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Late Quaternary vegetational history at Navarrés, Eastern Spain. A two core approach

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SUMMARY

Percentage and concentration pollen diagrams are presented for two cores (taken 5 m apart) at an upper Pleistocene and Holocene site at Navarrés (Valencia, eastern Spain). Chronological information is provided by an internally consistent radiocarbon dating series that extends from *c.* 20700 to 3075 yr BP. The results highlight the dangers of relying on a single core in interpreting the patterns of variation of particular taxa. Significant palynological differences, seemingly locational, are described between the two cores. The upper Pleistocene records accords well with the widely recognized European sequence of (*a*) upper Pleniglacial, (*b*) Bölling-Allerod warm period, and (*c*) Younger Dryas crisis. However, the sequence does not show disruption of vegetation patterns following the commencement of the Holocene, and *Pinus* continues to be dominant up to *c.* 5500–6000 yr BP. Later, there is evidence for *Quercus* forest, mesophilous trees, and xerosclerophyllous Mediterranean vegetation, which is coincident with eutrophication of the study site. These vegetation changes are discussed in the context of anthropogenic disturbance by Neolithic people, competitive exclusion, and climatic change.

Key words: Late Quaternary, palynology, palaeoecology, eastern Spain.

INTRODUCTION

Eastern Spain is not well served by detailed palynological and related dating information. A review of the pioneering work of J. Menéndez-Amor and M. Dupré is presented in Dupré (1988). Regarding the Canal de Navarrés area (Fig. 1), several preliminary reports of palaeoenvironmental data have been published. Menéndez-Amor & Florschütz (1961) presented palynological results for 12 samples from a 170-cm-thick peaty layer (Fig. 2). The uppermost 60 cm, characterized palynologically by *Quercus*, were dated between 6130 ± 300 BP and 3930 ± 250 BP. The pollen diagram shows alternate dominance of *Pinus* and *Quercus* in the arboreal pollen component. Herbs are not represented in the diagram, apart from Cyperaceae and Poaceae. Dupré, Fumanal & La Roca (1985) presented an interdisciplinary study of the late Quaternary evolution of the Canal de Navarrés. The palynological investigation was carried out on a sedimentary column in the open archaeological setting known as Ereta del Pedregal (Fig. 3). The pollen diagram shows dominance of *Quercus* in a basal peaty, archaeologically sterile layer. Subsequently, coincident with increased minerogenic sediments and Late Neolithic occupation (*c.* 4700–4000 BP, according to Pla-Ballester, Martí & Bernabeu, 1983), arboreal cover begins to decrease and pollen spectra are characterized by hygrophytes, composites, heliophytic herbs and Mediterranean shrubs. This was interpreted by the authors as the result of clearance association with increasing human pressure.

Two major objectives form the focus of the palynological research presented here. The first is to study the vegetational history during the late-glacial and Holocene in eastern Spain. We aimed to establish: whether the late-glacial *Quercus* colonization recorded at Padul (Pons & Reille, 1988) is detectable further north; whether it is possible to determine when and how the present-day landscape evolved; and whether there is palaeoecological evidence that the climax vegetation of the area is a *Quercus rotundifolia* forest. In this respect, it must be noted that communities of Mediterranean pines, which are widespread in the Valencia region, are not

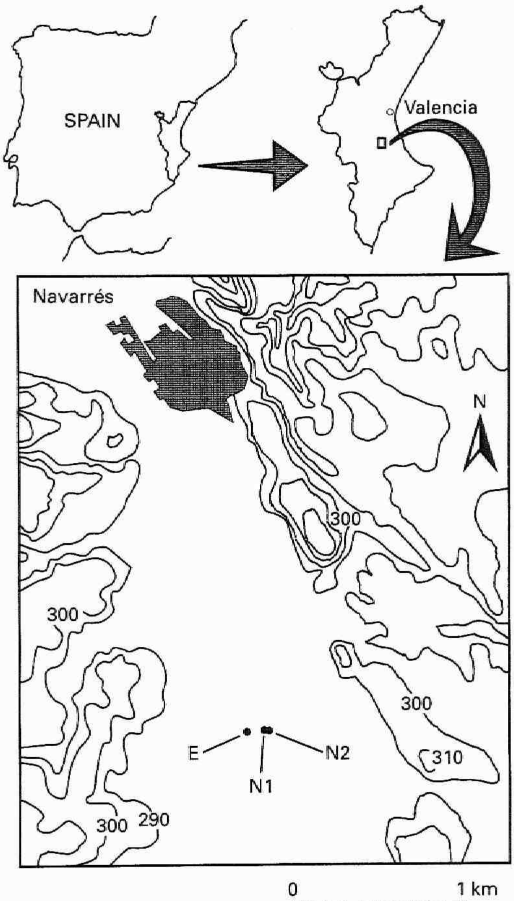

Figure 1. The site of Navarrés and coring locations. N1, N2: this study. E: Dupré, Fumanal & La Roca (1985).

considered by most phytosociologists to be climax vegetation anywhere, as they occur on unstable substrates or are derived from more or less ancient planting of trees (Costa, 1987). Our second aim is to elucidate primary factors involved in vegetational change. We were particularly interested in the ecological significance of pine and sclerophyllous oak forests and the extent to which anthropogenic disturbance can be considered responsible for forest clearances and/or changes in the forest dominants.

DESCRIPTION OF THE SITE

The Canal de Navarrés is a tectonic valley 1–2 km wide lying in the contact zone between the Baetic and Iberian geological systems in southwestern Valencia province, eastern Spain (Fig. 1). It is 225 m above sea level, and confined by the Caroig, Sumacárcer, Montot, and Malet mountains, and contains the Escalona and Riajuelo rivercourses. Although longitudinally divided by the Bolbaite river, the valley has been poorly drained even from its formation in the Upper Tertiary, leading to the development of multiple endorrheic areas. This paper reports the results of the pollen analyses carried out on one of these areas, nowadays vestigial and containing lacustrine sediments overlaid by a bed of clayey peat.

The area studied lies in the lower meso-mediterranean belt and has a dry to sub-humid rainfall régime (Dupré, 1988). Mean annual temperatures are around 15–16 °C and mean annual rainfall is higher than 550 mm, although in the nearby mountains it does not reach 500 mm, and can

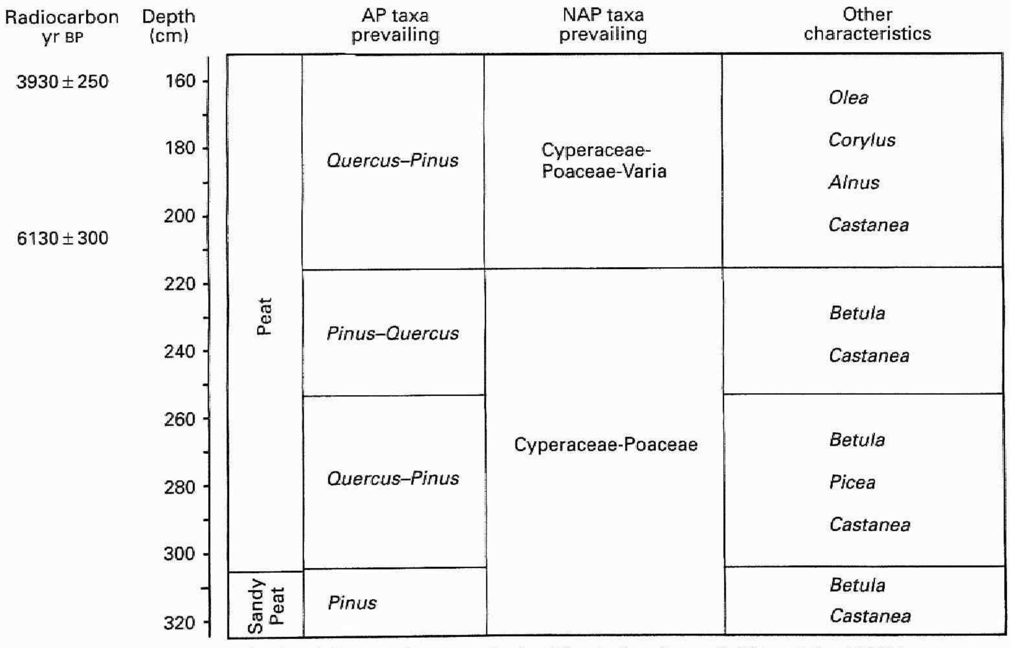

Figure 2. Synthesis of the previous results by Menéndez-Amor & Florschütz (1961).

