Il Quaternario
Italian Journal of Quaternary Sciences
9(2), 1996, 627-642

POLLEN-STRATIGRAPHICAL RECORDS OF THE LAST GLACIAL-INTERGLACIAL TRANSITION (CA. 14 - 9 ^{14}C ka BP) FROM ITALY: A CONTRIBUTION TO THE *PALICLAS* PROJECT*

J.J. Lowe (1) **- C.A. Accorsi** (2) **- A. Asioli** (3) **- S. Van Der Kaars** (1)** **- F. Trincardi** (3)
(1)Centre for Quaternary Research, Royal Holloway, University of London, Dept. of Geography, Egham, Surrey, U.K.
(2)Istituto ed Orto Botanico, Università di Modena, Modena, Italy
(3)CNR Istituto Geologia Marina, Bologna, Italy

RIASSUNTO - *Stratigrafie polliniche per l'ultima transizione glaciale-interglaciale (ca. 14 - 9 ^{14}C ka BP) in Italia: un contributo per il progetto* PALICLAS - Il Quaternario *Italian Journal of Quaternary Sciences,* **9**(2), 1996, 627-642 - Vengono presentate stratigrafie polliniche che comprendono l'ultima transizione glaciale-interglaciale (qui definita come il periodo compreso tra ca. 14 e 9 ^{14}C ka BP) per tre contesti geografici e geologici in Italia. In molti casi i dati dispongono di radiodatazioni e possono essere paragonati direttamente con dati ottenuti da altri *proxies* paleoambientali. *(1) Contesto montano, Italia settentrionale:* Vengono brevemente riassunte le evidenze ottenute da due successioni accumulatesi in piccoli bacini lacustri (*kettle holes*) nell'Appennino ligure-emiliano. Questi dati, che comprendono informazioni entomologiche dal genere *Coleoptera,* sono pubblicati altrove. I risultati indicano l'estensione dei cambiamenti paesaggistici alle alte quote nell'Italia settentrionale durante l'ultima transizione glaciale-interglaciale e le severe condizioni climatiche durante il Dryas III. *(2) Lago vulcanico vicino a Roma:* Viene presentato un nuovo profilo pollinico dal Lago di Albano (Roma, Lazio). La sequenza è stata indagata nell'ambito del progetto CEE PALICLAS da ricercatori provenienti da Zurigo, Bologna, Modena, Verbania Pallanza, Liverpool e Londra. La sequenza sembra estendersi dal *Oxygen Isotope Stage 2* all'attuale. In particolare, viene presentata la parte della sequenza che comprende l'ultima transizione glaciale-interglaciale (ca. 14 - 9 ^{14}C ka BP); i dati vengono quindi confrontati con altre sequenze dall'Italia meridionale, in particolare dal Lago Grande di Monticchio. La frazione olocenica è stata descritta altrove in riassunti congressuali sotto i nomi di Van der Kaars ed Accorsi. Il Dryas III è chiaramente visibile in questi dati. *(3) Successioni sedimentarie marine, Adriatico centrale:* Una serie di carotaggi, alcuni ottenuti nell'ambito del progetto PALICLAS, sono stati estratti da sedimenti marini dal gruppo di Geologia Marina di Bologna. Vengono presentate sequenze polliniche e stratigrafiche ad alta risoluzione originali per l'ultima transizione glaciale-interglaciale, ottenute da 2 carotaggi nell'Adriatico centrale. Dopo la presentazione dei dati, vengono discussi due aspetti di più ampio respiro: (a) il grado di consistenza tra i vari tipi di dati, sia in Italia sia nel contesto più ampio della regione mediterranea, ed il grado con cui possono indicare le marcate variazioni climatiche responsabili dei cambiamenti bio-stratigrafici registrati nei dati; (b) il grado di confrontabilità tra i dati Italiani e le sequenze bio-stratigrafiche ad alta risoluzione da siti a carattere oceanico nell'Europe nord-occidentale.

