. and AA-1388: 33,900 ± 1100 B.P.) must be added the younger dates of the last (TAN-89283: 30,160 ± 680 B.P. and GIF-7650: 26,040 ± 890 B.P.). Besides, it is difficult to evaluate the time-span involved in the erosional episodes between XI–X, VI–V, and V–IV. Therefore, it seems that new data must be awaited in order to complete a detailed chronoclimatic characterization of the later Mousterian and earlier Aurignacian. Third, possibilities of correlation are also reduced because southeastern Spain is not well served by detailed palynological information for the Upper Pleistocene. Comparison of the results of the Padul peat-bog (Florschütz et al., 1971; Pons and Reille, 1988) and Cova Beneito is complicated, as both records display very distinct pollen assemblages as regards their taphonomy. Furthermore, few archaeopalynological sequences from the Mediterranean region have been defined over sufficently long cycles, and most present ones have imprecise chronology. For these reasons, and pending new dates and new regional studies, the following correlations can only be tentative.

The lower part of the sequence at Beneito (pollen zones A and B) can be included in isotopic marine stage 3 (Shackleton, 1977). The dates (Table 1), the evolution of archaeological types (Fig. 2), and the sedimentary-palynological context itself, clearly support this hypothesis. When searching for palaeoclimatical counterparts for this part of the diagram, the question arises again whether the inferred vegetation can be taken as indicative of a climate improvement within the Middle Würm. Whilst there is little doubt that an oscillation towards warmer conditions could possibly allow an increase of Mediterranean evergreen elements, an inverse reasoning cannot be positively adopted. Such a vegetational pattern may not have been controlled entirely by prevailing climatic conditions, but perhaps have been in part conditioned by migrational, topographic or edaphic factors. It is, certainly, a point of controversy.

Pons and Reille (1988) point out that climatic fluctuations in the middle part of the last glacial are poorly characterized in Europe. Their investigations at Padul indicate the existence of an "interphase" (sensu Welten, 1982), with climatic gradations from one region to another. This could explain why there are oscillations in *Pinus* at Padul (Florschütz et al., 1971; Pons and Reille, 1988), and Tenaghi Philippon (Wijmstra, 1969) during an equivalent period to phase B of Beneito, but under harsher climatic conditions. Several events of $\delta^{18}O$ depletions and oak pollen peaks have been revealed by analysis of Tyrrhenian marine cores from southern Italy (Rossignol-Strick and Planchais, 1989), suggesting that on the one hand, pulses of moisture and temperature occurred during isotope stage 3, and on the other hand, that such pulses may have increased in the uplands, where rapid vegetational changes were evidenced. One can also find additional evidence to support an important interpleniglacial warming. Palynological investigations performed by Carrión (1992) at Carihuela Cave (Granada, SE Spain) suggest the existence of such a phase, somewhat resembling the Würmian interstadial from SW France (Laville et al., 1985). Tyrrhenian beds dated between 32,000 and 39,000 B.P. from the Mediterranean coast have been defined by Goy and Zazo (1986). Other geomorphological, sedimentological and biological evidences for an interWürmian climate improvement in the Iberian Peninsula have been reviewed elsewhere (Carrión, 1991).

Once the interpleniglacial thermal maximum had been passed, most European pollen sequences show evidence of steppe-like landscapes, as occurs in zones C and D at Beneito. Correlation of this phase with deep-sea isotope stage 2 presents problems because the upper limit of stage 3 outside the oceanic domain is still unclear (Berger, 1978). The most widely accepted chronologies for the Mediterranean put this limit at around 25,000 (Cheddadi, 1988) or 27,000 yr B.P. (Rossignol-Strick, 1985), so that at least pollen zone D could be included in this phase. Also, because of the clear climatic regression of zone C, and the hiatus separating zones B and C, it is reasonable to think that pollen zone C may represent in the study area what in Southern Europe was a long, cold, dry period, characterized in the oceanic domain by a marked increase in the $^{18}O/^{16}O$ ratio. It is likely that this is one of the three aridity crises in the Middle Würm at Padul (Pons and Reille, 1988) or Dar Fatma (Ben Tiba and Reille, 1982). For reasons already mentioned at the beginning of this section, reliable correlation of this period with one of the chronozones of the European Middle Würm and Upper Würm is still beyond our grasp.

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