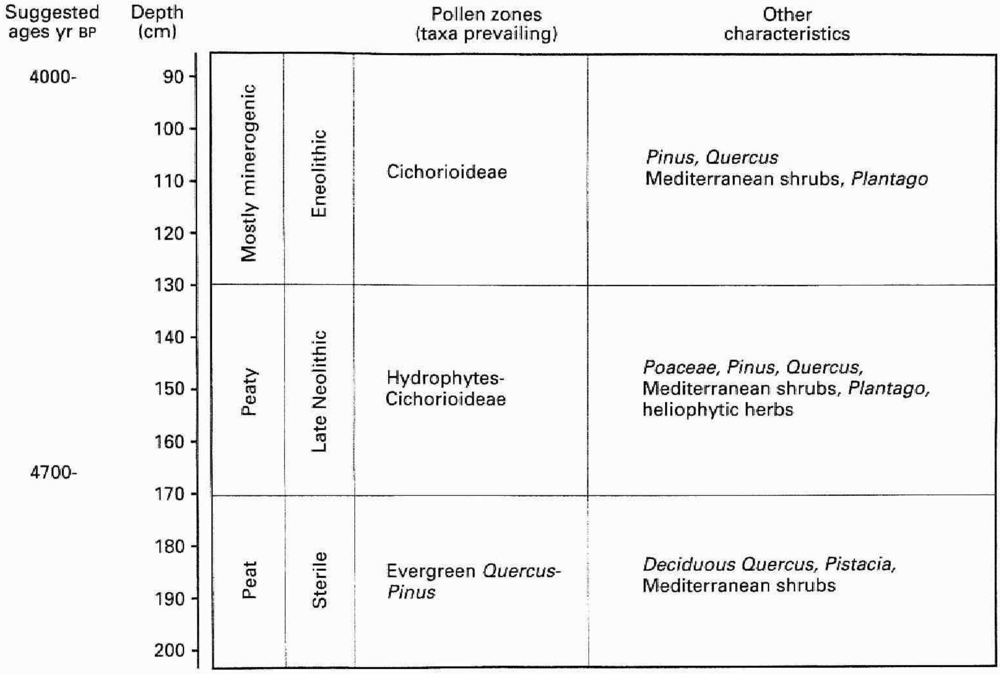

Figure 3. Synthesis of the previous results by Dupré, Fumanal & La Roca (1985).

even be below 300 mm. The valley has been, and continues to be, intensely exploited for grazing and the production of fruit trees, tobacco, vegetables, willow, alfalfa, etc. The valley edges support a garrigue vegetation of *Quercus coccifera*, *Pistacia lentiscus*, *Chamaerops humilis*, *Rhamnus alaternus*, *Juniperus oxycedrus*, with scattered stands of *Pinus halepensis*.

Unfortunately no studies of the pollen rain of the area have been made but, taking into account the location of the basin and its altitude and diameter, and the dispersal mechanisms of individual species (Markgraf, 1980) the expected pollen source area should include not only the 1–2 km-wide valley, mostly dominated by cultivars and garrigue, but also the surrounding 10–15 km of low mountains including present-day patches of *Quercus rotundifolia* forests, and the vegetation of the high altitude Iberian and Baetic ranges.

MATERIALS AND METHODS

Two cores were taken by means of a hydraulic drill rig mounted on a four-wheel trailer. Samples were extruded on site, measured, wrapped in plastic film, labelled, and stored before examination. The 'core changes' indicated in Figures 4, 5, 7, 8, 10 and 11, represent discontinuities resulting from the customary breakage of the core during its extraction. The 25 m core taken at the first site was sampled at intervals of 10 cm, but only the uppermost 150 cm provided pollen, corresponding to an accumulation of peat. Surprisingly, radiocarbon dating showed that such a thin deposit had formed over not less than 12000 yr. In order to obtain higher resolution in the pollen record, we sampled, at 5 cm intervals, taking the uppermost peaty layer of a second core very close (*c*. 5 m) to the first.

The preparation followed the standard HCl, HF, KOH (NaOH) method, with pollen concentration in Thoulet solution (Girard & Renault-Miskovsky, 1969). *Lycopodium clavatum* spores were introduced (*c*. 12100 spores per tablet) to calculate pollen concentration. Pollen percentages are based on the total pollen sum excluding Cyperaceae, *Typha* monads, *Apium* and spores of non-vascular cryptogams. They are presented as percentages of total pollen and spores. Relative (Figs 4, 5) and concentration pollen diagrams (Figs 7, 8) were constructed for the two cores. Relative pollen diagrams show pollen curves for the principal taxa defined as those with a minimum value of 2% total sum for any single level. Minor taxa are shown as pots. Local pollen assemblage zones have been adopted throughout and are based on the observed pollen stratigraphy, placing special emphasis on important changes in frequencies of arboreal and shrub taxa. Percentages within each zone for the most important taxa are shown in Figure 6.

Six samples were submitted for radiocarbon assay. They were dated by G. Possnert and M. Söderman at the Svedberg-Laboratoriet of Uppsala University, Sweden (five samples, core 1) and by M. A. Tamers at Beta Analytic Inc., Miami (1 sample, core 2).

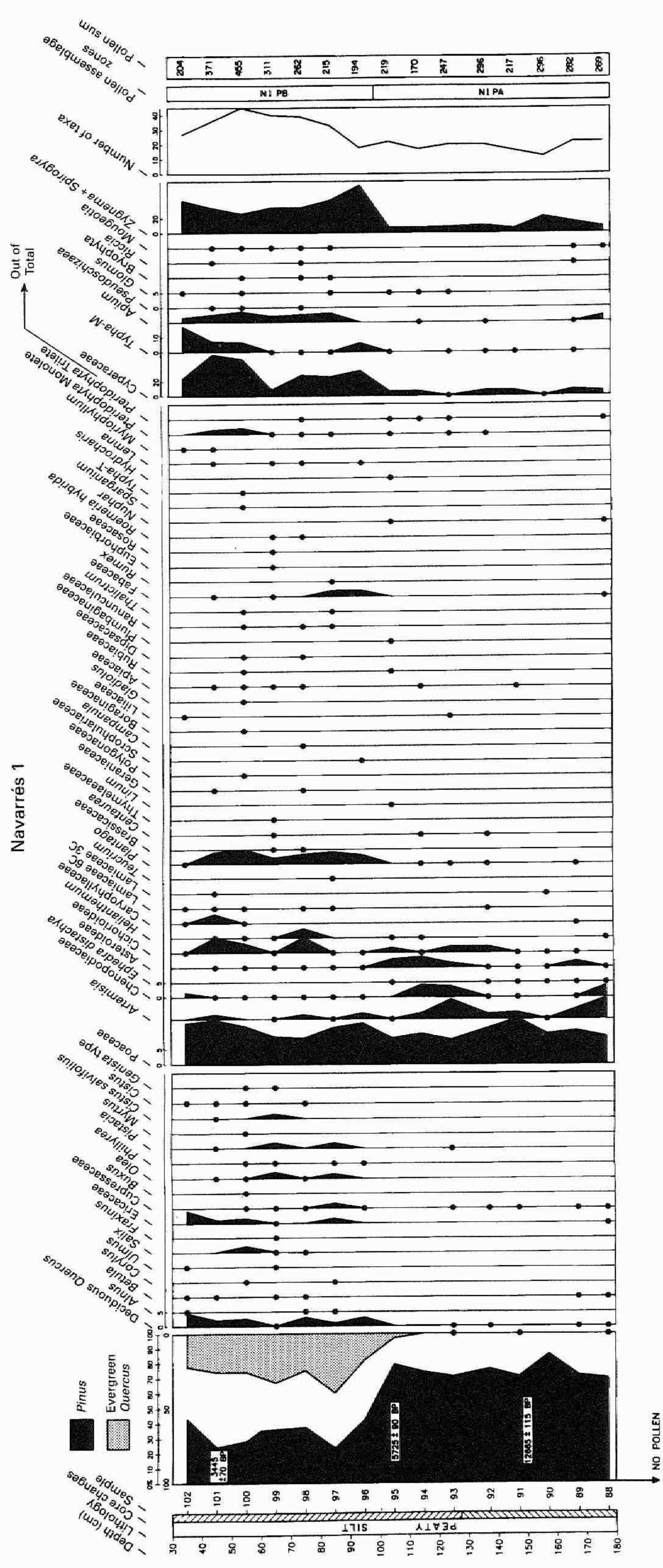

Figure 4. Percentage pollen diagram of Navarrés core 1.

