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Pollen stratigraphy of sediment sequences from lakes Albano and Nemi (near Rome) and from the central Adriatic, spanning the interval from oxygen isotope Stage 2 to the present day

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ABSTRACT

Pollen-stratigraphic data are presented for sediment cores obtained from the floor of two crater lakes situated close to Rome (Lake Albano and Lake Nemi) and from 4 sediment cores recovered from the floor of the Central Adriatic Sea. Lake Albano sequence spans the interval from OIS 2 to the present time, while that from the Lake Nemi provides a detailed record of the Holocene. The longest of the Central Adriatic cores probably extends back to before the last glacial maximum, though the precise age of the base of the sequence is unknown. Two other core sequences span the Lateglacial and Holocene, while the fourth provides a high-resolution record of the mid- to late-Holocene. The results are compared with the recently-published pollen-stratigraphic data from Lago Grande di Monticchio (Watts et al. *1996) and also with a number of other published pollen records obtained from sites in Italy and adjacent marine basins. It is shown that the new pollen data are not only internally consistent, but also show strong resemblances to previously-published pollen records from both terrestrial and marine sites. Pollen stratigraphy thus provides a basis for the correlation and relative dating of lake and marine sequences. For these purposes, a number of very clear pollen-stratigraphic 'marker' horizons can be recognised. These include (i) a series of very abrupt fluctuations in pollen concentrations during the last (Würm) glacial maximum, (ii) the expansion of deciduous trees at the onset of the Lateglacial period, (iii) the revertance to steppic plant associations during the Younger Dryas cold oscillation, (iv) the marked expansion of a number of tree types at the start of the Holocene, (v) progressive deforestation, accompanied by the increasing importance of so-called 'anthropogenic indicator plants' (e.g., cereal grasses, weeds of cultivated land), during the mid-Holocene, (vi) the rising percentages of olive, chestnut and the vine from the Roman period onwards, and (vii) the appearance of* Zea mays *during the historical period.*

Key words: rapid climatic fluctuations, anthropogenic indicators, deforestation, radiocarbon dating, land-marine correlations, high-resolution pollen records

1. INTRODUCTION

The Centre for Quaternary Research at Royal Holloway, University of London (RHUL) and the University of Modena, Orto Botanico (UMIB) have been responsible for establishing the main pollen-stratigraphical changes in cores recovered from (i) Lake Albano, (ii) Lake Nemi and (iii) the Central Adriatic. The cores selected for detailed study, the time periods represented by each core sequence and the amount of pollen data assembled are summarised in table 1. All of the pollen-stratigraphical data have been archived as TILIA files at RHUL and UMIB, as well as at the main PALICLAS repository in the Department of Geography, Newcastle University (UK). These TILIA files will be delivered to the European Pollen Data-base (Arles) during 1997 and 1998. In this paper, it will not be possible to describe the full range of the pollen-stratigraphical data assembled for the PALICLAS project. Instead, we have selected 6 of the core sequences which represent the full time period and stratigraphical variations investigated for the PALICLAS project, and which demonstrate some of the more important palaeobotanical features to emerge from the data. The core records we have selected are: PALB94.1E from the north-central part of Lake Albano, PNem 94.1B from Lake Nemi, and PAL94-8, CM/92-43, RF/93-77 and RF93-30 from the Central Adriatic.

Tab. 1. Summary of pollen-stratigraphical investigations completed by the RHUL and UMIB teams as contributions to the PALICLAS project.

Site & Core	Core[1] (cm)	Number[2] of spectra	Time-span[3] represented	Comments
L. ALBANO				
PALB94.1E	1387.5	138 (RHUL) 74 (UMIB)	Oxygen Isotope Stage 2 to present	Hiatus of *ca* 4,000 yr in mid-Holocene
PALB94.6A	860	39 (RHUL)	Part of OIS 2	Core does not extend to Holocene
PALB94.3A	1200	24 (RHUL)	Holocene	Probably a complete Holocene record
L. NEMI				
PNEM94.1B	915	87 (UMIB)	Holocene	Full Holocene - may also extend down into Younger Dryas
C. ADRIATIC				
RF93.77	800	77 (RHUL)	Form pre-OIS 2 to late Holocene	Age of earliest sediments pre-25 kyr BP, but not precisely known; may be significant hiatuses
PAL94.8	500	53 (UMIB)	Last glacial max. to present	Core selected for age scale assessment
PAL94.77	750	65 (RHUL)	Last cold max. to mid-Holocene	High resolution sequence of LGIT[4]
PAL94.9	680	43 (UMIB)	Full Holocene	Lower part may just extend into Y. Dryas and Lateglacial Interstadial
CM92.43	975	48 (RHUL)	LIGT[4] to late Holocene	High resolution sequence of LGIT[4]
RF93.30	620	63 (UMIB)	Mid-Holocene to late Holocene	High resolution sequence of upper Holocene

[1]Core length: vertical interval spanned by full core sequence
[2]Total number of samples from which pollen-stratigraphical data obtained
[3]Approximate time interval in conventional stratigraphical terms
[4]LGIT = Last Glacial-Interglacial Transition

For each of the cores investigated for pollen stratigraphy, the pollen data have been assessed in four different ways to record: (i) summary data, depicting variations in relative percentages of the principal, most diagnostic, *taxa* only; (ii) full data-sets of the relative pollen percentages recorded for all *taxa* identified in each profile; (iii) summary diagrams of relative pollen percentages zoned using the CONISS statistical package to assist in the interpretation of each sequence; and (iv) variations in the concentrations of each taxon for each counted level. The combined information of all of these data-sets has led to the zonation schemes and interpretations presented here. However, because of space constraints, only category (i) diagrams are included in this paper. Pollen influx diagrams will also be prepared in due course, following the establishment of a comprehensive chronology for each record, which will emerge from the integration of all of the proxy and geochronological information generated by the PALICLAS project. More detailed records and interpretations are being prepared for publication in a series of scientific papers.

2. METHODS

Samples were prepared for pollen analysis using a new method imported from the Institute of Earth Sciences, Vrije Universiteit Amsterdam. Both the London and Modena palynology teams used the same preparation methods to ensure data consistency within the PALICLAS investigations.

Sediment samples of 2 cm^3 were treated in 10% Na-pyrophosphate to deflocculate the sediment matrix. Where necessary, these were sieved through meshes of 200 μ and treated with 10% HCl to remove calcareous material. The residues were subsequently washed through 7 μm sieves and then subjected to acetolysis for 10 minutes. A heavy liquid separation method was then introduced, using Na metatungstate hydrate of s.g. 2.0 and centrifugation at 2000 rpm for 20 minutes. Following this procedure, the retained fractions were treated with 40% hydrofluoric acid, washed in methanol and finally prepared in glycerol. The final residues were mounted on slides in glycerol jelly and the coverslips were sealed with paraffin.

Pollen sums varying between 200 and 700 of 'dry-land' *taxa* have been adopted, and all percentages are expressed as percentages of total 'dry-land' pollen. A different approach was necessary, however, for some of the Central Adriatic cores. Marine deposits frequently contain very high percentages of coniferous pollen (due to their ease of transport and buoyancy). Thus pollen of *Pinus* have been omitted from all of the pollen sums of the Central Adriatic pollen diagrams, while, for some, pollen of *Abies, Pinus* and *Picea* are not included in the pollen sums. Pollen of *Pinus* have also been omitted from the PNem 94.1B and PALB94.1B (UMIB) diagrams.

3. LAKE ALBANO (PALB94.1E)

3.1. Major pollen-stratigraphic changes

Borehole PALB94.1E was located in the north-central part of Lake Albano, at a water depth of about 70m. Pollen data compiled by RHUL from 98 sample horizons in the PALB94.1E sequence are summarised in figure 1. The sequence has been divided on a preliminary and subjective basis into three broad biostratigraphic zones, which, with the exception of the complex succession of changes between approximately 650 and 500 cm depth, matches reasonably well to the CONISS plot for the sequence.

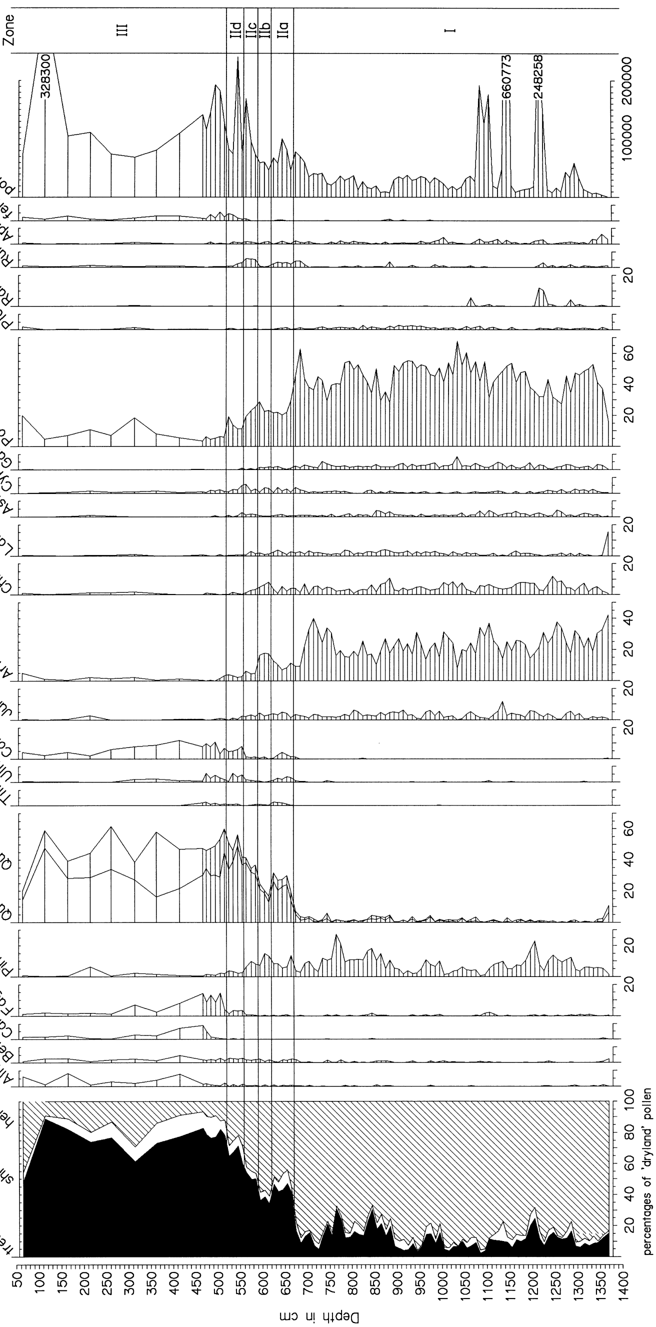

Fig. 1. Percentage pollen diagram (selected *taxa* only) obtained from the PALB94.1E profile, Lake Albano, based upon minimum pollen sum of 200 'dryland' pollen.