ABSTRACT - *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 *Italian Journal of Quaternary Sciences,* **9**(2), 1996, 627-642 - Pollen-stratigraphical records, spanning the last glacial-interglacial transition (here defined as the period between ca. 14 and 9 ^{14}C ka BP), are presented for three geographical and geological contexts in Italy. In most instances the records are supported by radiocarbon dates and can be compared directly with data obtained using other palaeoenvironmental proxies. *(1) Mountain context, north Italy:* The evidence obtained from two successions that have accumulated in small lakes or kettle hole basins in the northern (Ligurian-Emilian) Apennines is briefly reviewed. These records, which include some coleopteran data, have already been published by Lowe and Lowe with others. The data indicate the scale of landscape changes in upland northern Italy during the last glacial-interglacial transition, and the severity of climatic conditions during the Younger Dryas chronozone. *(2) Crater lake, near Rome:* A new profile is available from Lago Albano (Lazio) near Rome. This crater lake sequence is being investigated as part of the multi-proxy PALICLAS project funded by the EU under the joint efforts of teams from (*inter alia*) Zürich, Bologna, Modena, Verbania Pallanza, Liverpool and London. The record appears to span the interval from Oxygen Isotope Stage 2 to the present time. Here we describe the part of the sequence spanning the last glacial-interglacial transition, which can be compared with other records from southern Italy, especially that from Lago Grande di Monticchio. The Holocene parts of the records are outlined in Congress abstracts under the names of Van der Kaars and Accorsi. The Younger Dryas is clearly discernible in these records. *(3) Marine sediment successions, Central Adriatic:* A number of cores have been obtained from the sea-bottom sediments of the Adriatic by the marine geology group at Bologna, some of which were recovered as part of the PALICLAS project. High resolution pollen-stratigraphical records of the last glacial-interglacial transition obtained from two cores in the Central Adriatic are presented here for the first time. It will be shown that the records are directly comparable with those obtained from terrestrial sequences, and they therefore reveal the potential for land-sea correlations using pollen stratigraphy. Following the presentation of these various data-sets, two wider issues are discussed: (a) the degree of consistency between the various records, both within Italy and in the wider context of the Mediterranean region (see the literature), and the extent to which they indicate that marked climatic variations were responsible for the biostratigraphic changes recorded; and (b) the degree of comparison between the Italian records and high-resolution biostratigraphical data from sites in oceanic NW Europe.

Keywords: Lateglacial, Younger Dryas, Bølling-Allerød interval, pollen stratigraphy, foraminiferal assemblages, radiocarbon dating, volcanic maar lake sequence, Central Adriatic
Parole chiave: Tardi-glaciale, Dryas III, intervallo Bølling-Allerød, stratigrafia pollinica, assemblaggi di foraminiferi, radiodatazioni; sequenze sedimentarie da laghi vulcanici, Adriatico centrale