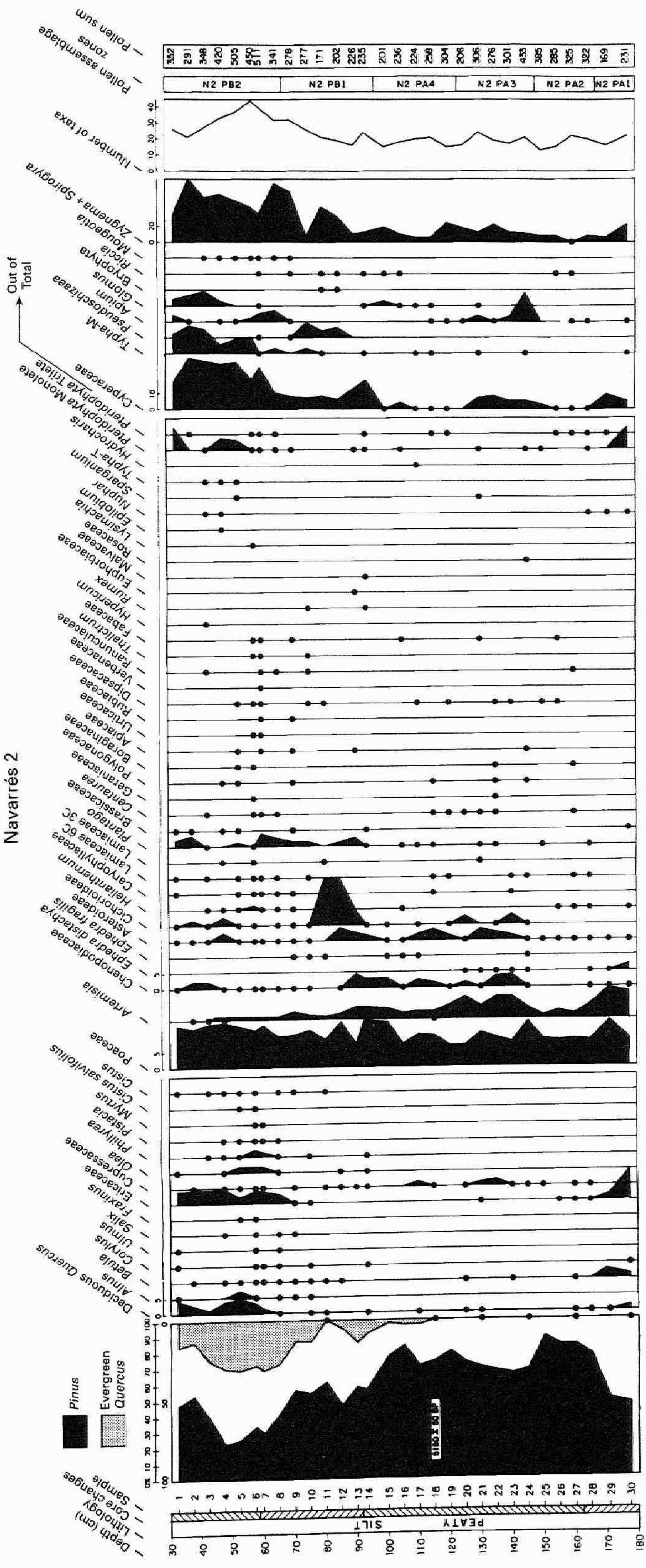

Figure 5. Percentage pollen diagram of Navarrés core 2.

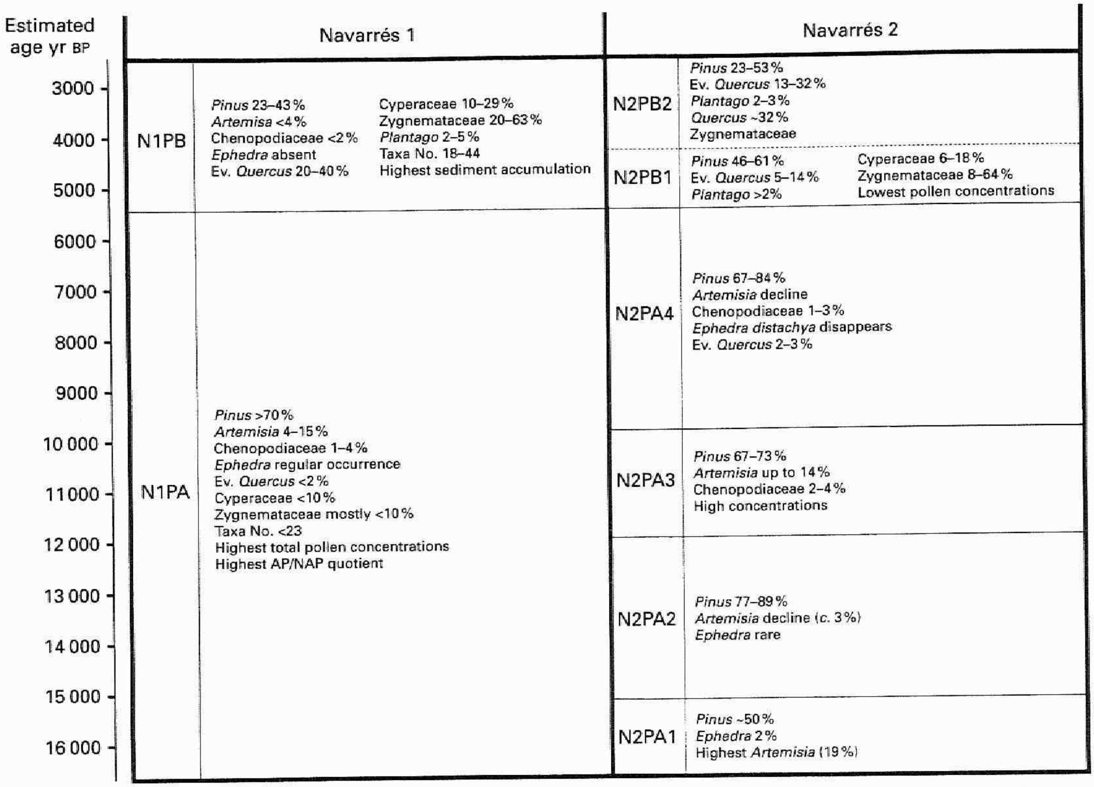

Figure 6. Major trends and correlation of the pollen percentage zones for Navarrés 1 and Navarrés 2.

Table 1 shows the results. The measurements provide an internally consistent chronostratigraphic series that extends from *c.* 20700 to 3075 yr BP, except for the date β-7945 : 5150 ± 50 BP from core 2, which we considered to be the result of contamination with younger material. The time-depth curve for core 1 is presented in Figure 9.

Following Magri (1994), we examined the variation of percentages and concentrations of AP, NAP, and the AP/NAP quotient, in order to estimate temporal changes of the tree density in the landscape and to assess the relationship between the pollen percentages and local sedimentary processes (Figs 10, 11). Likewise, in order to visualize the comparative variation in pollen percentage curves of some selected taxa, a two-core comparison was made (Figs 12, 13). This comparison assumes equivalence of respective time intervals and sedimentary rates, which is supported partly by chronological control and identical thickness in the peaty, polliniferous layer.

RESULTS AND DISCUSSION

Two-core comparison

Similar palynological patterns can be identified in both sequences (Figs 4–6). N1PB and N2PB reflect increased frequencies of *Quercus*, Mediterranean and mesothermophilous taxa, *Plantago*, heliophytic, hygrophytic herbs, and Zygnemataceae. Pollen spectra of N1PA and N2PA are dominated by *Pinus*, with important percentages of *Poaceae* and, eventually, *Artemisia* and *Chenopodiaceae*. *Ephedra distachya* type regularly occurs in N1PA and N2PA, but is absent from N1PB and N2PB. Likewise, the highest sedimentary input is recorded in N1PB, although the sediment accumulation rate continues to be very low (Fig. 9). Navarrés 1 lacks the resolution evident in Navarrés 2 subzones, but some of these can be also seen in Navarrés 1 as slight tendencies. For example, the patterns of variation in the curves of *Pinus*, *Artemisia*, and *Ephedra* for the N2PA1-N2PA4 interval can be seen within N1PA.