Zone PALB94.1E-I (1369-670 cm) is characterised by very high percentages of herbaceous *taxa*, commonly around 80% of total pollen, and notable in the records are *Artemisia*, *Juniperus*, Poaceae/Gramineae and Chenopodiaceae. Tree percentages are generally low and are dominated by *Pinus*.
Zone PALB94.1E-II (670-520 cm) is a transitional zone between the herb-dominated assemblages of Zone I, and the assemblages dominated by arboreal pollen in *Zone III*. *Zone II* has been sub-divided into 4 sub-zones. In *sub-zone IIa* (670-620 cm), *Quercus ilex* type, *Tilia*, *Ulmus* and *Corylus* show increased percentages, while *Artemisia*, Poaceae/Gramineae and other herb *taxa* are strongly reduced. In *sub-zone IIb* (620-590 cm) *Artemisia* and Poaceae/Gramineae percentages (in particular) increase once more, while values for *Quercus ilex* type, *Tilia*, *Ulmus* and *Corylus* are sharply reduced. A more sustained rise in values for *Quercus ilex* type and a marked drop in *Artemisia* values distinguishes *sub-zone IIc* (590-559 cm). In *sub-zone IId* (559-520 cm) the values for herbaceous pollen types are reduced even further, while strong increases are recorded in *Fagus*, *Quercus ilex* type, *Quercus robur* type, *Ulmus* and *Corylus*.
Pollen zone *PALB94.1E-III* is characterised by high percentages for tree pollen in general, but notably including *Alnus*, *Betula-Ostrya*, *Carpinus*, *Fagus*, *Quercus* and *Corylus*. Fern spores are also recorded in relatively high numbers. By contrast, herbaceous and *Pinus* pollen values are low throughout this zone. Towards the top of the zone (but not shown on figure 1), from 250 to 200 cm upwards, there are significant records for the first time of *Castanea*, *Juglans* and *Olea* type.

The variations described above are also evident in pollen concentration data (not shown here), with the abrupt changes during the last glacial-interglacial transition (Zone II) remaining quite distinct. The most interesting features within the concentration data, however, are the abrupt, high amplitude fluctuations characteristic of the lower part of Zone I, which are discussed further below.

3.2. Chronology

Unfortunately there are no radiocarbon dates currently available for most of this core record, since macrofossils were extremely rare, and the sediments are occasionally calcareous (Chondrogianni *et al.* 1996, this volume; Calanchi *et al.* 1996, this volume). However, one radiocarbon date and a tephra horizon of known age are available from the upper part of the sequence (see Fig. 2) which confirm a mid-Holocene age for this part of the sequence. Other grounds for establishing a preliminary chronology for the sequence are described below.

A. Other cores from Lake Albano have been investigated, which have been dated using the radiocarbon method (Chondrogianni, *et al*. 1996, this volume), and for which pollen diagrams have been produced (Van der Kaars *et al*. 1995; Accorsi *et al*.1995; Accorsi *et al.* unpublished). These include core PALB94-3B, which shows a typical Holocene pollen sequence, an interpretation supported by 5 radiocarbon dates. Zone PALB94.1E-III can be correlated directly with the PALB94-3B sequence, for the marked expansion of *Quercus* is diagnostic of the early Holocene, while records of *Castanea*, *Juglans* and *Olea* are confined to the upper Holocene.

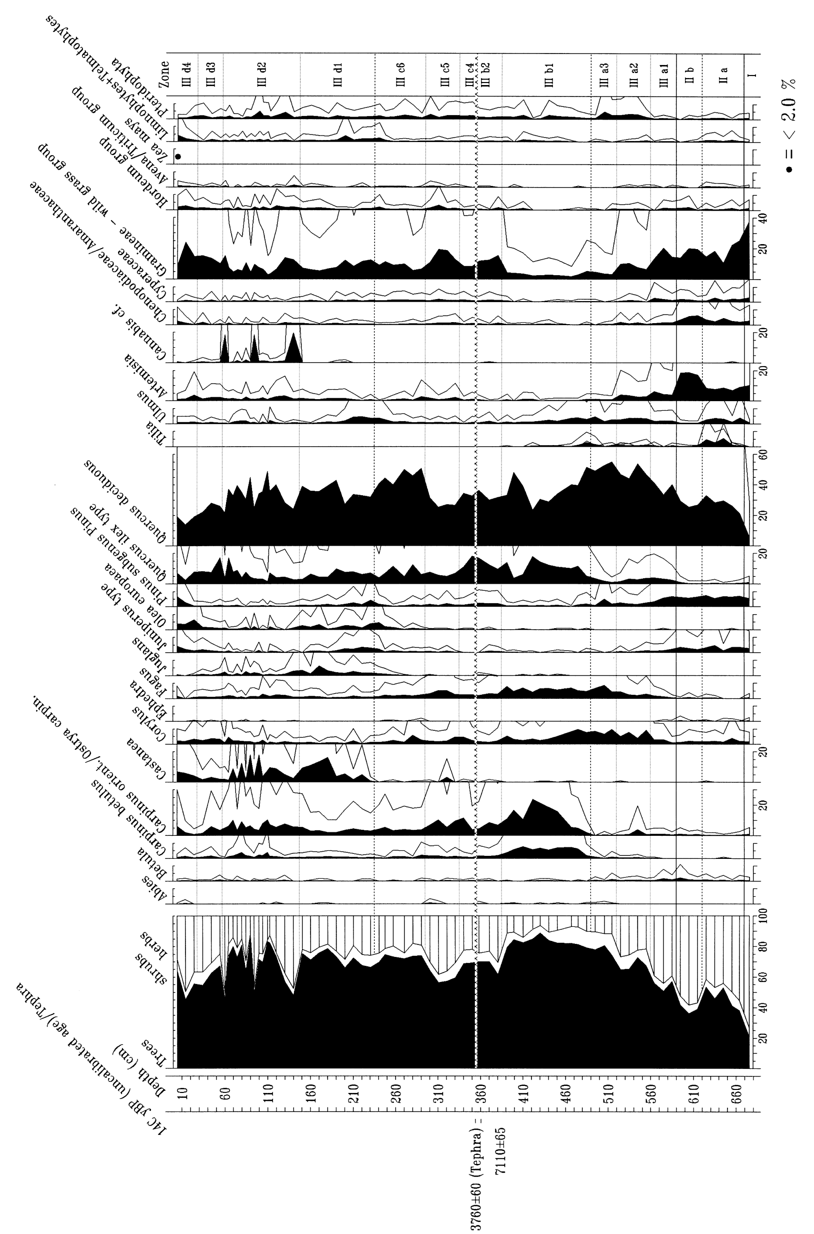

Fig. 2. Percentage pollen diagram (selected *taxa* only) obtained from the upper (mainly Holocene) part of the PALB94.1E profile, Lake Albano, based upon minimum pollen sum of 300 'dryland' pollen (excluding *Pinus*).

B. The sequence of pollen-stratigraphical changes identified in pollen zone PALB94.1E-II compares very well with pollen-stratigraphical changes described by Lowe (1992; see also Lowe & Watson 1993) for sites in the northern Apennines. The initial expansions of *Quercus ilex* type, *Tilia, Ulmus* and *Corylus* and concomitant reductions in *Artemisia*, Poaceae/Gramineae and other herb *taxa*, match almost exactly the developments recorded in the sequences from the Northern Apennines, which have been radiocarbon-dated to the Lateglacial Interstadial (or Bølling-Allerød interval), dated to *ca* 13-11 radiocarbon years BP. *Sub-zone IIb* in the PALB94.1E profile, which is a clear 'revertance' phase characterised by re-increases in *Artemisia* and Poaceae/Gramineae, is therefore correlated with the Younger Dryas episode.

C. The Albano record can also be compared with the recently-published new results from Lago Grande di Monticchio in south-central Italy (Watts *et al.* 1996). The Monticchio sequence has been dated using a variety of approaches, including radiocarbon dating, tephrochronology and counting of laminated sediment layers (Zolitschka & Negendank 1996). Although there are differences in detail, the three-fold pollen zonation scheme described for the PALB94.1E profile from Lake Albano matches very well to the record from Monticchio that spans the last 25,000 years or so. Thus zone PALB94.1E-I matches the *Artemisia*-Poaceae (Gramineae)-Chenopodiaceae-*Pinus-Juniperus* assemblages of zone 4 at Monticchio, which is dated approximately to between 25 and 15 k calendar years BP, and which equates therefore with the period spanning the Würmian cold maximum. Zone PALB94.1E-II compares well with Monticchio zones 2 and 3, and both sequences show identical reductions in *Quercus*, *Tilia* and *Corylus* percentages, associated with increases in *Artemisia* and Poaceae/Gramineae, which Watts *et al*. (1996) also equate with the Younger Dryas cold episode. The last glacial-interglacial transition and early Holocene at Monticchio, like the Albano records, are also characterised by very high percentages of *Quercus* pollen.

There can be little doubt, therefore, that the Lake Albano PALB94.1E profile spans the Würmian maximum to late Holocene period (approximately the last 30,000 years or so), and that palaeobotanical changes during the last glacial-interglacial transition, including a distinct Younger Dryas signal, are well resolved.

3.3. Detailed Holocene record

A more detailed examination of the Younger Dryas/Holocene transition and the Holocene records have been undertaken by the UMIB team based upon 74 samples (Fig. 2). The sequence is divided into 3 pollen assemblage zones, the upper two of which are further divided into sub-zones, as follows.

Zone I (678-669 cm). This includes only 1 pollen spectrum, which is characterised by high percentages of herbaceous pollen types (*ca* 80%), notable among which are Poacae/Gramineae (including cereal types, especially *Hordeum*), *Artemisia*, Chenopodiaceae and *Rumex*. The spectrum is compatible with assemblage Zone I of figure 1 (described above).

Zone II (669-590 cm). This transitional zone between the herb-dominated spectrum of Zone I and the spectra dominated by deciduous woodland *taxa* in Zone III contains a number of pollen-stratigraphical changes that are almost identical to those of the equivalent levels in figure 1 (sub-zones IIa and IIb). Arboreal pollen percentages range between 30 to 55% of total, the principal *taxon* being *Quercus*, while *Juniperus* and *Pinus* remain significant. *Artemisia* is also recorded in relatively high values (10-20%), and there are continuous records of Chenopodiaceae, Asteroideae, *Rumex* and *Ephedra*. The most notable feature, a very pronounced rise in *Artemisia* percentages, clearly identifies the Younger Dryas signal once more. This high degree of compatibility in the independent pollen counts between UMIB and RHUL for this part of the succession is gratifying, and places confidence in the use of pollen stratigraphy for reconstructing palaeovegetation changes.