---

* Invited paper / *Comunicazione ad invito.*

** Present Address: Dept. of Geography & Environmental Science, Monash University, Clayton, Victoria 3168, Australia.

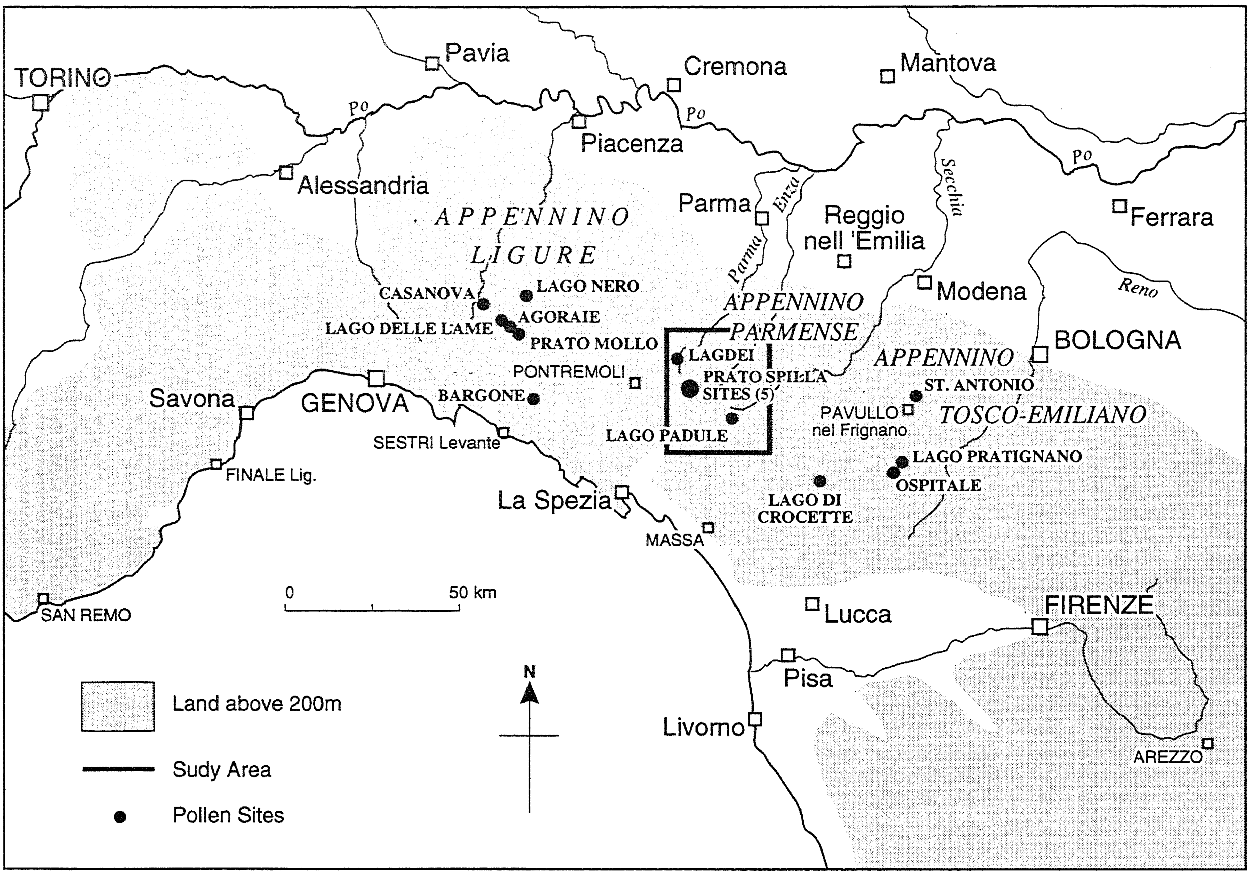

Fig. 1 - Location of Prato Spilla sites in the northern Apennines.
Posizione dei siti di Prato Spilla, Appennino settentrionale.

1. INTRODUCTION

Until fairly recently the view was held that the Younger Dryas climatic deterioration, inferred from the evidence of many sites throughout oceanic NW Europe and dated in radiocarbon years to approximately 11-10 ka BP, had little impact on southern Europe, since a number of stratigraphical sequences investigated in the region provided little or no evidence for significant climatic cooling during that period (*e.g.* Watts, 1980; 1986; Turner & Hannon, 1988). Recent research has led to a re-evaluation of this assumption, however, for clear records of a very sharp deterioration in climate, which correlates approximately with the Younger Dryas episode of NW Europe, have been reported from Italy, Spain and southern France (Lowe *et al.,* 1994a; Watts *et al.,* 1996), as well as from several parts of the eastern Mediterranean (Bottema, 1995; Rossignol-Strick, 1995). Reasons why evidence for a Younger Dryas climate signal may have been overlooked or misinterpreted in some previous research include (a) the limited stratigraphical resolution employed in some of the earlier studies, and (b) the fact that a marked hiatus is common in the sediment records of many sites in southern Europe, often resulting in the absence of records for part or all of the Younger Dryas and early Holocene time intervals (*e.g.* Reille & Lowe, 1993). Such marked hiatuses possibly reflect the effects of the arid conditions that may have dominated in the region during those times (De Beaulieu *et al.*, 1994). Here we report on pollen-stratigraphical and associated records from five sediment sequences which span the last glacial-interglacial transition and which are free of these particular problems. Two of the sites are located in the northern Apennines, one is the volcanic crater lake of Lago Albano near Rome, and two are core sites in the Central Adriatic. A distinct Younger Dryas signal has been found in each of the five stratigraphical profiles, and the fact that these records have been obtained from three very different sedimentary contexts (small kettle holes in mountainous terrain, a marine shelf basin and a maar lake basin), from widely-separated localities and at varying altitudes, suggests that probably the whole of peninsular Italy was markedly cooler than today during the Younger Dryas. This point will be developed in this paper. A wider question, however, is the extent to which the sequence of climatic changes in Italy during the last glacial-interglacial transition as a whole (ca. 14-9 ^{14}C ka BP) conforms with that that has been inferred from the stratigraphical evidence from oceanic NW Europe. This issue is an important one, since it has a bearing on theories concerning the causal mechanisms of climatic changes during the last glacial-interglacial transition, a point that will be elaborated in the final section of this paper.

2. SITES FROM THE NORTHERN APENNINES

The pollen-stratigraphic data available from 23 post-Würmian successions in the northern Apennines have been reviewed by Lowe *et al.* (1994b) and Watson *et al.* (1994). They report only three biostratigraphical records from the whole of the northern Apennines that span the last glacial-interglacial transition: Lagdei (Bertoldi, 1980), Prato Spilla 'C' (Lowe, 1992) and Prato Spilla 'D' (Ponel & Lowe, 1992). All three sites lie within presumed late Würmian moraine ridges in the Appennino Parmense in western Emilia-Romagna (Fig. 1). Radiocarbon dates are presently available only for the Prato Spilla sites and thus the evidence from these sites has been used to define regional pollen assemblage zones for the Appennino Parmense (Lowe, 1992; Lowe & Watson, 1993).