In terms of presence/absence of the major pollen taxa, the two profiles agree. Of the pollen and spore taxa in each profile, 58 are common to both. On the other hand, 12 taxa present in core 1 are absent from core 2: *Genista* type, *Teucrium*, Thymelaeaceae, *Linum*, Scrophulariaceae, *Campanula*, Lilaceae, *Gladiolus*, Plumbaginaceae, *Roemeria hybrida* type, *Lemna*, and *Myriophyllum*. Seven pollen taxa present in core 2 are absent from core 1: *Ephedra fragilis*, Urticaceae, Verbenaceae, *Hypericum*, Malvaceae, *Lysimachia*, and *Epilobium*. All these taxa are incidental herbs, and constitute only small amounts of the total pollen sum, generally not more than 1 % and, in all cases below 2 %.

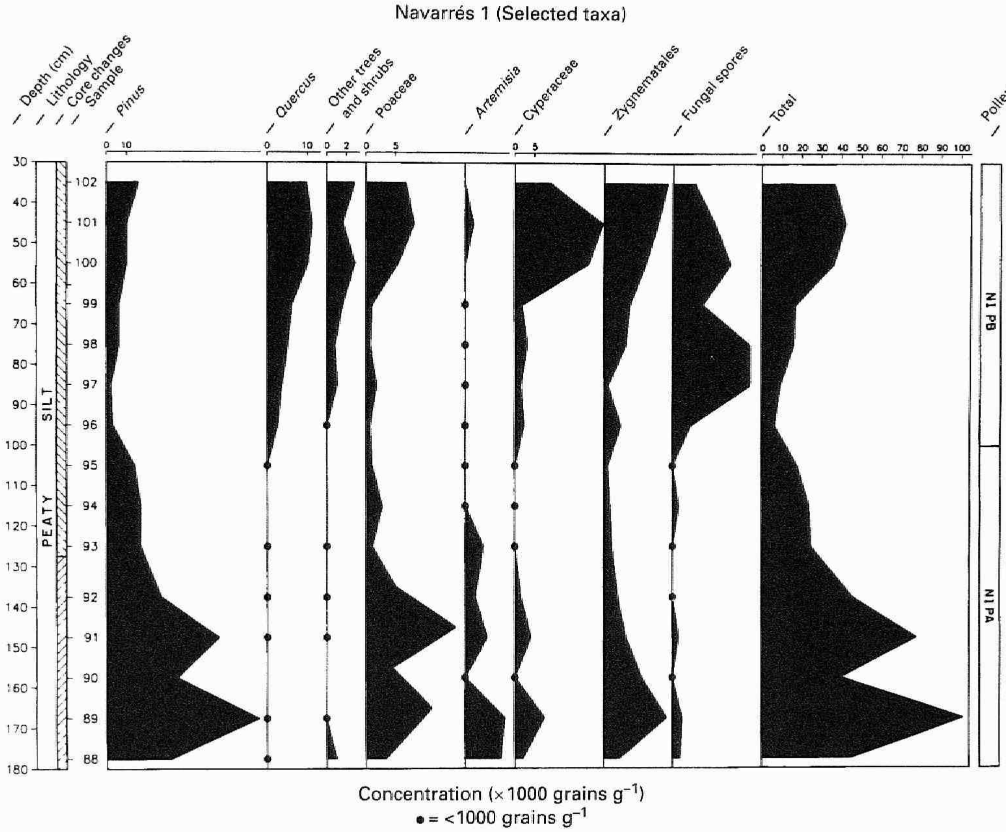

Figure 7. Concentration pollen diagram of selected taxa of Navarrés core 1.

Despite the parallelism, the results of this two-core study highlight the danger of relying on a single core if the primary goal is high resolution of patterns of variation in particular taxa. Thus, even though the cores are from sites only a short distance apart, they show significant palynological differences, sources of variation which could well be locational. The following are particularly noteworthy (Figs 4, 5, 12, 13).

(1) A difference of *c.* 1000 yr between Navarrés 1 and Navarrés 2 in the times of the beginning of the curve of evergreen *Quercus*, although, as mentioned earlier, the date of 5150±50 yr BP might be too recent. Between 70–50 cm the evergreen *Quercus* percentage increases in core 2, whereas it decreases in core 1.

(2) An earlier beginning of the curve of deciduous *Quercus*, Ericaceae and *Olea* in Navarrés 1. Thus, peaks in the curves of Mediterranean shrubs do not coincide.

(3) Lack of *Betula* and Ericaceae in the bottom of Navarrés 1.

(4) Differences in the curves of *Plantago* and heliophytic herbs, with maxima at 40–60 cm in Navarrés 1 and 60–70 cm in Navarrés 2. Towards the top of the sequence, *Plantago* frequency increases in core 1, but decreases in core 2.

(5) The second maximum of the *Artemisia* curve appears at 140 cm in Navarrés 2 and at 125 cm in Navarrés 1.

(6) A peak of Chenopodiaceae at 140 cm is uniquely present in Navarrés 2.

(7) Asteraceae shows a dramatic increase (up to 22%, at *c.* 80 cm) only in Navarrés 2.

(8) The curves of pollen concentrations are markedly dissimilar (Figs 7, 8, 13). Close correlation lies only within the 75–105 cm zone, where concentrations are the lowest for the two cores (2K grains g^{-1} in Navarrés 2). Below 140 cm, total concentrations become considerably higher for Navarrés 1 (Fig. 13). Lack of correspondence between percentages and concentration curves for some taxa is also noticeable. For example, the highest percentages of *Artemisia* pollen in N2PA1 (Fig. 4) do not correspond to the highest pollen concentrations (Fig. 7). It is likely that the peaks of *Artemisia* are related to the relatively low frequencies of *Pinus* pollen.

(9) In both profiles studied, AP percentage and AP concentration fail to display clear parallelism (Figs 8, 9). Seemingly, AP concentrations are strongly dependent at Navarrés on taphonomic processes, and they do not appear to be due to changes in forest density, since the variation of AP

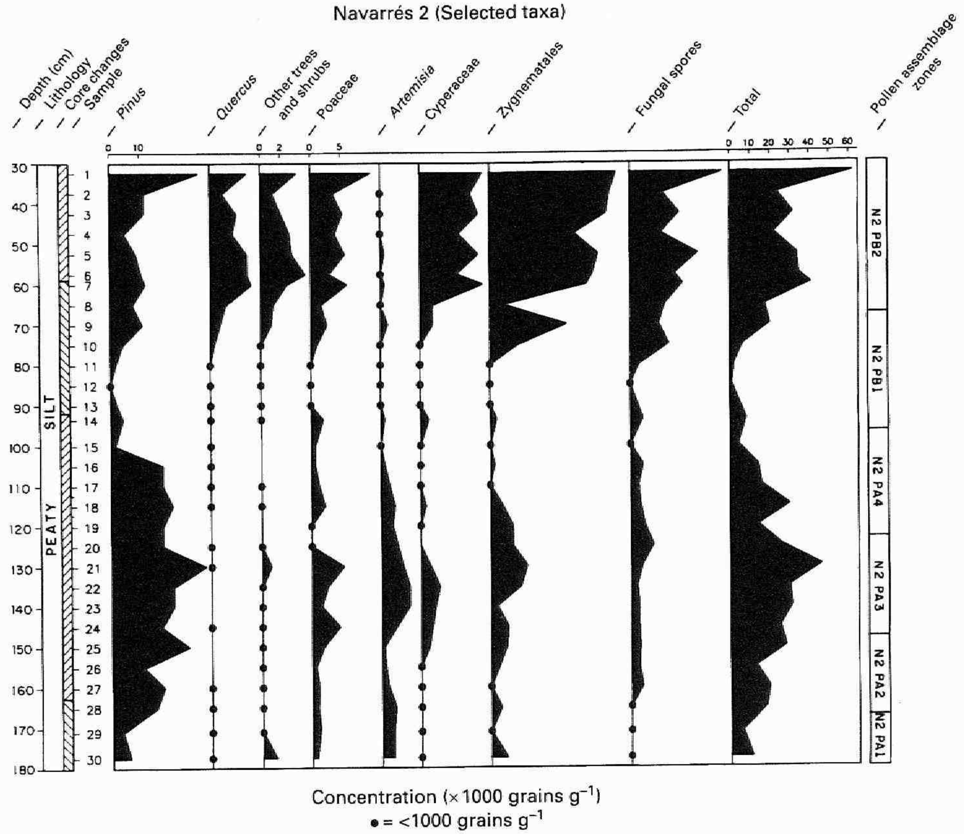

Figure 8. Concentration pollen diagram of selected taxa of Navarrés core 2.