Zone III (590-002 cm). This extensive pollen zone spans the Holocene, though the base may contain a few levels that fall within the Younger Dryas chronozone. The main *taxa* show pollen-percentage variations that are similar, in broad outline, to those of pollen Zone III in figure 1. However, both the taxonomic diversity and the stratigraphical resolution are higher in figure 2. Thus the sequence of events can be defined in much more detail from this record.

Sub-zone IIIa (590-490 cm). Arboreal percentages increase in a progressive fashion throughout the zone. Deciduous oak dominates the spectra, but there are also expansions in *Corylus*, *Fagus*, *Fraxinus*, *Ulmus*, and *Quercus ilex* type, and in spores of Pteridophyta. There are concomitant reductions in *Artemisia*, Poaceae/Gramineae (including *Hordeum*), and *Rumex*. Further subdivision can be made on the basis of persistent values of *Artemisia* (phase a1), a sustained increase in *Corylus* (phase a2) and increasing forest diversity (phase a3).

Sub-zone IIIb (490-340 cm). Arboreal pollen dominate the spectra in this sub-zone (60-85%) with notable expansions of *Carpinus betulus*, *Carpinus orientalis*/*Ostrya* and *Quercus ilex* type. Cereal types are sporadic and of low values.Two phases are recognised, which is consistent also with the evidence from Lake Nemi (see section 5 below): phase b1 has arboreal pollen of about 80%, Poaceae/Gramineae at less than 10% and sporadic cereal pollen types; phase b2 shows the first signs of forest reduction, with increases in Poaceae/Gramineae, cereal types and other anthropogenic indicator pollen types.

Sub-zone IIIc (340-238 cm). In this zone there are increasing signs of human interference in the vegetation cover. There are increased percentages of cereal and ruderal pollen types, while there are also fluctuating arboreal pollen percentages. The sub-zone is further subdivided into: phase c4, which has many similarities to c4 of PNEM 94.1B; phase c5 is a period of apparent forest reduction, though *Fagus* percentages increase while *Quercus* percentages are significantly reduced; phase c6 reflects a period of re-expansion of *Quercus*. Note that the phases have been numbered to reflect comparable episodes in the PNEM 94.1B sequence; there is a hiatus in the PALB 94.1E sequence, so that phases c1 to c3 of the PNEM 94.1B sequence are missing.

Sub-zone IIId (238-002 cm). This sub-zone is characterised by prominent representations of *Castanea*, *Juglans* and *Olea* pollen percentages, while pollen of cereal and ruderal plants also increase in importance. The sub-zone clearly marks a period of increasing anthropogenic influences in the local vegetation, the *Juglans* and *Castanea* pollen in particular probably increasing in importance during the Roman period. The sub-zone is further sub-divided into: phase d1, marked by an increase in *Castanea*, accompanied by the first prominent records of *Juglans*; phase d2, an increase in *Cannabis* pollen, accompanied by increases in pollen of cereal and ruderal pollen types; phase d3, a marked decrease in *Quercus* and in *Cannabis*, but increased representation of Poaceae/Gramineae and cereal types; phase d4, an increase in *Olea* and a single record of *Zea mays*.

3.4. Abrupt pollen-stratigraphical changes in the lower part of the Albano 94.1E record

Of particular interest in the lower part of the PALB94.1E (Fig. 1) succession are the distinct oscillations in *Pinus, Artemisia* and *Juniperus* that occur throughout Zone PALB94.1E-I. These suggest some form of cyclical changes within the sediment record of this part of the last cold stage. Furthermore, three distinct peaks in *Ranunculus* pollen (at *ca* 1300, 1210 and 1060 cm depth) are evident in the percentage pollen diagrams, but are more pronounced in concentration data (Fig. 1, for curve of total pollen concentration), which also show dramatic increases in concentrations of *Pinus, Juniperus, Artemisia, Quercus, Chenopodium* and Poaceae/Gramineae (RHUL archived data). Indeed, the peak pollen concentration value at *ca* 1150 cm exceeds the highest values recorded in the Lateglacial and Holocene parts of the profile. These coincide with important changes in the records for diatoms, plant pigments and magnetic susceptibility measures, as is discussed in other sections of this volume. These clearly suggest important changes in pollen recruitment and/or in the nature of the lake and sedimentation processes. It is possible that these high-resolution changes in Zone PALB94.1E-I indicate short-term climatic or other palaeoenvironmental influences during the last cold stage. It was therefore decided to examine this part of the Albano 94.1E sequence at a higher resolution.

Within the temporal and cost constraints of the project, there has only been time to examine the pollen content of 42 additional levels between 1305 and 1160 cm, and the results are provided in figure 3. The data show variations at 2 cm intervals for pollen and spores, plus total desmids, *Pediastrum* and *Botryococcus,* and span two of the marked pollen concentration peaks shown in figure 1. The data show extremely abrupt changes in the relative abundance of a number of *taxa*, that clearly indicate sudden shifts in lake water conditions.

The first *taxa* to record significant increases are Cyperaceae and *Botryococcus*, and these are followed, in order of succession, by *Ranunculus* (probably aquatic varieties) and *Pediastrum,* followed by desmids. However, the changes do not appear to have been confined to the lake waters and to lake marginal plant communities, for there are also marked increases in values for *Pinus* and *Juniperus*, with some minor increases in *Quercus*.

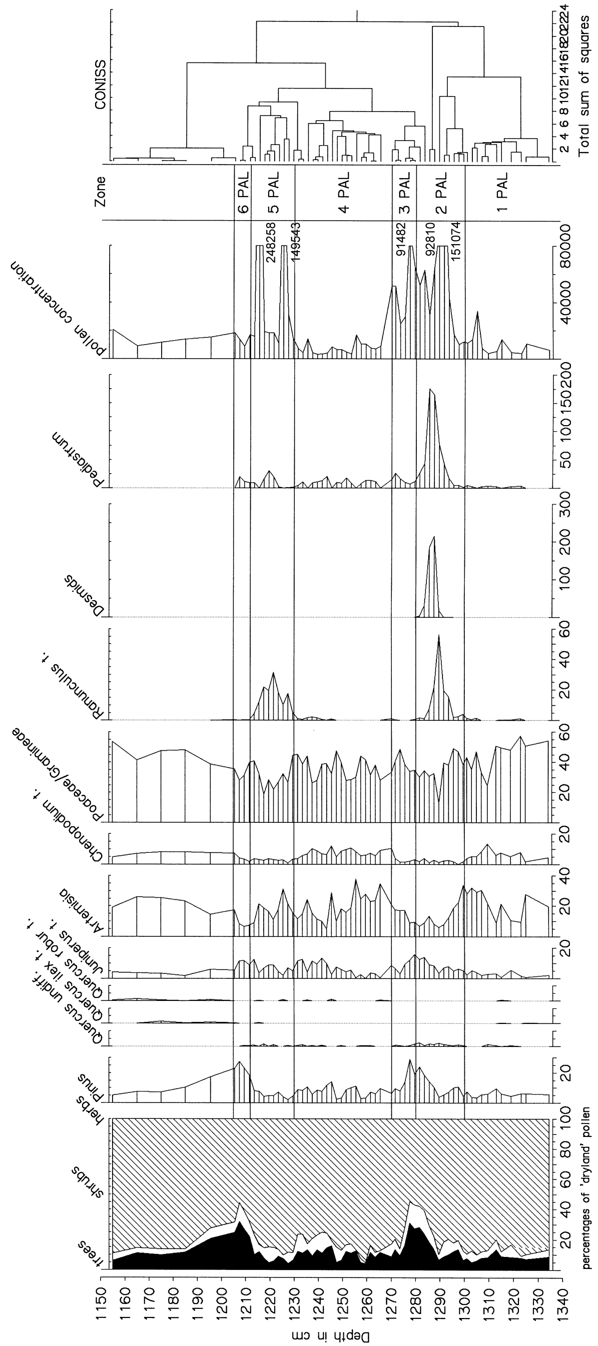

Fig. 3. High-resolution percentage pollen diagram (principal *taxa* only) obtained from basal sediments (*Zone I*) of the PALB94.1E profile, Lake Albano.

3.5. Synopsis

Lake Albano PALB.1E pollen-stratigraphical data provide a high resolution record of (approximately) the last 30,000 years. During the early part of the record, short-lived oscillations in climate appear to have occurred, which led to marked changes in the lake flora. It is possible that these match the rapid fluctuations in climate during the last cold stage reflected in ice-core (Dansgaard-Oeschger events) and North Atlantic marine records (Heinrich Events), an idea also advanced by the Monticchio investigators (Watts *et al.* 1996). The exact correlation of these records is not yet possible, though it does appear that the Albano data include evidence of oscillations additional to those recognised in the Monticchio, ice-core and marine records for around this period. Other investigators in the PALICLAS programme (Chondrogianni *et al.* 1996, this volume) have suggested that a hiatus may affect the PALB 94.1E record at or immediately before the onset of the late-glacial period (*ca* 13,000 ^{14}C yr BP). The pollen-stratigraphical data cannot help to resolve this issue, since there are no clear pollen-stratigraphical markers prior to the marked rise in *Quercus*, which represents the start of the late-glacial.

The record clearly shows a marked oscillation during the last glacial-interglacial transition, with a sharp re-increase in *Artemisia* percentages (sub-zone IIb, Fig. 1; sub-zone IIb, Fig. 2) representing the Younger Dryas cold period. Clearly the cold conditions of the Younger Dryas had a significant effect on Central Italy.

The Holocene record (Fig. 2, Zone III) shows clearly the increasing influence of humans on the local vegetation. The marked rises in the representation of cultivated or managed plants, especially *Castanea, Juglans, Olea, Cannabis* and cereal plants, are some of the best resolved of such records obtained from volcanic maar sites in Europe.

The Holocene record appears to be interrupted by a marked hiatus at 350 cm depth (indicated by the dashed line on Fig. 2). This is demonstrated by the juxtaposition of the radiocarbon age of 7110±65 BP and the tephra which is correlated with one of matching geochemistry that has been dated to *ca* 3,700 ^{14}C BP. The hiatus is not very evident in the pollen-stratigraphical data, although some notable changes can be observed. A comparison with the Lake Nemi Holocene profile, however, provides a basis for estimating the segment of Holocene time that is not represented in the Albano profile (see section 5). This underlines the importance of obtaining independent geochronological data for this type of research.