The most complete record for the last glacial-interglacial transition from the Apennines that is supported by a series of radiocarbon dates is that of Prato Spilla 'C' (Fig. 2). The Prato Spilla 'D' record (Fig. 3) does not extend to the early part of the Lateglacial period, but is particularly significant, since it is the only known exposure of Lateglacial sediments in the northern Apennines. Several radiocarbon dates have been obtained from this site which are free of the problems of sediment mixing that can be introduced when using coring devices. Moreover, coleopteran data derived from this sequence provide independent inferences on the former vegetational cover and palaeoclimatic history that are consistent with the interpretations based upon the pollen data (Ponel & Lowe, 1992). Taken as a whole, the biostratigraphical data and radiocarbon dates from the Prato Spilla sites are internally consistent and, in summary, suggest the following stages in vegetational change during the last glacial-interglacial transition:

a) *Lateglacial Interstadial (Bølling-Allerød interval):* The earliest vegetational phase recorded in the region is characterised by a *Pinus-Abies* pollen assemblage. The oldest date obtained for this part of the succession is from the Prato Spilla 'C' sequence (12,360 ± 55 y BP), and this provides a minimum age for the onset of this phase in the Appennino Parmense. This phase is succeeded by one in which *Quercus, Tilia, Corylus* and *Abies* pollen are recorded in increased percentages. The coleopteran data from Prato Spilla 'D' support the notion that a mix of angiosperm and coniferous trees were present in the region during the Lateglacial Interstadial, since they include remains of beetles that are dependent upon tree bark, leaves, leaf litter or active or decaying wood (Ponel & Lowe, 1992). The end of this period is dated to earlier than 11.5 ^{14}C ka BP at Prato Spilla 'C' but to ca. 11 ^{14}C ka BP at Prato Spilla 'D' (Lowe & Watson, 1993).

b) *Younger Dryas Stadial:* A marked Younger Dryas vegetation 'revertance' phase is recognised in the Prato Spilla successions. Very high percentages of non-arboreal pollen, notably including *Artemisia,* Caryophyllaceae, *Rumex,* Chenopodiaceae and Poaceae, and markedly reduced percentages of arboreal pollen (especially *Quercus* and *Corylus*) characterise the pollen assemblages. This part of the sequence is dated approximately to between 11.5 and 10.5 ^{14}C ka BP at Prato Spilla 'C' but to between ca. 11 and 10.2 ^{14}C ka BP at Prato Spilla 'D'.

c) *Early Holocene:* Following the harsh environment of the Younger Dryas, rapid climatic improvement in the northern Apennines at the beginning of the Holocene is reflected in sudden increases in pollen percentages of (successively) *Quercus, Betula, Fraxinus, Corylus* and *Abies.* This succession is also found in the early Holocene records from other sites in the northern Apennines (Lowe & Watson, 1993). The onset of this phase is dated approximately to 10.5 ^{14}C ka BP at Prato Spilla 'C' and to ca. 10.2 ^{14}C ka BP at Prato Spilla 'D'. There is also evidence from several sites in Liguria and Emilia-Romagna, in the form of sediment hiatuses or coarse sand lenses, for exceptionally dry conditions in the northern Apennines during the early Holocene (Lowe & Watson, 1993; Lowe *et al.*, 1994b).

The differences in age estimates between the Prato Spilla 'C' and 'D' sites for the onset and close of the vegetational revertance phase that is interpreted as representing the Younger Dryas makes it difficult to assign precise ages to these boundaries. A further limitation is the paucity of quantified estimates of the climatic variations that are considered to have occurred in the northern Apennines during the last glacial-interglacial transition. Both of these difficulties are discussed in a later section of this paper following the presentation of the new pollen-stratigraphic data from Lago Albano and the Central Adriatic.

3. LAGO ALBANO, COLLI ALBANI, CENTRAL ITALY

Lago Albano, the deepest of the volcanic craters in the Colli Albani (current water depth in excess of 175 m), lies some 25 km to the south-east of Rome (Fig. 4). The site is currently being investigated as part of a major, inter-disciplinary study within the PALICLAS (1) research project funded by the European Union. The bathymetry of the site is well known through a series of seismic surveys (Niessen *et al.*, 1993) and a transect of boreholes along which 16 piston cores have been recovered by ETH Zürich from 6 localities within the lake using a Kullenberg coring device(2). The record discussed in this paper (borehole PALB 94.1E) was obtained from the north-central part of the lake, at a water depth of about 70 m (Fig. 4). Over 1300 cm of sediment were recovered from this station, comprising interbedded units of silts and muds, occasionally laminated, and occasionally calcite- or diatom-rich. At the base of the sequence is a

---

(1) PALICLAS is a major inter-disciplinary research project involving laboratories in Italy, Switzerland and the UK, co-ordinated by F. Oldfield (PAGES Office, Bern) and funded by the EU (contract no. EU5V-CT93-0267).

(2) Seismic and coring work at Lago Albano within the PALICLAS project has been undertaken by D. Ariztegui and associates from the Geologisches Institut, ETH Zürich.