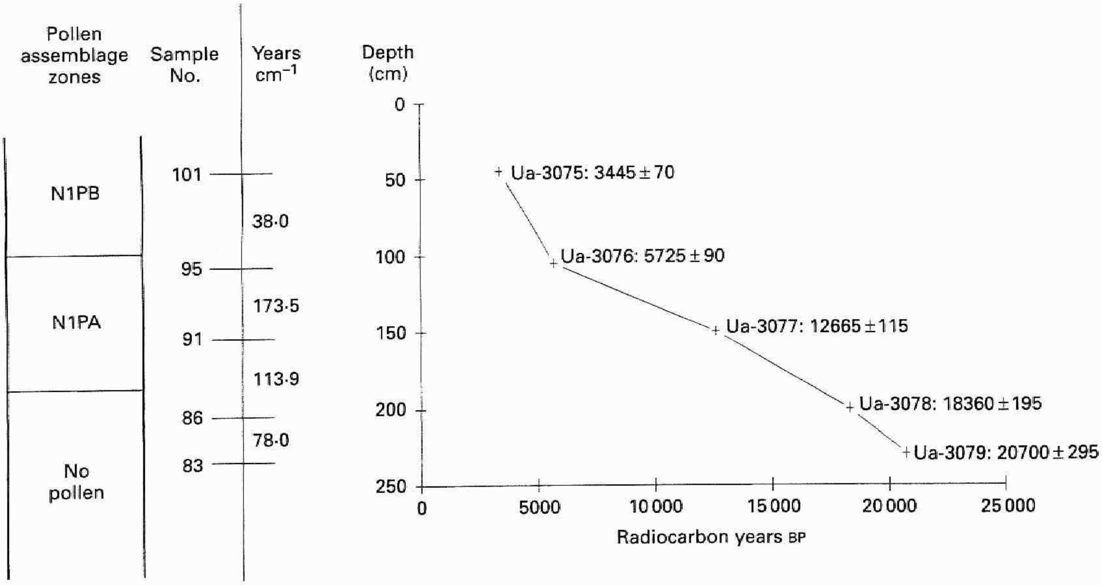

Figure 9. The time–depth curve for Navarrés 1.

concentration is concomitant with that of NAP concentration. Thus, in evaluating vegetational development, the use of AP percentages seems appropriate. Likewise, in estimating temporal variation of tree-shrub density on the landscape, the best development can be seen at a depth of *c.* 150–160 cm.

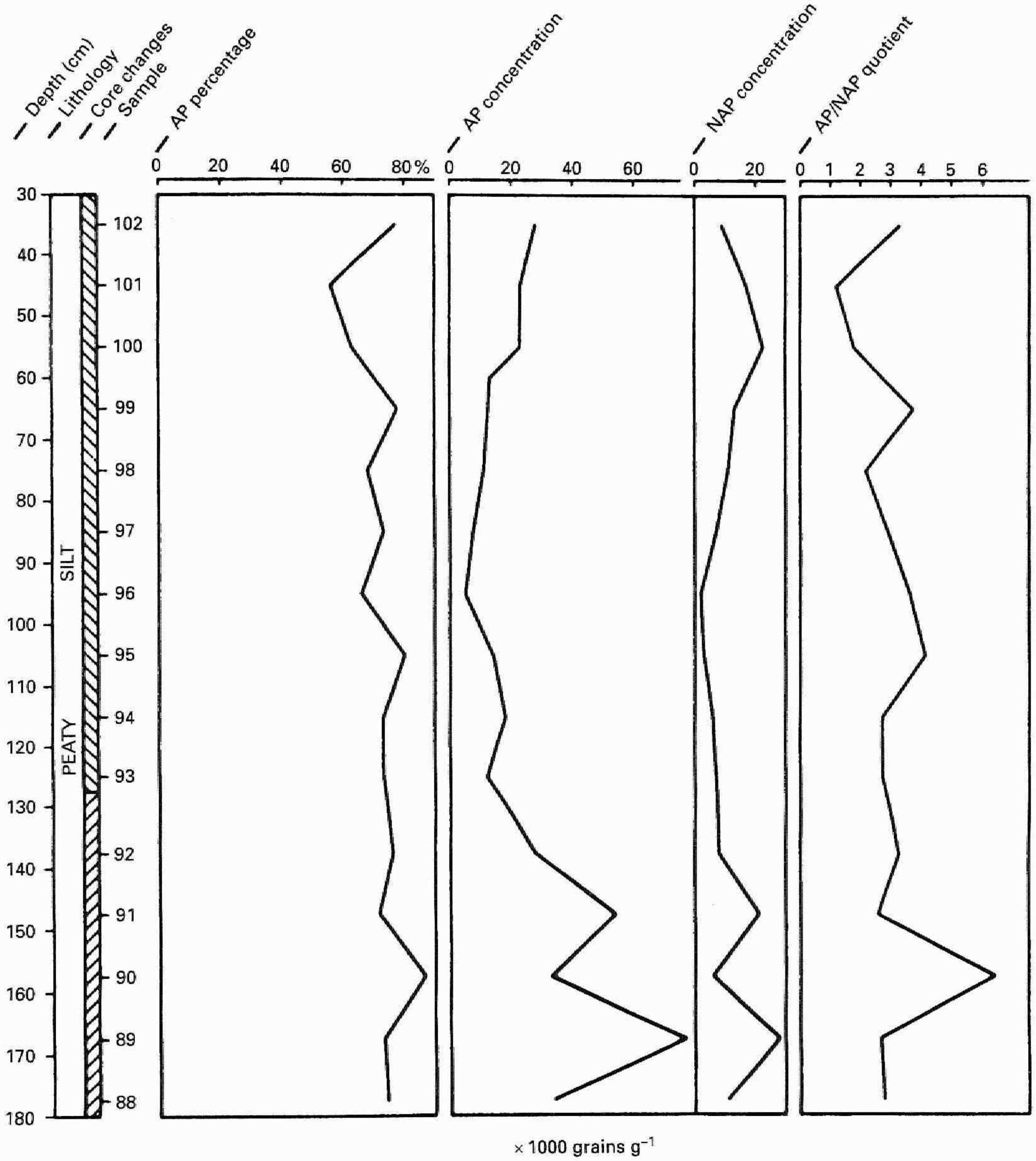

Figure 10. AP percentage, AP and NAP concentration, and AP/NAP quotient for Navarrés 1.

It was realized long ago that differences between cores from a single study site might reflect different influences operating in the area (Davis, Brewster & Sutherland, 1969), but little research has been carried out on multiple samples (Turner, Innes & Simmons, 1989). This is especially true of short-distance within-site studies. The topic was extensively reviewed by Edwards (1983), who concluded that some differences should be expected between nearby profiles, even those close to one another. He argued that, quite apart from errors arising from sampling, laboratory procedures, and counting, there can be intrinsic differences due to the local vegetation in pollen production and subsequent deposition at the sampling site. It is worth remarking that at the Navarrés site, factors such as bioturbation, or erosion of the base or top of one of the cores might have been crucial in determining palynological differences between adjacent cores. It must also be taken into account that 16000 yr of sedimentation are compressed into less than 2 m.

Vegetational and environmental developments

Late-glacial. The variations in the curves of *Pinus*, *Artemisia*, Chenopodiaceae and *Ephedra* at Navarrés