4. LAKE NEMI

Core PNEM.1B, a 915 cm long sediment sequence, was obtained from Lake Nemi in a water depth of 30 m by the ETH-Zürich team. From this sequence, 87 samples were examined for pollen analysis. The resulting pollen diagram (Fig. 4) has been divided into two local pollen assemblage zones, the first (Zone II) representing the Younger Dryas-Holocene transition, and Zone III the Holocene. Zone III is further sub-divided into 4 sub-zones (a to d), which are further sub-divided into phases which have diagnostic pollen-stratigraphical signatures.

Zone II (914.5-900 cm). This zone consists of just two pollen spectra, these having strong affinities with the YD/Holocene transitional spectra identified in the PALB.1E sequence from Albano. Thus arboreal percentages do not exceed 55%, *Pinus* and *Juniperus* percentages are around 5%, *Quercus* shows signs of a major increase (35%) and *Artemisia* is recorded in significant amounts, together with Chenopodiaceae, Asteroideae, *Ephedra* and *Betula*.

Zone III (900-000 cm). This zone spans almost the whole of the core sequence, which is assigned to the Holocene. It is characterised throughout (with a few minor, but important exceptions) by high arboreal pollen percentages, and a diverse woodland flora. *Quercus* is the dominant genus throughout, with *Quercus ilex* type always present. Poaceae/Gramineae are generally below 20% and *Artemisia* is reduced to very low percentages. The profile is divided into sub-zones on the basis of (a) variations in the mix of woodland *taxa* represented, and (b) evidence for the role of so-called 'anthropogenic indicators' within the pollen spectra.

Sub-zone IIIa (900-785 cm). Arboreal percentages increase steadily through this part of the sequence, with oaks dominant. Other deciduous trees are also increasingly represented, such as *Corylus, Fagus, Fraxinus, Ulmus* and *Quercus ilex* type. Non-arboreal pollen fall to low percentages, especially *Artemisia* and Poaceae/Gramineae. Three phases are recognised: *phase a1* where the main reductions in non-arboreal pollen, and the commencement of the rise in arboreal percentages, occur; *phase a2*, where *Corylus, Fagus, Ulmus* and *Tilia* record marked increases; and *phase a3*, where arboreal percentages achieve 80% of total land pollen.

Sub-zone IIIb (785-524 cm). Arboreal pollen remain between 70 and 80% in this part of the sequence, with marked increases in the representation of *Carpinus betulus, Carpinus orientalis/Ostrya* and *Quercus ilex* type. Poaceae/Gramineae percentages remain below 20% and although cereal types are recorded, they are sporadic. This part of the sequence is further sub-divided into two phases: *phase b1*, the acme for arboreal pollen percentages (80%); *phase b2*, the start of a slow but steady decline in arboreal pollen percentages, and increased representation of cereal pollen types and pollen of other 'anthropogenic indicators'.

Sub-zone IIIc (524-320 cm). This sub-zone marks the first major signs of deforestation, with Poaceae/Gramineae percentages increasing to exceed 20% of total, and pollen of cereal and ruderal plants becoming more evident. The sub-zone is further divided into six phases, three representing short episodes of deforestation (*phases c1, c3* and *c5*) and three representing short episodes of re-afforestation (*phases c2, c4* and *c 6).*

Sub-zone IIId (320-000 cm). This sub-zone is characterised by clear indicators of human influences on the local vegetation, with the first sustained increases in pollen of *Castanea, Juglans, Olea, Cannabis* and a variety of ruderal *taxa*. Four phases are recognised, *viz.*: *phase d1*, the main increase in *Castanea*; *phase d2*, the main increase in *Cannabis*, associated with pollen of cereal and ruderal plants; *phase d3*, a marked reduction in *Quercus*, associated with increases in Poaceae/Gramineae (including cereals) and a decrease in *Cannabis*; and *phase d4*, a marked increase in *Olea* and a record of *Zea mays.*

The Lake Nemi profile (described above) provides a longer, and thus higher resolution Holocene record than that of Albano 1E, from which it is possible to deduce a complex history of human influences on the local vegetation (and landscape) from a fairly early stage. Indeed, it is a close examination of the Nemi pollen profile that indicates the scale of the hiatus that has been suggested for the Lake Albano profile (section 4.5 and Fig. 2). Sub-zones b and c of Zone III in the Nemi 1B sequence (785-320 cm, Fig. 4) match very well to sub-zones b and c of Pollen Zone III of the Lake Albano *PALB94.1E* sequence (490-238 cm, Fig. 2). The Nemi succession is thicker than that of Albano, however, and has some additional pollen-stratigraphical features that are absent from the Albano profile. The main differences are:

1. *Carpinus betulus* and *Carpinus orientalis/Ostrya* show two peaks in the Nemi diagram, whereas only 1 is recorded in the Albano profile;
2. *Abies* percentages are continuous over the two *Carpinus* peaks at Nemi, but are reduced to zero in the Albano diagram;
3. a peak in *Fagus* (19% at 603.5 cm) is recorded in the Nemi profile, and an equivalent is not evident in the Albano profile;
4. a peak in *Quercus ilex* type (36.6%) is recorded in the Nemi profile at 437 cm, while there is no equivalent in the Albano profile;
5. the rise in Poaceae/Gramineae is gradual in the Nemi profile, whereas it is abrupt, at the suggested hiatus, in the Albano profile.

If this reasoning is correct, calculations of comparative sedimentation rates between the two profiles suggests that the part of the Nemi sequence between 660 and 424 cm (an interval of 236 cm, comprising the upper part of sub-zone IIIb and the lower part of sub-zone IIIc, Fig. 4) may not be represented in the Albano profile.

5. CENTRAL ADRIATIC CORE RF93.77

Core RF93.77 was obtained by the CNR-IGM Bologna group (Trincardi *et al.* 1994; Asioli *et al.* 1996; Trincardi *et al.* 1996, this volume) from a position on the southern flanks of the Meso-Adriatic Depression in a water depth of just over 140 m. Pollen-stratigraphical information was obtained from 77 levels, and the resulting relative pollen diagram has been divided on a preliminary basis into four pollen assemblage zones (Fig. 5).

Zone I (799-620cm) is characterised by high *Pinus* (outside the pollen sum) and *Quercus* percentages, but also high *Artemisia* and Poaceae/Gramineae percentages occur at around 750 and 660 cm core depth.

Zone II (620-210 cm): *Pinus, Juniperus, Artemisia* and *Chenopodium* type are recorded in high values, along with Cyperaceae and Poaceae/Gramineae pollen, while pollen of angiosperm trees and fern spores are low in number.

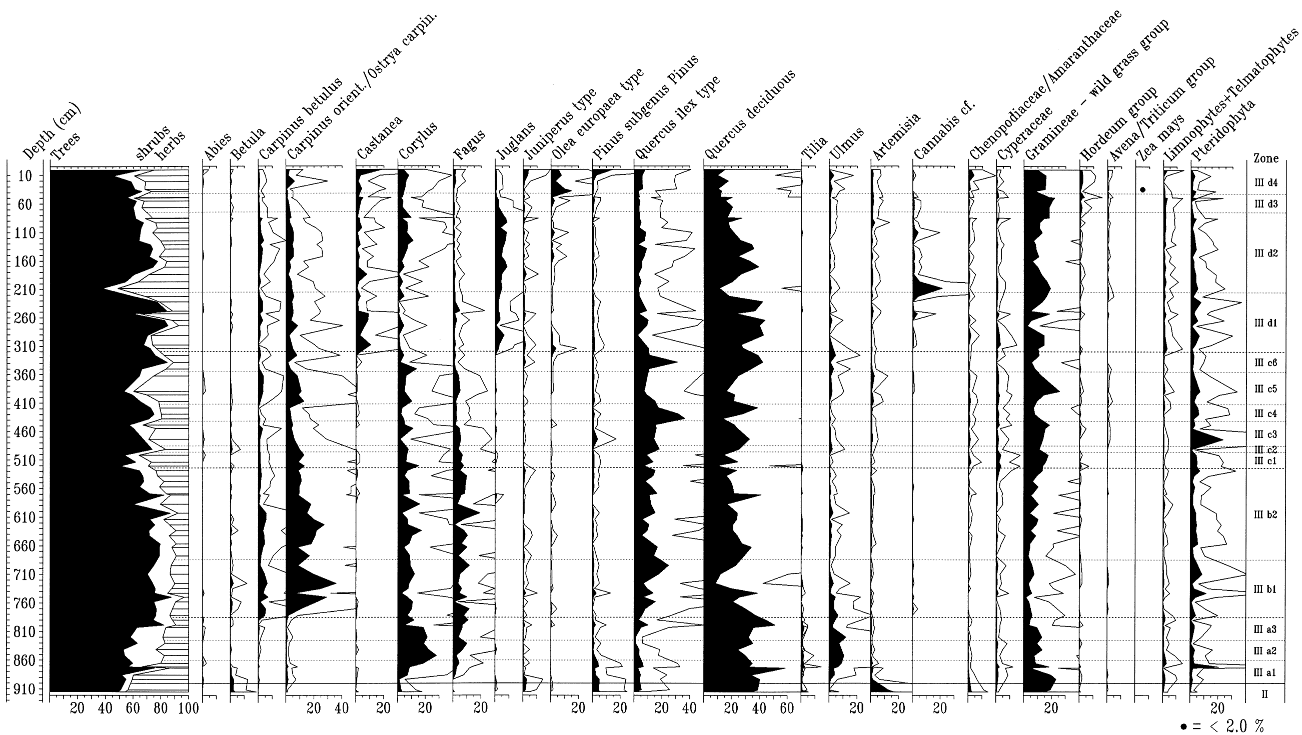

Fig. 4. Percentage pollen diagram (selected *taxa* only) obtained from the PNEM 94.1B profile, Lake Nemi, based upon minimum pollen sum of 500 'dryland' pollen (excluding *Pinus*).