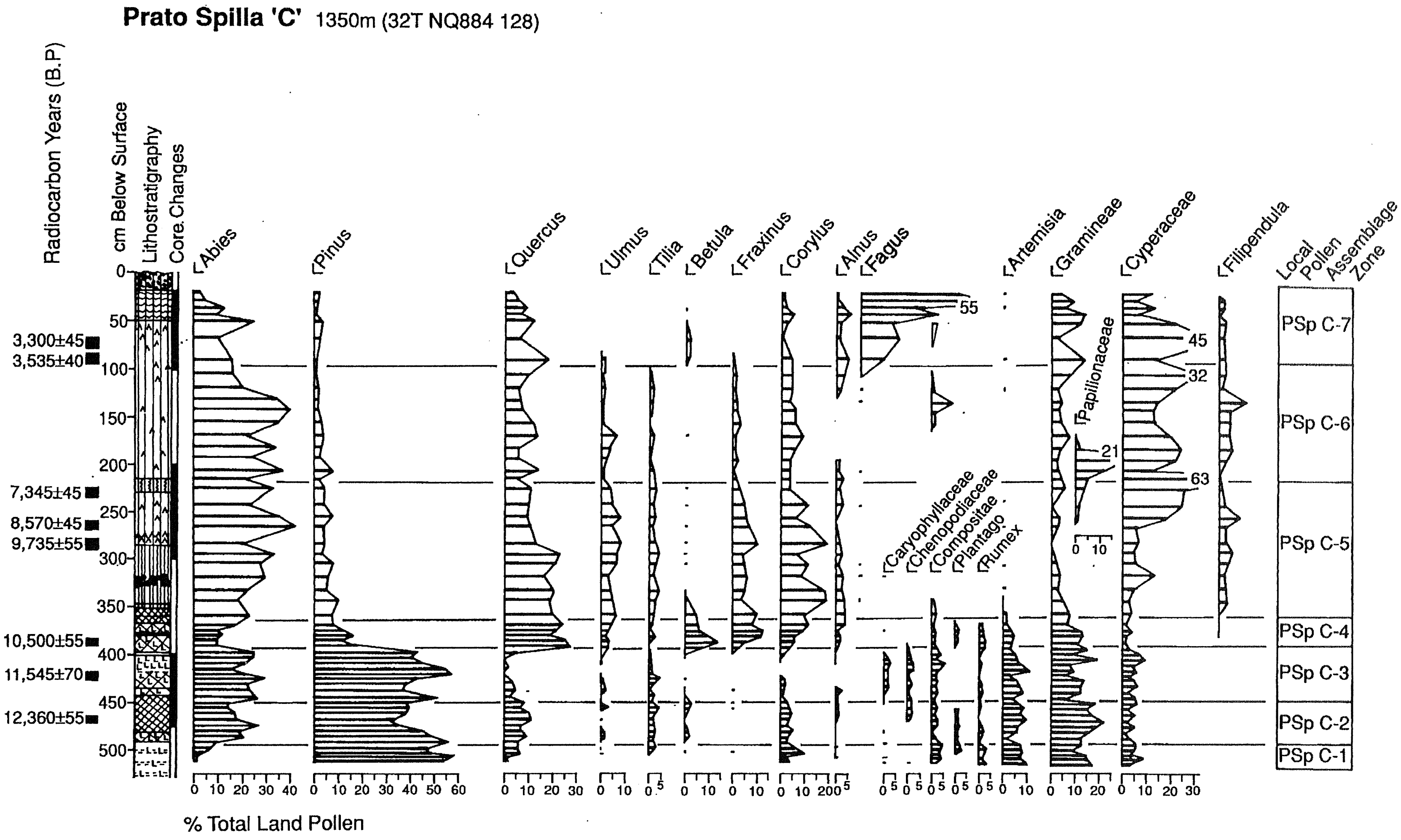

Fig. 2 - Percentage pollen diagram (principal taxa only) and radiocarbon dates, Prato Spilla 'C', northern Apennines (from Lowe, 1992).
Prato Spilla 'C', Appennino settentrionale. Diagramma pollinico percentuale (solamente taxa principali) e radiodatazioni (da Lowe 1992).

thick (ca. 40 cm) layer of tephra (volcanic debris). Comprehensive accounts of the lithostratigraphy and the various proxy records obtained from the PALB94.1E succession are currently being prepared for publication in a special issue of the "Memorie dell'Istituto Italiano di Idrobiologia", other monographs and a series of journal articles (F. Oldfield and P. Guilizzoni, in prep.).