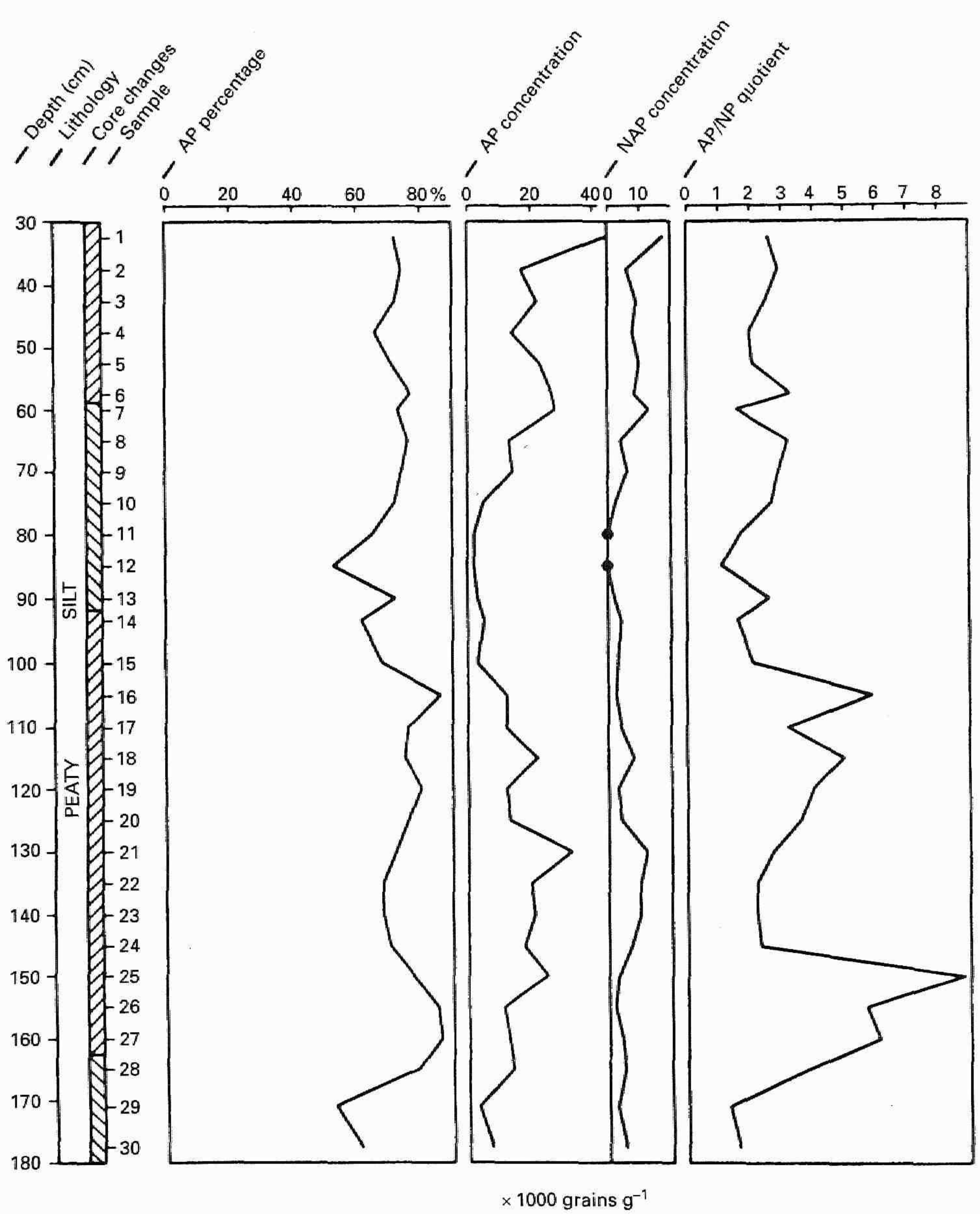

Figure 11. AP percentage, AP and NAP concentration, and AP/NAP quotient for Navarrés 2.

Table 1. *Radiocarbon dates*

Laboratory No. (yr BP)	Core	Depth (cm)	Sediment type	Radiocarbon age
Ua-3075	1	45	Peaty silt/gyttja	3445±70
β-79495	2	115	Peaty silt	5150±50
Ua-3076	1	105	Peaty silt	5725±90
Ua-3077	1	150	Peaty silt	12665±115
Ua-3078	1	200	Peaty sand	18360±195
Ua-3079	1	230	Peaty sand	20700±295

parallel events in the wider European scene. Thus, N2PA1 represents the Upper Pleniglacial, N2PA2 the Bolling-Allerod warm period, and N2PA3 the short-lived climatic deterioration of the Younger Dryas. The N2PA2 deposits reveal interstadial conditions less clearly than do other pre-Holocene

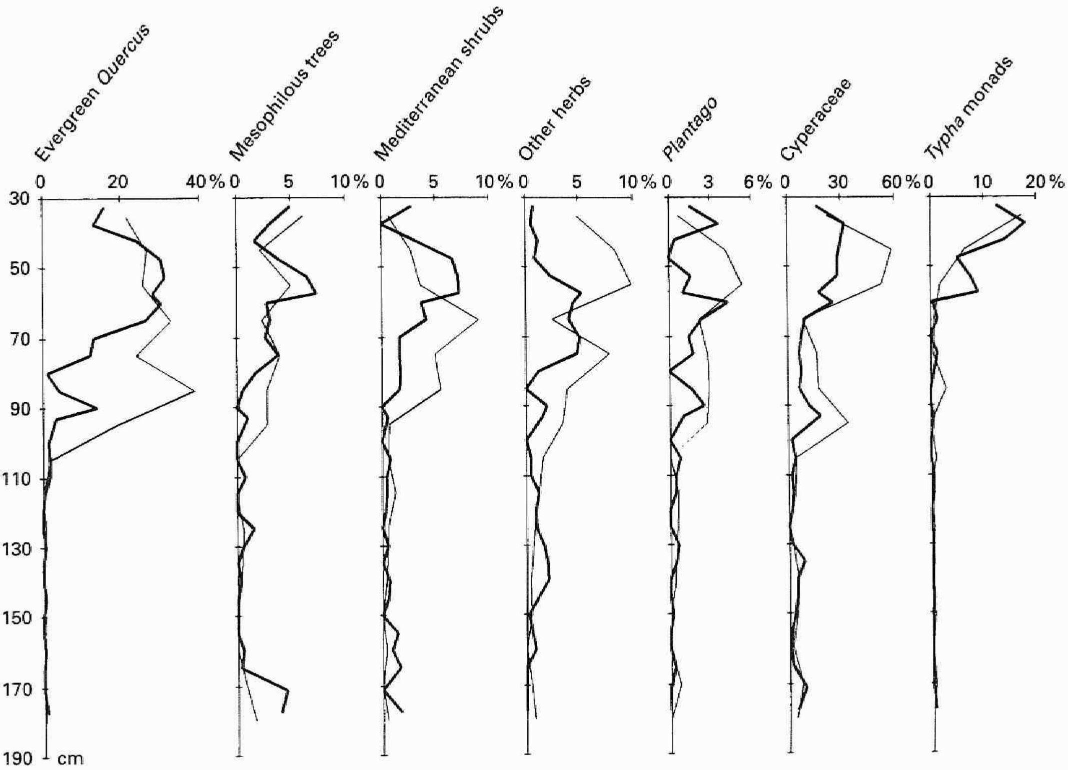

Figure 12. Comparative pollen curves for selected taxa in the two percentage diagrams (I). ——, Navarrés 1; ——, Navarrés 2.

studies of *Quercus* colonization, for instance, Padul (Granada) *c.* 13000 yr BP (Pons & Reille, 1988), Delta del Ebro (Tarragona) before 11000 yr BP (Yll & Pérez-Obiol, 1992) and Lago de Ajo (León) *c.* 12000 yr BP (Watts, 1986). However, the Navarrés percentage diagrams for *c.* 13000–14000 yr BP show a concomitant decline of *Artemisia*, *Ephedra* and Chenopodiaceae (Fig. 13), supported by the *Artemisia* concentration curves (Figs 7, 8) and coincident with maximum forest cover (Figs 10, 11). It is worth mentioning that the pollen diagram of Menéndez-Amor & Florschütz (1961) shows a presumably late-glacial *Quercus* expansion (Figs 2, 14), which did did not see in Navarrés 1 or Navarrés 2. These differences could be due to erosive processes or differential peat accumulation, but to test these possibilities is difficult, as we do not know the exact position of their study site.

It is widely recognized that in northwestern Europe after the late-glacial interstadial there was a brief return to fully glacial conditions from *c.* 11000 to 10200 yr BP (Berger, 1990). Some authors have discovered a better localization of the Younger Dryas towards the south and at high altitude sites (Pons & Reille, 1988; Peñalba, 1989; Lowe & Watson, 1993; Willis, 1994). The record of the N2PA3 Navarrés zone, characterized by coincident increases in *Artemisia*, *Chenopodiaceae* and *Ephedra*, suggests the continental scale of this event. However, more precise dating is needed, since the concomitant rises in those taxa at around 140 cm was found only in Navarrés 2 (Fig. 13). On the other hand, there is no uniform pattern of vegetation response to the Younger Dryas in Spain. Although the sequences from Padul (Pons & Reille, 1988), Quintanar de la Sierra (Peñalba, 1989), and Banyoles (Pérez-Obiol & Julià, 1994) show synchronous rises in *Artemisia*, Chenopodiaceae or Poaceae, and *Ephedra*, together with decrease in *Pinus* and *Quercus*, at other Spanish sites there is no decrease in the arboreal pollen sum, or it is too slight to indicate a supposedly marked climatic deterioration (Turner & Hannon, 1988; Montserrat, 1991; Burjachs & Julià, 1994). In semi-arid southeastern Spain, the whole Late Glacial appears to have been dominated by Chenopodiaceae and *Artemisia*, with constant presence of xero-thermophilous Mediterranean and Ibero-Mahgrebian elements (Munuera & Carrión, 1991).