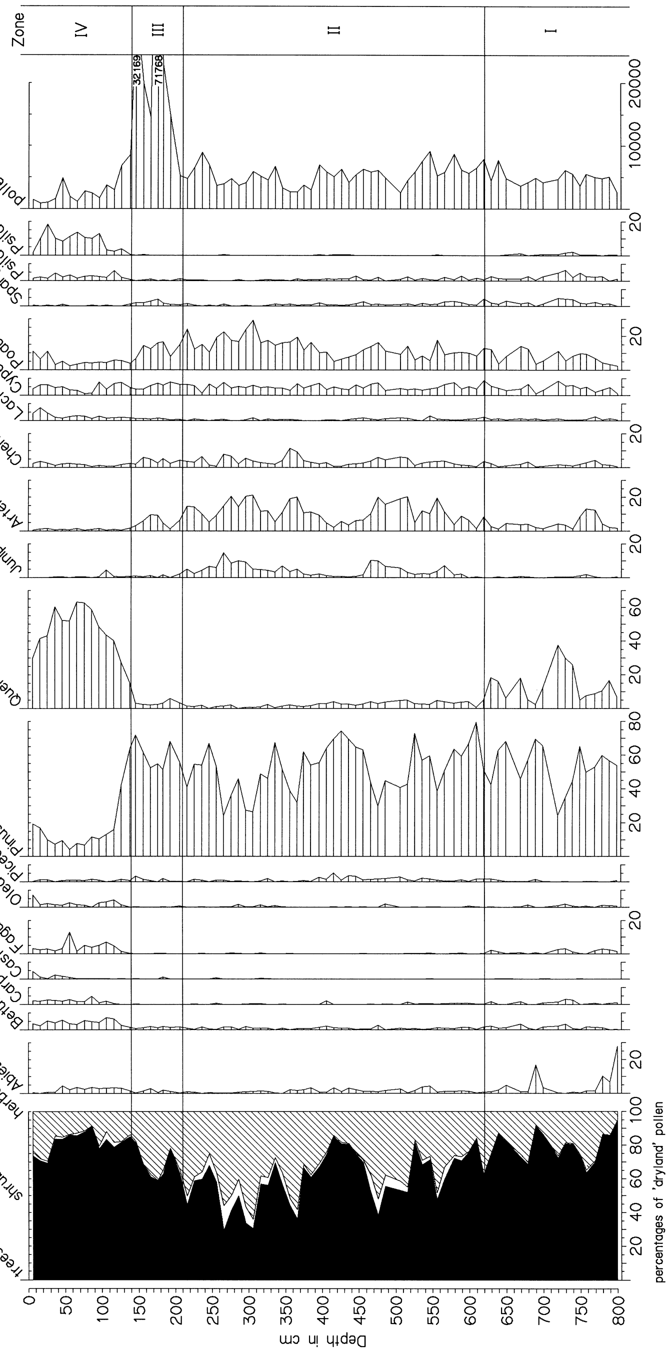

Fig. 5. Percentage pollen diagram (principal *taxa* only) for the core sequence RF93.77 in the Central Adriatic. Pollen sum excludes *Pinus*.

Zone III (210-140 cm) records a transition phase between assemblages dominated by herbaceous pollen and *Pinus* on the one hand, and assemblages dominated by angiosperm trees on the other.

Zone IV (140-0 cm) consists of assemblages with high percentages of *Quercus* pollen and continuous records for *Betula, Carpinus* and *Fagus*. From 60 cm upwards *Castanea* pollen were recorded continuously in low percentages.

It is clear from comparisons with the Lake Albano and Lago Grande di Monticchio pollen data referred to above that pollen *zone IV* represents the Holocene period, *zone III* corresponds to the last glacial-interglacial transition, and *zone II* to the Würmian glacial maximum. The pollen sequences obtained from all three records are entirely compatible when changes in the principal *taxa* are compared. This interpretation of the Central Adriatic record is also supported by a series of radiocarbon dates obtained from the profile (Tab. 2) and based on the AMS measurement of selected foraminiferal tests (Asioli *et al.* 1996; Lowe *et al.* 1996).

There is no equivalent in the Lake Albano PALB94.1E sequence, however, for *zone I* in the Adriatic sequence. The assemblages in this zone do compare reasonably well, though, with those published for the Monticchio sequence (Watts *et al.* 1996) and dated to earlier than 25,000 calendar years ago (i.e. pre-Würm cold maximum). That the basal sediments in core RF93.77 probably pre-date the Würmian cold maximum is also indicated by 5 radiocarbon assays obtained from between 394 and 810 cm depth in the profile, one of which provided a finite date of 39,040±800 BP, while the others gave infinite ages (Tab. 2).

There is a clear indication of a Younger Dryas vegetational revertance phase in the RF93.77 profile. The initial rise in *Quercus* percentages at a depth of *ca* 200 cm coincides with a fall in *Artemisia* and Poaceae/Gramineae pollen percentages. This is followed by a reduction in *Quercus* percentages and re-increase in *Artemisia* and Poaceae/Gramineae, these features occurring between *ca* 185 and 150 cm depth (Fig. 5). Radiocarbon dates limit this phase to sometime between 11,990±60 and 10,160±90 radiocarbon years BP (Tab. 2). It is highly likely, therefore, that this upper *Artemisia* peak reflects the Younger Dryas cooling, a conclusion supported by the strong resemblances between these pollen data and those from Albano, Monticchio and from the northern Apennines (Lowe 1992; Lowe & Watson 1993). The calibrated radiocarbon ages for this phase (13,384±100 to 10,940±60 BP) also compare favourably with the calendar age estimates of the comparable revertance phase in the Monticchio sequence (Watts *et al.* 1996, zone 2).

6. CENTRAL ADRIATIC CORE PAL94-8

Core PAL 94-8 was recovered by the CNR-IGM (Bologna) team from the Central Adriatic in a water depth of 150 m. Altogether 500 cm of sediment was recovered by coring, the top 490 cm of which were examined for pollen stratigraphy. The resulting pollen diagram (Fig. 6), consisting of 53 pollen spectra, has been divided into 3 pollen zones, which are further sub-divided into sub-zones. Note that the pollen sum excludes pollen of *Pinus.* The chronology of this sequence is supported by 6 radiocarbon dates and 3 diagnostic tephra layers of defined radiocarbon age. These data indicate that the sequence spans the last (approx.) 18,000 radiocarbon years, with the Younger Dryas/Holocene boundary situated at about 210 to 220 cm in the profile.

Tab. 2. Radiocarbon and calibrated dates (in years BP) from the CM92.43 and RF93.77 core sequences in the Central Adriatic, based on AMS measurement of foraminiferal tests[1].

Sample depth	Radiocarbon age	Calibrated age[2]
CORE CM92.43		
78.5-81.5	3,200±60	2,830±80
220-224	6,160±60	6,440±70
295.5-298.5	8,220±70	8,500±90
368.5-371.5	9,090±80	9,550±120
389.5-391.5	9,880±60	10,477±110
400-404	10,450±90	11,390±255
431.5-435.5	10,640±90	11,747±261
451.5-455.5	10,740±70	12,005±217
486.5-491.5	11,270±60	12,679±86
491.5-495.5	11,290±100	12,699±117
505-510	10,520±80	11,499±199
510-513	11,010±90	12,408±136
556.5-561.5	12,290±80	13,720±140
587.5-591.5	12,620±70	14,114±155
641.5-645.5	12,720±100	14,240±187
CORE RF93.77		
83-85	5,090±60	5,290±40
134-137	10,160±90	10,940±60
184-187	11,990±60	13,384±100
394-395	39,040±800	43,000
423-425	>41,700	-
657-658	>41,000	-
707-708	>42,900	-
808-810	>40,800	-

[1]Reservoir age applied to these data = 570 years.
[2]Calibrated using scheme of Stuiver & Reimer (1993).

Zone I (492-248 cm). This zone is characterised by high percentages of *Pinus* (30-50%), and very high percentages of pollen of herbaceous plants (*ca* 80%). Among the latter, Poaceae/Gramineae (including the *Hordeum* group), Cyperaceae and *Artemisia* figure most prominently, but Chenopodiaceae is also important. *Juniperus* percentages are also significant (10 to 20%) while *Abies* is recorded sporadically. *Quercus* percentages are low (3 to 5%) but the record is continuous. The curves for *Abies*, deciduous broadleaf *taxa* and *Artemisia* show cyclic behaviour throughout the zone. The zone is divided into two sub-zones:

Sub-zone Ia (492-372 cm). Recycled (rebedded) pollen are common in this sub-zone, while the contemporaneous pollen assemblage is dominated by pollen of Poaceae/Gramineae and hygrophilous *taxa*.

Sub-zone Ib (372-248 cm). This sub-zone is distinguished on the basis of increased representation of pollen of *Quercus ilex* type and *Olea,* and decreased representation of recycled pollen and pollen of hygrophilous *taxa*.

Zone II (248-208 cm). This is a transitional zone between the assemblages of *Zone I*, dominated by non-arboreal pollen, and those of *Zone III*, which are dominated by arboreal *taxa*. Arboreal pollen totals in *Zone II* (which exclude *Pinus* pollen) are between 35 and 55%. There is a significant decrease in *Juniperus* throughout the zone, while *Quercus* (up to 35%) increases. Chenopodiaceae pollen and *Artemisia* percentages remain quite prominent throughout. The zone is divided into 2 sub-zones:

Sub-zone IIa (248-222.5 cm). Features that distinguish this sub-zone include acme percentages for *Pinus*, the start of a sustained rise in *Quercus* percentages, the first notable increases in several deciduous tree *taxa* (e.g., *Carpinus orientalis/Ostrya, Corylus*, *Tilia* and *Fagus*), and a sharp decrease in *Juniperus*.

Sub-zone IIb (222.5-208 cm). There is a reduction in arboreal percentages in this sub-zone, but these recover at the top of the interval. Coincident with the reduction in tree pollen are increases in *Artemisia,* Poaceae/Gramineae and Chenopodiaceae pollen, while *Betula* pollen reach their maximum percentages in the diagram.

Zone III (208-025 cm). This zone is characterised by high arboreal pollen percentages, mainly of broadleaf types, since *Pinus* percentages decline sharply. Deciduous *Quercus* dominates the spectra, accompanied by a rich variety of other trees, with *Quercus ilex* type always present. Poaceae/Gramineae percentages are normally less than 10%, and *Artemisia* percentages are insignificant. The zone is divided into 5 sub-zones:

Sub-zone IIIa (208-185 cm). In this sub-zone *Quercus* first reaches the maximal values recorded in the profile (from 28 up to 45%). Some slight increases also occur in other tree *taxa*, such as *Corylus, Acer* and *Ulmus. Quercus ilex* type remain low, while *Artemisia* falls to <1%. Arboreal pollen percentages are high (60 to 80%) throughout the sub-zone.

Sub-zone IIIb (185-130 cm). Arboreal percentages remain high, and consist predominantly of pollen of *Quercus, Fagus, Carpinus betulus, Carpinus orientalis/Ostrya,* and *Quercus ilex* type. *Pinus* percentages are reduced from 40 to 20%. Poaceae/Gramineae percentages remain below 15%.

Sub-zone IIIc (130-88 cm). There is a progressive reduction in arboreal percentages in this sub-zone, and this zone shows increased representation of pollen of ruderal plants, associated with anthropogenic activities.