Pollen data have been obtained from 98 sample horizons in the PALB94.1E sequence. Here, a relative pollen diagram is shown for the principal and most diagnostic taxa (Fig. 5). It is based upon a minimum pollen sum of 200 'dryland' pollen types. The sequence has been divided on a preliminary basis into three broad biostratigraphic zones. (More detailed subdivisions of the record will be made in due course, once all of the biostratigraphical data available from this site have been assimilated.) 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 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 2A (670-620 cm), *Quercus ilex* type, *Tilia, Ulmus* and *Corylus* show increased percentages, while *Artemisia,* Poaceae and other herb taxa are strongly reduced. In sub-zone 2b (620-590 cm) *Artemisia* and Poaceae 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, Carpinus, Fagus, Quercus* and *Corylus.* Fern spores are also recorded in relatively high numbers. By contrast,

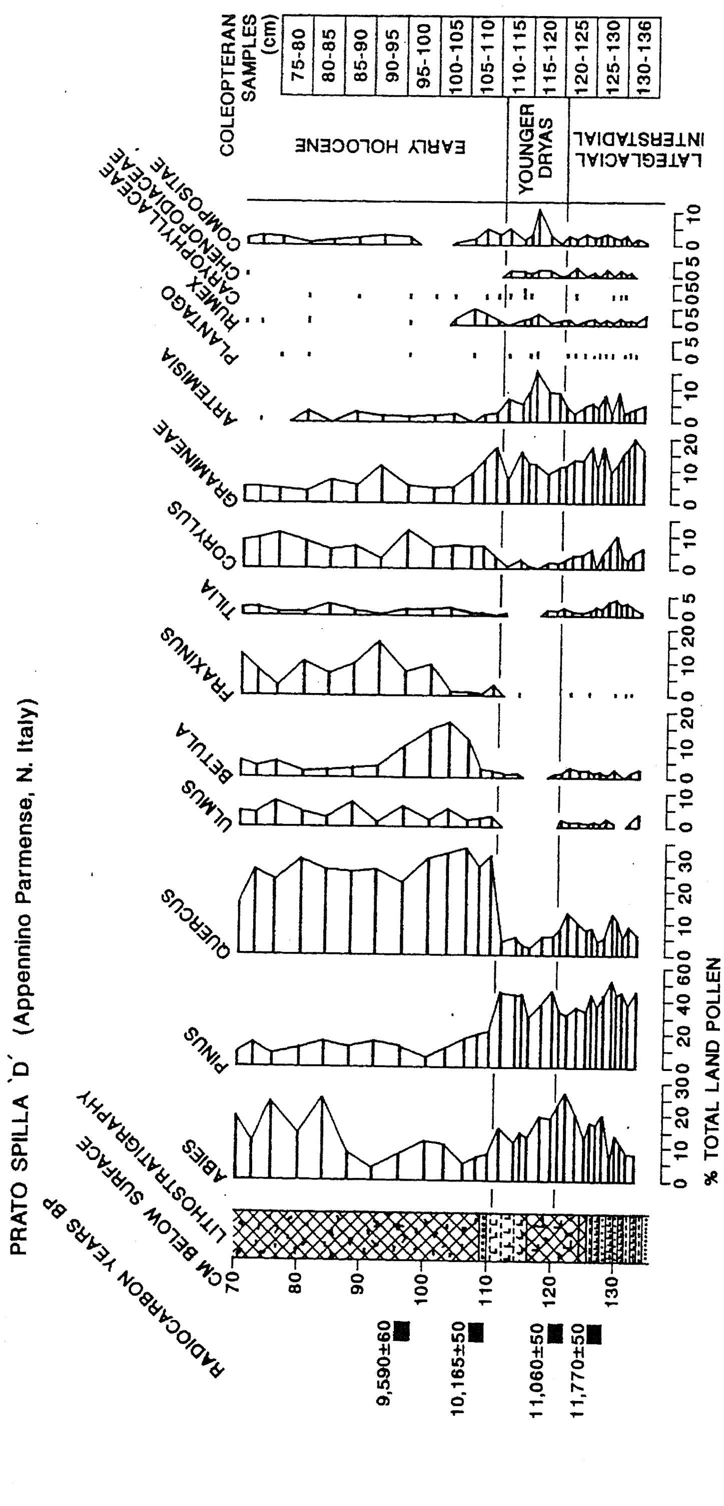

Fig. 3 - Percentage pollen diagram (principal taxa only) and radiocarbon dates, Prato Spilla 'D', northern Apennines (From Ponel & Lowe, 1992).
Prato Spilla 'D', Appennino settentrionale. Diagramma pollinico percentuale (solamente taxa principali) e radiodatazioni (da Ponel & Lowe 1992).