Early Holocene. It is generally accepted, from different lines of evidence, that the climatic optimum during the Holocene was the Atlantic period, dated *c.* 8000–5000 BP. In northern Europe, summer temperatures at 6000 yr BP could have been up to 2 °C warmer than today (Kutzbach *et al.*, 1993). In the Iberian Peninsula, this hypothesis is supported

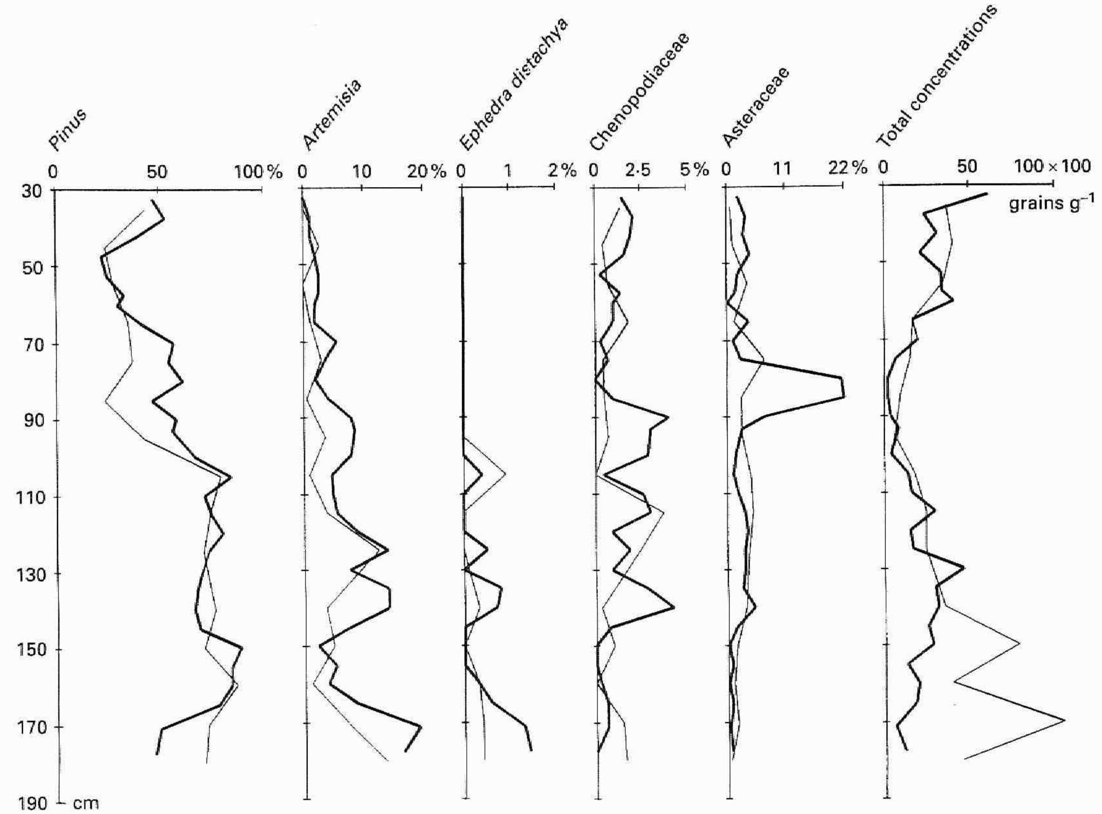

Figure 13. Comparative pollen curves for selected taxa in the two percentage diagrams (II). Comparison with the total pollen concentration curve. ——, Navarrés 1; ——, Navarrés 2.

by several pollen records. For example, Pons & Reille (1988) consider the establishment of *Quercus suber* at Padul, *c.* 8000 yr BP, as indicating the beginning of the postglacial thermic and humid optimum. The results of other studies do not, however, provide conclusive evidence that maxima in mesophilous taxa correspond well with the Atlantic period of the north European succession. Thus, Burjachs & Julià (1994) report such a maximum in the playa-lake of Salines (Alicante) between 9000 to 8000 yr BP. Van der Knaap & Van Leeuwen (1994) find the maximum of indicator species at *c.* 9410–7850 yr BP in Serra da Estrela, Portugal. In the Navarrés pollen record, mesophilous taxa are diverse (deciduous *Quercus*, *Betula*, *Corylus*, *Alnus*, *Ulmus*, *Salix*, *Fraxinus*) but their higher frequencies after *c.* 5000 yr BP are insufficient to suggest mesic forest development. In any case, mesophilous taxa of Navarrés increase in the Subboreal (*c.* 4500–2500 yr BP) rather than the Atlantic period.

The most striking feature of the Navarrés pollen record is the lack of disruption of vegetational patterns from the beginning of the Holocene onwards. No other sites in Mediterranean Spain have an equivalent stratigraphical record. At Navarrés, there is no immediate response of *Quercus* to the climatic change at *c.* 10000 BP and *Pinus* continues to be dominant up to *c.* 5500–6000 yr BP. A *Quercus* postglacial colonization can be seen in the northerly sites of Olot (Péret-Obiol, 1988) and Banyoles (Pérez-Obiol & Julià, 1994), and in the sequence at Padul (Pons & Reille, 1988). Other non-Iberian records also reveal early Holocene *Quercus* development, such as those from Valle di Castiglione, Italy (Follieri, Magri & Sadori, 1988), and several sites in Greece and the Balkans (Willis, 1992, 1994).

The Quercus *expansion.* Another feature of the Navarrés pollen record is the partial replacement of *Pinus* by *Quercus* after *c.* 5000 yr BP. A major problem, yet to be resolved, is which species of *Pinus* and *Quercus* were present, and therefore, the types of plant communities involved. Palaeoanthracaological research (e.g. Badal, Bernabeu & Vernet, 1994) suggests that *Pinus nigra* was the most abundant pine species during late-glacial times in the region. This pine continued to be important in coastal areas up to 7000 BP. At the Atlantic-Sub-boreal transition, other Mediterranean species such as *P. halepensis*, and to a lesser extent, *P. pinaster* and *P. pinea* could have

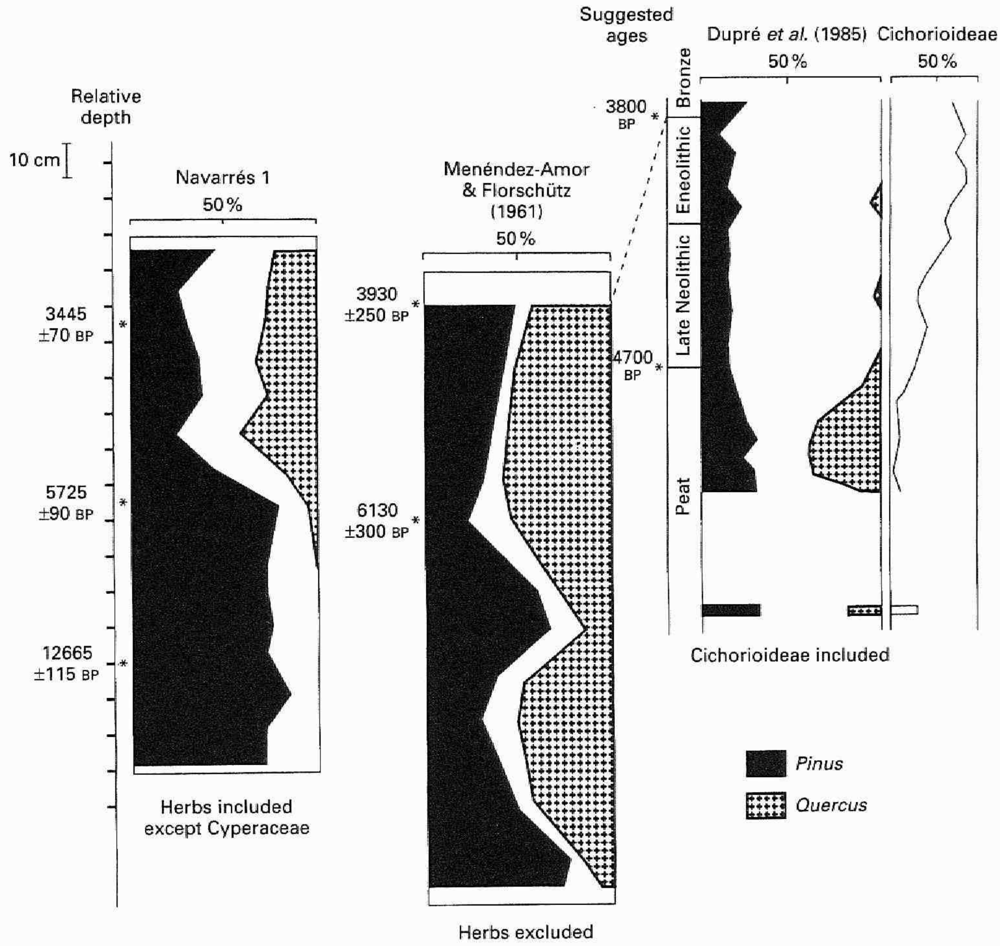

Figure 14. Comparative pollen curves for *Pinus* and *Quercus* in Menéndez-Amor & Florschütz (1961), Dupré, Fumanal & La Roca (1985) and Navarrés 1 (this study).