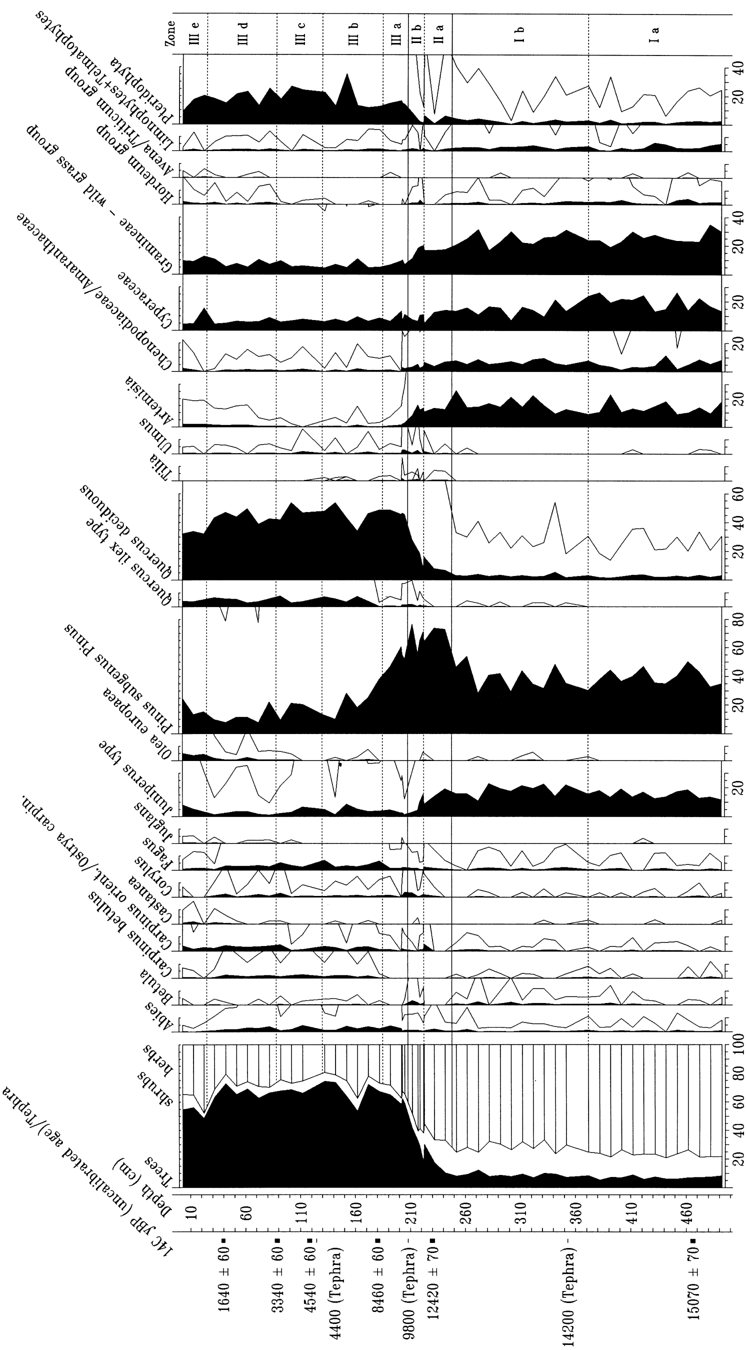

Fig. 6. Percentage pollen diagram (principal *taxa* only) for the core sequence PAL94-8 in the Central Adriatic. Pollen sum excludes *Pinus*.

Sub-zone IIId (88-25 cm). Further reductions in the proportion of arboreal pollen occur in this sub-zone, while the first sustained records of *Castanea, Juglans* and *Olea* also occur in this interval. There are increased representations of pollen of cereal and ruderal plants.

Sub-zone IIIe (25-002 cm). The uppermost few spectra in the profile contain increased values for *Olea* in particular, but also for *Castanea*, and *Juglans.*

The pollen-stratigraphic succession is clearly consistent with the radiocarbon dates, and compares well with the profiles from Lake Albano and Adriatic core RF93.77. Thus pollen *Zone I* represents the end of the last full glacial period, *Zone II* the last glacial-interglacial transition, and *Zone III* the Holocene. The progressive reduction in tree pollen totals and increased representation of *Castanea*, *Juglans* and *Olea* clearly shows that the sediment sequence extends through to post-Roman times.

7. CENTRAL ADRIATIC CORE CM92.43

Central Adriatic core CM92.43 was raised from a water depth of 250 m from a more central part of the Meso-Adriatic Basin than cores RF93.77 and PAL94.77. The resulting core sediment sequence is 975 cm long, but it clearly does not extend as far back in time as the RF93.77 sequence. Pollen-stratigraphical information has been obtained from 48 levels from this core sequence. A series of 15 radiocarbon dates, based on the AMS measurements of selected foraminiferal tests, have been obtained from the succession (Tab. 2). A detailed analysis of the foraminiferal assemblages has also been undertaken, and these complement the pollen-stratigraphical information generated by the PALICLAS investigations (Asioli *et al.* 1996, in press; Guerzoni *et al.* 1996, this volume).

The core succession has been divided into four pollen zones based on percentage changes (Fig. 7), and these principal pollen zone boundaries are also distinct within the CONISS plot for this profile.

Zone I (950-620 cm) has high *Pinus, Artemisia* and Poaceae/Gramineae percentages, with consistent but low percentages of *Juniperus* and Chenopodiaceae. This zone compares reasonably well with the Würmian cold stage pollen zones of Albano and Monticchio referred to earlier, so that the base of the *CM92.43* sequence is likely to be considerably less than 25,000 years in age.

Zone II (620-500 cm) shows increasing values for *Quercus* pollen percentages and much reduced values for *Juniperus, Artemisia* and Chenopodiaceae Poaceae/Gramineae values fluctuate and do not show a straightforward pattern.

Zone III (500-400 cm) shows reduced percentages for *Quercus*, but only marginally increased values for Chenopodiaceae and *Artemisia.* Nevertheless, this overall pattern of increase and then reduction in *Quercus* indicates that *Zones II* and *Zone III* together span the last glacial-interglacial transition, an interpretation which is fully supported by 11 of the radiocarbon dates obtained from between approximately 645 and 391 cm, the majority of which are internally consistent, and which date this part of the succession to between 12,720±100 and 9,880±60 radiocarbon years BP. Furthermore, an independent assessment of this sequence using foraminiferal assemblages has also led to a similar set of inferences for the sequence, with assemblages dominated by species indicative of cold and productive waters (e.g. *Globigerina bulloides* and *Globigerina quinqueloba*) characterising the sediments between *ca* 500 and 400 cm depth (Asioli *et al.* 1996).

Zone IV (400-0 cm) consists of assemblages dominated by *Quercus,* but also containing relatively high percentages of *Abies, Fagus* and *Betula,* with some *Carpinus* and (towards the top of the sequence) *Olea.* This zone clearly equates with the Holocene period.

8. CENTRAL ADRIATIC CORE RF93-30

Core RF93-30, a sediment core sequence of some 627 cm, was recovered by the CNR-IGM (Bologna) teams from the Central Adriatic in a water depth of *ca* 77 m (see Trincardi *et al.*1996, this volume). A total of 63 pollen spectra were constructed for the sequence (Fig. 8). Five radiocarbon dates indicate that the sequence provides a high-resolution record of the mid- and late-Holocene. The pollen diagram is considered, therefore, to equate with the later part of *Zone III* in the PAL 94-8 pollen diagram (Fig. 6), and thus the full sequence of RF93-30 is designated pollen *Zone III*, with three sub-zones equated with sub-zones IIIc, IIId and IIIe of the PAL94-8 profile.

Sub-zone IIIc (623-485 cm). This sub-zone has the highest percentages of arboreal pollen (up to 80%), with the dominant taxon being deciduous *Quercus*. Other important tree components include *Quercus ilex* type, *Fagus* and *Pinus.* Poaceae/Gramineae (including cereal type) values are low, and *Castanea, Juglans* and *Olea* are recorded only sporadically.

Sub-zone IIId (485-132 cm). There is a significant reduction, recovery and second reduction of arboreal percentages in this sub-zone. *Olea* pollen, and subsequently *Castanea* and *Juglans* pollen, become more frequent or increase in value in the later part of the sub-zone. Pollen of cereal and ruderal plants become more evident and continuous in the records.

Sub-zone IIIe (132-003 cm). This sub-zone is distinguished on the basis of records of *Zea mays,* as well as increased values of *Hordeum* group and *Avena-Triticum* group. This sub-zone is therefore likely to extend into the modern period.

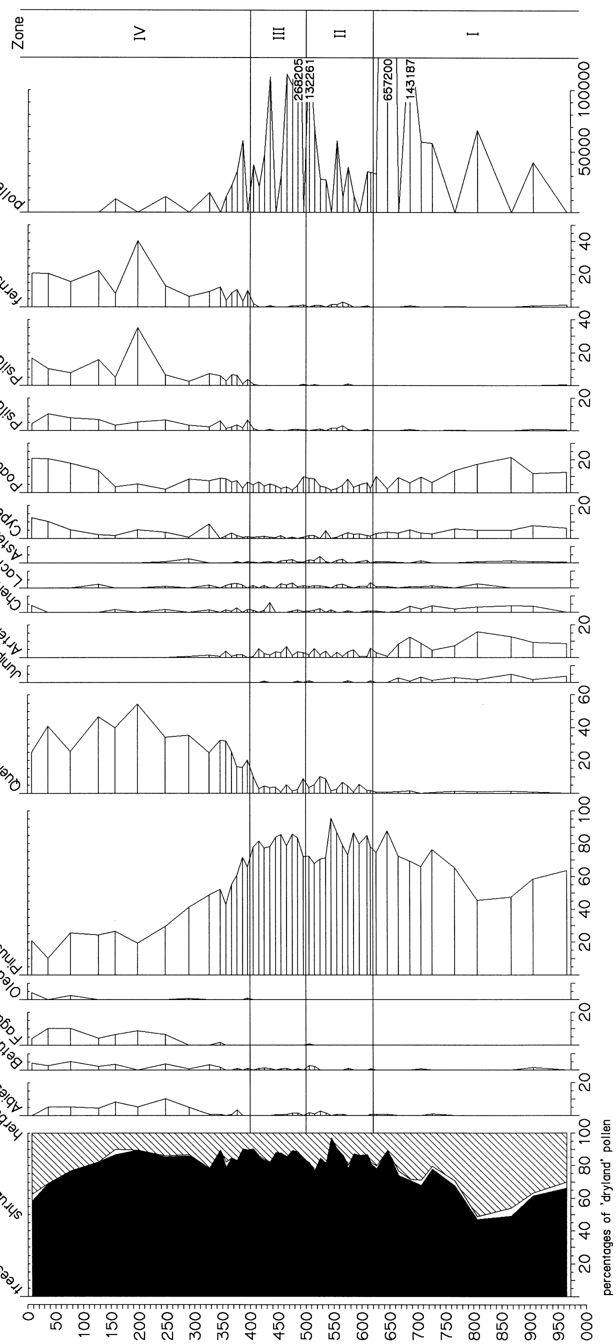

Fig. 7. Percentage pollen diagram (principal *taxa* only) for the core sequence CM92.43 in the Central Adriatic. Pollen sum excludes *Pinus*.