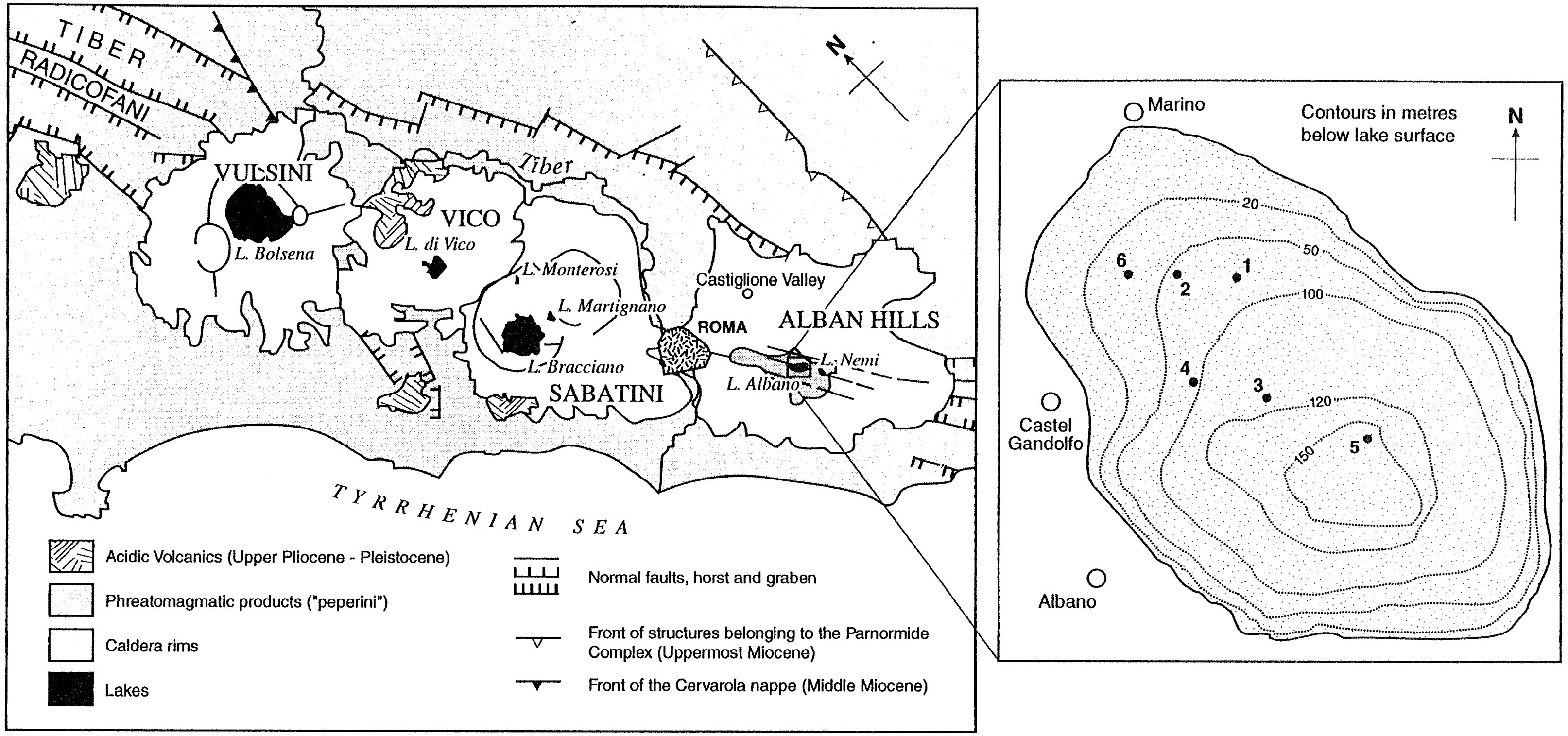

Fig. 4 - Location of Lago Albano, Central Italy, and of the PALB1E core.
Lago Albano, Italia centrale e posizione del carotaggio PALB1E.