occurred. Regarding the question of evergreen *Quercus* the vegetation might have been patchy with both shrub-dominated *Quercus coccifera* assemblages and *Quercus rotundifolia* woodlands. Indicators of shrubby formations include *Pistacia*, *Olea*, *Buxus*, *Myrtus*, Ericaceae, Lamiaceae, *Cistus* and *Helianthemum*. Indicators of arboreal formations include *Fraxinus*, *Alnus*, *Betula*, *Corylus* and deciduous *Quercus* (presumably *Q. faginea*), among others. In any case, it is likely that the *Quercus* species involved in the partial substitution of *Pinus* were mainly shrubby, because their development coincides with peaks of both Mediterranean shrubs and heliophytic herbs (Fig. 12). Palynological data from the Neolithic Cova de l'Or (Alicante) suggest open environments and important matorralization from *c.* 6000 BP (Dupré, 1988). To sum up, the most likely explanation is that shrubby *Quercus*-dominated formations were established by clearance of *Pinus P. nigra* and/or *P. halepensis* woodlands.

It is possible to invoke a myriad of local factors in order to explain our results (disease, fire, human activity, competitive exclusion, climate change). No sedimentary evidence supports edaphic change or an explanation involving a natural catastrophe. But the other possibilities merit consideration, for instance that the substitution of *Pinus* by *Quercus* was due to anthropogenic disturbance, either local or regional. Human influence on the environment throughout eastern Spain has been repeatedly invoked to explain anthracological findings dated from *c.* 7000 yr BP onwards (Bernabeu & Badal, 1992; Badal *et al.*, 1994). However, the evidence from charcoal analysis does not suggest the replacement of *Pinus* forests by sclerophyllous *Quercus*-dominated scrub. On the contrary, the information charcoal diagrams from Cova de l'Or and Cova de les Centres (Alicante) (Badal *et al.*, 1994) show that (*a*) the development of the Neolithic (from 7000 BP) on the eastern coast of the Iberian Peninsula took place in the context of a dominant evergreen oak forest, (*b*) localized vegetational degradation probably started between 7000 and 6000 BP, (*c*) clearance of *Quercus* forest between 6000 and 4700 BP favoured development of

Pinus halepensis and *Olea*, and (*d*) later, in the Sub-boreal period, there are both maximum decline of *Quercus* and important expansion of matorral with *Rosmarinus officinalis*, *Erica multiflora*, *Cistus*, Fabaceae and *Pistacia lentiscus*, although *Pinus halepensis* is still the dominant tree in the charcoal spectra. Badal *et al.* (1994) interpret these vegetation changes as related to changes in exploitation by man.

The introduction of agricultural practices in the region, *c.* 7000 BP, is indicated by the seed remains of cereals such as *Hordeum vulgare*, *Triticum dicoccum*, *T. durum*, *T. monococcum* and *T. compactum* and legumes, such as *Lens culinaris*, *Vicia faba*, *V. ervilia* and *Pisum sativum*, among others (Hopf, 1966; Hopf & Schubart, 1965; Martí, 1988). Archaeobotanical evidence of pulses suggest that the agricultural cycle included rotation of crops. The presence of domestic animals, such as sheep and goats, in the early Neolithic period is also demonstrated from analysis of faunal remains at Cova de l'Or (Martí *et al.*, 1980).

Interpreting the presence of *Quercus* in Navarrés as due to human impact creates a dilemma, in that *Quercus* assemblages seem to represent a degradation stage of *Pinus* forests, rather than the climax vegetation. For humid and subhumid climates, the question of the ecological significance of sclerophyllous oak forests in the western part of the Mediterranean Basin has been examined by Reille & Pons (1992). They put forward evidence, from pollen analysis and palaeoanthracology, which suggests that the establishment of the *Quercus ilex* forests occurred after 6000 BP, human activity having degraded the original *Q. pubescens* forest. Perhaps in southern latitudes, influenced by marine effects or drier climates, the successional role of deciduous *Quercus* was performed by *Pinus*. In southwest Spain, in the coastal valley mire of El Acebrón (Huelva), Stevenson & Moore (1988) have remarked on a succession from *Pinus* forest to *Quercus* scrub since 4500 yr BP presumably provoked by fire. Another situation has been found in Corsica, where *Erica arborea* forests were quickly destroyed by dramatic man-made fires, leading to establishment of *Quercus ilex* during the Sub-boreal (Reille, 1992).

At Navarrés, it seems plausible that human activity was initially responsible for Sub-boreal replacement of *Pinus* by *Quercus*. However, the onset of the evergreen *Quercus* curve at Navarrés 2 precedes the development of *Plantago*, and no other pollen taxa have been found of cereal type, or characteristic of arable land. Thus, although it is manifestly clear that human activity must have been intense in the area from at least 5000 yr BP, there is no clear evidence from the Navarrés pollen records that such activity had substantially altered the local landscape. More detailed palynological studies are needed before the hypothesis of man-induced *Quercus* invasion can be accepted.

The early *Quercus* expansion recorded by Menéndez-Amor & Florschütz (1961) is synchronous with the dominance of *Pinus* in Navarrés 1 and Navarrés 2 (Fig. 14). A likely explanation is that both *Quercus* and *Pinus* grew locally and were in constant competition throughout the Holocene, undergoing periodic mutual replacement. We lack endeavour to test this hypothesis. It must be borne in mind, however, that there is a millennial time-scale for *Pinus-Quercus* interactions at Navarrés and at this scale perhaps factors such as succession and species dispersal are of less importance.

The hypothesis of climatic control of vegetation types cannot be rejected *a priori*. Research into agricultural origins in the Mediterranean basin is still poorly developed and, as data are still sparse, the scale of crop cultivation in Spanish Neolithic habitats might have been overestimated. It is well known that farming spread gradually in western Europe. The density of agricultural communities was generally low in comparison with that of southeastern Europe, where the early Neolithic agriculture appears as an intrusive phenomenon (Dennell, 1992). Even in the Balkans, for which palynological records are abundant, the evidence for a relationship between the spread of agriculture and the timing of forest clearance is far from conclusive (Willis & Bennett, 1994), and some authors have suggested that climatic conditions were a major factor in determining the history of vegetation in this area from the mid-Holocene (Magri, 1996).

Vegetational changes, such as those described in this paper, occur spatially in some critical regions of the Iberian Peninsula. One of these is southeastern Spain, mostly semi-arid, but with mountainous areas where pluviometric gradients cause great vegetational diversity over short distances. Here, for example, a transition from *Pinus pinaster* forests to sclerophyllous *Quercus* scrub can be firmly related to a decrease in rainfall (Carrión, Munuera & Dupré, 1996). The quantity and annual distribution of precipitation is also a determinant of the tree vegetation limit in the provinces of Murcia and Almería. Along these bioclimatic boundaries there are no signs of present or past differential anthropogenic disturbance.

It is clear that human activity must have been intense in eastern Spain from at least 5000 yr BP, but the environmental balance was likely to have been delicate in those ares, where rainfall was very limited and persistent summer drought occurred. As a consequence of agrarian activities, deforestation, and fires would have resulted in strong erosion. Further, successional studies on burnt areas in Albacete and Murcia provinces (Martínez-Sánchez, 1994) have demonstrated that the post-fire response of vegetation is strongly dependent upon mean annual rainfall. Without denying the existence of important human disturbance in the environment, in conclusion we question whether intense anthropic pressure was the limiting factor involved in most of the recent vegetational changes in the Spanish Mediterranean context.

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