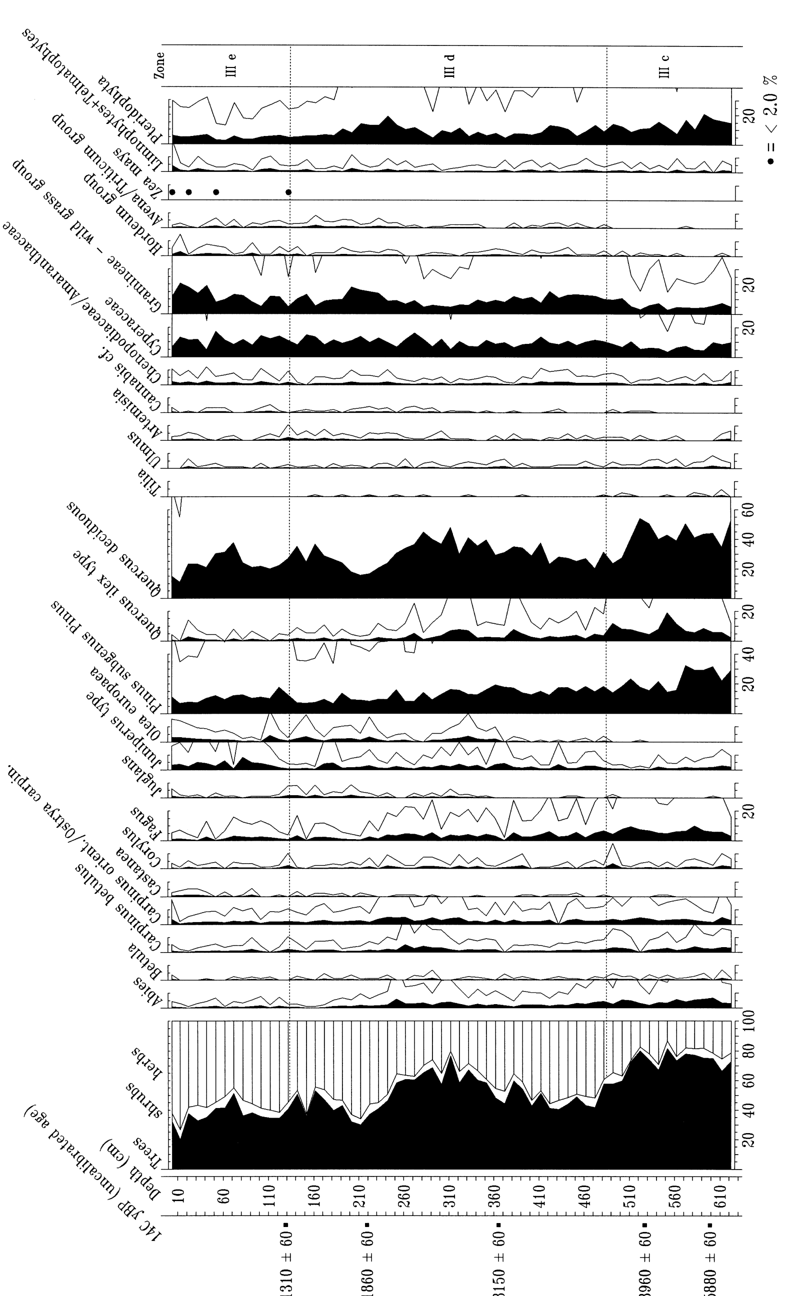

Fig. 8. Percentage pollen diagram (principal *taxa* only) for the core sequence RF93-30 in the Central Adriatic. Pollen sum excludes *Pinus*.

9. CONCLUSIONS

1. The pollen-stratigraphic data generated by the PALICLAS project can be internally correlated in a straightforward manner and can also be correlated in a direct fashion with data published from other parts of Italy (e.g., Alessio *et al*. 1986; Bottema 1974; Follieri *et al.* 1988, 1989; Francus *et al.* 1993; Frank 1969; Grüger 1975; Huntley *et al.* 1996; Kelly & Huntley 1991; Magri 1989, 1996; Magri & Follieri 1991; Magri & Sadori 1993; Rossignol-Strick *et al.* 1995), especially with records spanning the last 25,000 years from Lago Grande di Monticchio (Watts *et al*. 1996), high resolution records of the last glacial-interglacial transition from the northern Apennines (Lowe 1992; Ponel & Lowe 1992; Lowe & Watson 1993; Lowe *et al.* 1994; Watson *et al*. 1994), and palynological, dinoflagellate and foraminiferal data obtained from other core locations in the Adriatic Sea (Bottema & Van Straaten 1966; Jorissen *et al*. 1993; Rossignol-Strick *et al.* 1992; Zonneveld 1995, 1996; Zonneveld & Boessenkool 1996; Asioli *et al.* 1996). This high degree of compatibility strongly suggests that pollen stratigraphy can be used as a basis for inter-regional correlation between widely separated sites in peninsular Italy, and might thereby provide a 'first order' or 'rangefinder' chronology for the principal biostratigraphic boundaries upon which the correlations are based. Where radiometric dates and other chronological information are available (e.g. the 'calendar year' timescale of Lago Grande di Monticchio, based upon counting of laminated sediments - Zolitschka & Negendank 1996; Watts *et al*. 1996), they provide support for this contention.

2. The results also demonstrate that pollen stratigraphy provides a useful basis for correlating between marine and terrestrial records. One important point to emerge from the collective data now assembled is that the abrupt climatic perturbations of the last glacial-interglacial transition are not only clearly discernible in the pollen records from Italy and the central Adriatic, but that the climatic signals appear to be equally pronounced in both the marine and terrestrial realms (Lowe *et al.* 1996). Whether the climatic history of Italy and the Adriatic is directly comparable with that of northern Europe remains to be established. If, however, it can be shown that there were close parallels between developments in the Atlantic seaboard of Europe and the Mediterranean region then this would mean either (i) that the influence of North Atlantic circulation changes extended into the Mediterranean region, or (ii) that both the North Atlantic and Mediterranean regions were responding to a different but common climatic forcing mechanism. This is clearly an important issue to resolve, and the new data generated by the PALICLAS project significantly add to the growing body of data providing new insights into the nature and causes of abrupt climatic changes in the Mediterranean region during the last glacial-interglacial transition (*cf* Reille & Lowe 1993; De Beaulieu *et al*. 1994; Bottema 1995; Rossignol-Strick 1995).

3. If the chronological deductions outlined earlier are correct, then the longest sequence recovered so far from the Lake Albano basin (PALB94.1E) provides a sedimentary sequence that spans most of the interval from Oxygen Isotope Stage

2 to the present day. On the basis of comparisons with the Monticchio sequence, we estimate that the sediments span approximately the last 30,000 years. The longest sequence recovered so far from the Central Adriatic is core RF93.77, the base of which, according to the pollen-stratigraphic correlations with the Monticchio record, must pre-date 25,000 BP. How much older is difficult to determine at present, but if the radiocarbon date from depth 395-394 cm is to be believed (Tab. 2), the base of the sediment sequence may pre-date 40,000 years ago. Core CM92.43 from the Central Adriatic appears to contain a very high resolution sequence of the last glacial-interglacial transition - the highest published from this region so far - with the Younger Dryas episode (pollen zone CM92.43-III - Fig. 7) alone being represented by a 1m-thick body of sediment.

4. The pollen-stratigraphic records for the last (Würm) cold stage from Lake Albano (Pollen Zone PALB94.1E-I, Figs 1 and 2) and from the Central Adriatic (Pollen *Zone RF93.77-II* - Fig. 5 and Pollen *Zone PAL94-8-I*, Fig. 6) all show evidence for cyclic fluctuations in the principal pollen *taxa*. There are also indications of very rapid changes affecting a range of proxy records during this period, including diatoms, plant pigments and magnetic susceptibility measures.

5. The interpretations presented in this paper are almost entirely based upon non-quantified (relative) estimates of climate variation. Very few attempts have been made so far to quantify late Quaternary palaeoclimatic variations in the Mediterranean region. Some attempts have been made to derive quantified climate estimates from palynological data using pollen-climate response surfaces (Watts *et al.* 1996), and the PALICLAS pollen data are being employed in this way, in collaboration with J. Guiot at the Université d'Aix-Marseille (Juggins & Lowe, unpublished). However, as has been noted by other research teams, the results are seriously limited by the fact that there are no modern analogues for the majority of the pollen assemblages encountered in the late Würm and Lateglacial successions from Italy (*cf* Huntley & Prentice 1993; Huntley 1993). Quantitative estimates of mean annual temperature and precipitation values from the PALB94.1E record (Lake Albano) are currently being calculated by S. Juggins and J. Guiot (in preparation) using different combinations of taxon weightings and various analogue assumptions in the pollen response surface model.

6. Pollen concentration variations within the Central Adriatic core records show discrete, high magnitude variations that appear to reflect changing palaeoenvironmental conditions or sedimentary processes. More detailed examination of these data in conjunction with lithostratigraphical information is in progress in order to determine whether the fluctuations reflect the combined effects of rising sea level and migrating submarine flow regimes. In 2 out of the three profiles studied, the transition from the last cold stage to the Holocene appears to have created the sedimentary conditions in the Meso-Adriatic basin whereby pollen accumulation was greatly enhanced.

7. Several of the records provide high-resolution records of the Holocene, and RF93-30 in particular shows an extended record of the mid- to late-Holocene. All

of the Holocene records show clear evidence for widespread deforestation from the Mesolithic period onwards. Those that extend through to the late Holocene also show evidence for the increasing impact of humans from the Neolithic to modern times. There are clear pollen-stratigraphic signatures representing the Roman and modern periods. The history is not one of continuous, progressive increasing influence, however, for there appear to have been significant fluctuations in the magnitude of human influences on the vegetation and the landscape. The precise sequence of events, and the magnitude of the impacts during each stage, are key aims of the PALICLAS project, and will form the focus of multidisciplinary data comparisons currently under way.

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REFERENCES

Accorsi, C.A., M. Bandini Mazzanti, J.J. Lowe, A. Mercuri, C. Rivalenti, P. Torri, & S. Van der Kaars. 1995. Late Quaternary pollen diagrams from the central Adriatic Sea (part of the 'paliclas' multidisciplinary project. *Giornale Botanico Italiano*, 129: 1.

Alessio, M., L. Allegri, F. Bella, G. Calderoni, C. Cortesi, G. Dal Pra, D. De Rita, D. Esu, M. Follieri, S. Improta, D. Magri, B. Narcisi, V. Petrone & L. Sadori. 1986. ^{14}C dating, geochemical features, faunistic and pollen analyses of the uppermost 10 m core from Valle di Castiglione (Rome, Italy). *Geologica Romana*, 25: 287-308.

Asioli, A., F. Trincardi, A. Correggiari, L. Langone, L. Vigliotti, S. Van der Kaars & J.J. Lowe. (1996). The late-Quaternary deglaciation in the central Adriatic basin. *Il Quaternario*: in press.

Bottema, S. 1974. Implications of a pollen diagram from the Adriatic Sea. *Geologie en Mijnbouw*, 53: 401-405.

Bottema, S. 1995. The Younger Dryas in the Eastern Mediterrranean.. *Quaternary Science Reviews*, 14: 883-892.

Bottema, S. & L.M.J.U. van Straaten. 1966. Malacology and palynology of two cores from the Adriatic sea floor. *Marine Geology*, 4: 553-564.

Calanchi, N., E. Dinelli, F. Lucchini & A. Mordenti. 1996. Chemostratigraphy of late Quaternary sediments from Lake Albano and central Adriatic Sea cores (PALICLAS Project). In: Guilizzoni, P. & F. Oldfield (Eds), *Palaeoenvironmental Analysis of Italian Crater Lake and Adriatic Sediments (PALICLAS)*. Mem. Ist. ital. Idrobiol., 55: 247-263.

Chondrogianni, C., D. Ariztegui, F. Niessen, C. Ohlendorf & G.S. Lister. 1996. Late Pleistocene and Holocene sedimentation in Lake Albano and Lake Nemi (central Italy). In: Guilizzoni, P. & F. Oldfield (Eds), *Palaeoenvironmental Analysis of Italian Crater Lake and Adriatic Sediments (PALICLAS)*. Mem. Ist. ital. Idrobiol., 55: 23-38.

De Beaulieu, J-L., V Andrieu, J.J. Lowe, P. Ponel, & M. Reille. 1994. The Weichselian Lateglacial in southwestern Europe (Iberian Peninsula, Pyrenees, Massif Central, Northern Apennines). *Journal of Quaternary Science*, 9: 101-108.

Follieri, M., D. Magri & L. Sadori. 1988. 250,000 year pollen record from Valle di Castiglione (Roma). *Pollen et Spores*, 30: 329-356.

Follieri, M., D. Magri & L. Sadori. 1989. Pollen stratigraphical syntheses from Valle di Castiglione (Roma). *Quaternary International*, 3/4: 81-84.

Francus, P., S. Leroy, I. Mergeai & G. Seret. 1993. A multidisciplinary study of the Vico Maar sequence (Latium, Italy): part of the last cycle in the Mediterranean area. Preliminary results. *Lecture Notes in Earth Sciences,* 49: 289-304.

Frank, A.H.E. 1969. Pollen stratigraphy of the Lake of Vico (Central Italy). *Palaeogeography, Palaeoclimatology, Palaeoecology,* 6: 67-85.

Grüger, E. 1975. Pollenanalyse spätpleistozäner und holozäner Sedimente aus der Adria. *Geologisches Jahrbuch*, A29: 3-32.

Guerzoni, S., R. Portaro, F. Trincardi, E. Molinaroli, L. Langone, A. Correggiari, L. Vigliotti, M. Pistolato, G. De Falco & V. Boccini. 1996. Statistical analyses of grain-size, geochemical and mineralogical data in core CM92-43, Central Adriatic basin. In: Guilizzoni, P. & F. Oldfield (Eds), *Palaeoenvironmental Analysis of Italian Crater Lake and Adriatic Sediments (PALICLAS)*. Mem. Ist. ital. Idrobiol., 55: 231-245.

Huntley, B. 1993. The use of climate response surfaces to reconstruct palaeoclimate from Quaternary pollen and plant macrofossil data. *Philosophical Transactions of the Royal Society of London, Series B - Biological Sciences,* 341: 215-223.

Huntley, B., J Allen & W.A. Watts. 1996. Glacial, late-glacial and Holocene environment and vegetation at Lago Grande di Monticchio (Southern Italy). In S.P. Evans, S. Frisia, A. Borsato, M.B. Cita, M. Lanzinger, C. Ravazzi & B. Sala (Eds), *Conference Abstracts: Late-glacial and early Holocene climatic and environmental changes in Italy* (Trento, Italy, February 1996), 104-107.

Huntley, B. & I.C. Prentice. 1993. Holocene vegetation and climates of Europe. In: Wright, H.E., J.E. Kutzbach, T.III Webb, W.F. Ruddiman, F.A. Street-Perrott & P.J. Bartlein (eds.), *Global Climates Since the Last Glacial Maximum,* University of Minnesota Press, Minneapolis, 136-168.

Jorissen, F.J., A. Asioli, A.M.Borsetti, L. Capotondi, J.P. de Visser, F.J. Hilgen, E.J. Rohling, K. Van der Borg, C. Vergnaud-Grazzini & W.J. Zachariasse. 1993. Late Quaternary central Mediterranean biochronology. *Marine Micropalaeontology,* 21: 169-189.

Kelley, M.G. & B. Huntley. 1991. An 11,000-year record of vegetation and environment from Lago di Martignano, Latium, Italy. *Journal of Quaternary Science,* 6: 209-224.

Lowe, J.J. 1992. Lateglacial and early Holocene lake sediments from the Northern Apennines, Italy - pollen stratigraphy and radiocarbon dating. *Boreas*, 21: 193-208.

Lowe, J.J., C.A. Accorsi, A. Asioli, S. Van der Kaars & F. Trincardi. (1996). Pollen-stratigraphical records of the last glacial-interglacial transition (ca 14-9 ^{14}C ka BP) from Italy: a contribution to the PALICLAS project. *Il Quaternario:* in press.

Lowe, J.J., N.P. Branch & C. Watson. 1994. The vegetational history of the Northern Apennines during the Holocene. *Monografie di Natura Bresciana,* 20: 153-168.

Lowe, J.J. & C. Watson. 1993. Lateglacial and early Holocene pollen stratigraphy of the northern Apennines, Italy. *Quaternary Science Reviews,* 12: 727-738.

Magri, D. 1989. Palinologia di sedimenti lacustri olocenici a Lagaccione, presso il Lago di Bolsena. *Giornale Botanico Italiano,* 123: 297-306.

Magri, D. 1996. La sequenza pollinica tardo-quaternaria di Lagaccione, presso il Lago di Bolsena. *Giornale Botanico Italiano:* 130-322.

Magri, D. & M. Follieri. 1991. Primi risultati delle analisi polliniche sui sedimenti lacustri olocenici della Piana del Fucino. A*tti Conv. Il Fucino nell'Antichità, Avezzano:* 45-53.

Magri, D. & L. Sadori. 1993. A new pollen record from Lago di Vico. *Abstracts of INQUA Symposium, Quaternary Stratigraphy in volcanic areas* (Rome, September 20-22, 1993), 46.

Ponel, P. & J.J. Lowe. 1992. Coleopteran, pollen and radiocarbon evidence from the Prato Spilla 'D' succession, N. Italy. *Comptes Rendus de l'Academie des Sciences, Paris,* t. 315, ser. II: 1425-1431.

Reille, M. & J.J. Lowe. 1993. A re-evaluation of the vegetation history of the eastern Pyrenees (France) from the end of the last glacial to the present. *Quaternary Science Reviews,* 12: 47-77.

Rossignol-Strick, M. 1995. Sea-land correlation of pollen records in the Eastern mediterranean for the glacial-interglacial transition: biostratigraphy versus radiometric time-scale. *Quaternary Science Reviews,* 14: 893-916.

Rossignol-Strick, M., N. Planchais, M. Paterne & D. Duzer. 1992. Vegetation dynamics and climate during the deglaciation in the south Adriatic basin from a marine record. *Quaternary Science Reviews,* 11: 415-423.

Stuiver, M. & P.J. Reimer. 1993. Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program. *Radiocarbon,* 35: 215-230.

Trincardi, F., A. Correggiari & M. Roveri. 1994. Late Quaternary transgressive erosion and deposition in a modern epicontinental shelf: the Adriatic semi-enclosed basin. *Geo-Marine Letters,* 14: 41-51.

Trincardi, F., A. Cattaneo, A. Asioli, A. Correggiari & L. Langone. 1996. Stratigraphy of the late-Quaternary deposits in the central Adriatic basin and the record of short-term climatic events. In: Guilizzoni, P. & F. Oldfield (Eds), *Palaeoenvironmental Analysis of Italian Crater Lake and Adriatic Sediments (PALICLAS)*. Mem. Ist. ital. Idrobiol., 55: 39-70.

Van der Kaars, S., J.J. Lowe, A. Accorsi, M. Bandini, A. Mercuri & P. Torri. 1995. Pollen stratigraphy of Late Quaternary successions from the North Adriatic and from two crater lakes near Rome (part of the PALICLAS multi-proxy investigation). *Terra Nostra* (Schriften der Alfred-Wegener-Stiftung), 2/95: INQUA Abstracts, pp. 283.

Watson, C., N.P. Branch & J.J. Lowe. 1994. The chronology of human interference in the landscape of the northern Apennines during the Holocene. *Monografie di Natura Bresciana,* 20: 169-188.

Watts, W.A., J.R.M. Allen, B. Huntley & S.C. Fritz. 1996. Vegetation history and climate of the last 15,000 years at Laghi di Monticchio, southern Italy. *Quaternary Science Reviews,* 15: 113-132.

Zolitschka, B. & J.F.W. Negendank. 1996. Sedimentology, dating and palaeoclimatic interpretation of a 76.3 ka record from Lago Grande di Monticchio, southern Italy. *Quaternary Science Reviews,* 15: 101-112.

Zonneveld, K.A.F. 1995. Palaeoclimatical and palaeoecological changes during the last deglaciation in the Eastern Mediterranean: implications for dinoflagellate ecology. *Review of Palaeobotany and Palynology,* 84: 221-253.

Zonnefeld, K.A.F. 1996. Palaeoclimatic reconstruction of the last deglaciation (18-8 ka BP) in the Adriatic Sea region: a land-sea correlation based on palynological evidence. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 122: 89-106.

Zonnefeld, K.A.F. & K.P. Boessenkool. 1996. Palynology as a tool for land-sea correlation; an example from the eastern Mediterranean region. In: J.T Andrews, W.E.N. Austin, H. Bergsten & A.E. Jennings (Eds), *Late Quaternary Palaeoceanography of the North Atlantic Margins,* Geological Society Special Publication No. 111: 351-357.