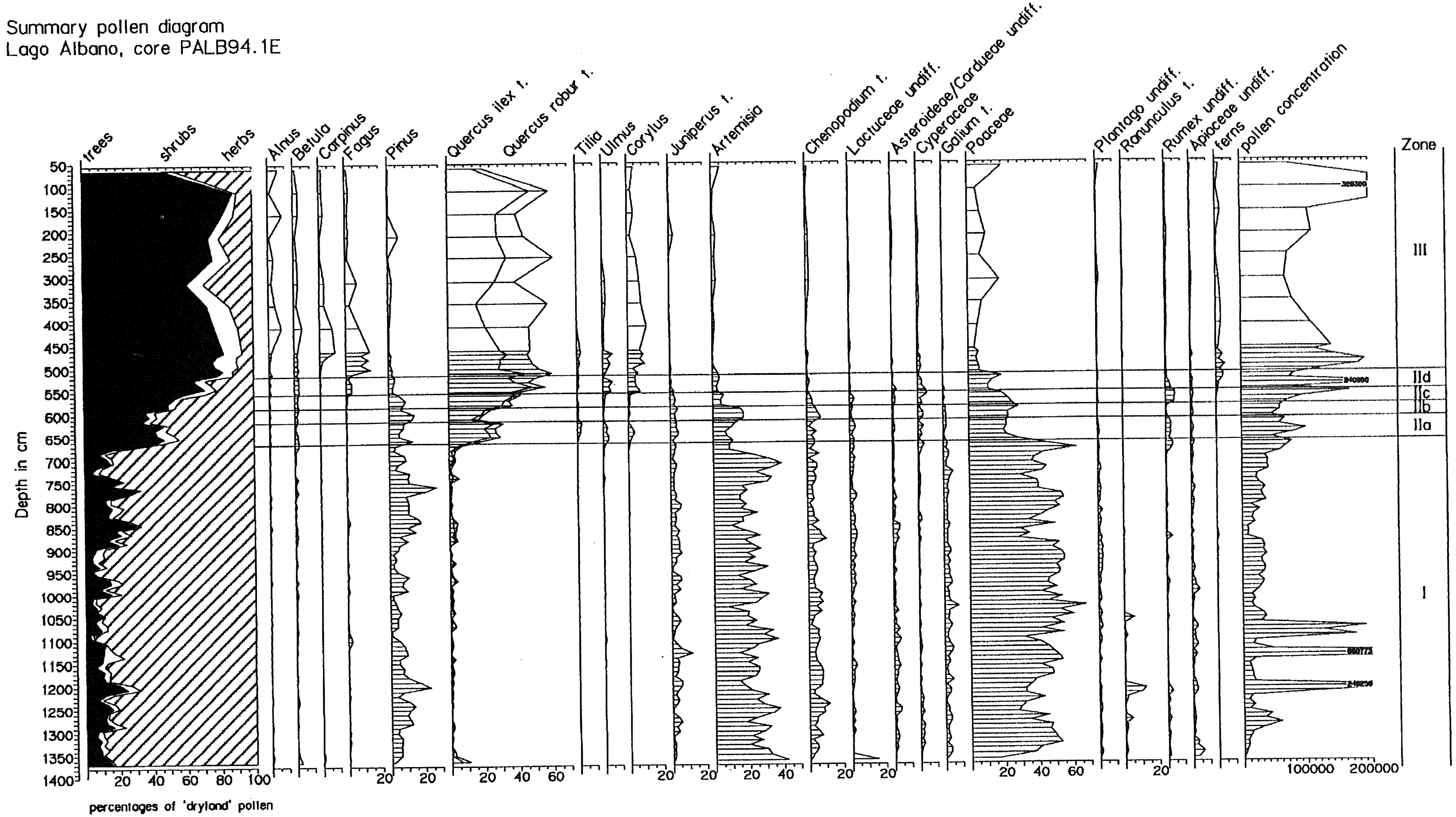

Fig. 5 -Percentage pollen diagram (principal taxa only) obtained from the PALB1E profile, Lago Albano, based upon pollen sum of 200 'dryland' pollen.

Lago Albano, Italia centrale. Digramma pollinico percentuale (solamente taxa principali) ottenuto dal carotaggio PALB1E, basato sulla somma di 200 pollini di 'terra asciutta'.

TABLE 1 - Radiocarbon and calibrated dates (in years BP) from the CM92.43 and RF93.77 cores sequences in the Central Adriatic, based on AMS measurement of foraminiferal tests (1).

Radiodatazioni e date calibrate (in anni BP) dalle sequenze nei carotaggi CM92.43 ed RF93.77 dall'Adriatico centrale. Le date si basano su misure AMS di tests foraminiferi (1).

Sample Depth	Radiocarbon Age	Calibrated Age (*)
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	12,62 ± 70	14,114 ± 15
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	—

(*) Calibrated using scheme of Stuiver & Reimer, 1993.

herbaceous and *Pinus* pollen values are low throughout this zone. Towards the top of the zone (but not shown on Figure 5), from 250 to 200 cm upwards, there are significant records for the first time of *Castanea, Juglans* and *Olea* type.

Unfortunately there are no reliable radiocarbon dates currently available for this core record, since no suitable macrofossils have been recovered, and the sediments are frequently highly calcareous (D. Ariztegui, pers. comm.). However, the chronology of the sequence can be established with some confidence, at least in general outline, on the following grounds:

1) Other cores from Lago Albano have been investigated, which have been dated using the radiocarbon method (D. Ariztegui & C. Chondrogianni, in prep.), and for which pollen diagrams have been produced (Van der Kaars *et al.*, 1995; Accorsi *et al.*, 1995). These include core PALB94-3A/3B, which shows a typical Holocene pollen sequence, an interpretation supported by 5 radiocarbon dates (Lowe *et al.*, unpubl.). Zone PALB94.1E-III can be correlated directly with the PALB94-3A/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 (radiocarbon-dated to post 3.5 ka BP).

2) The sequence of pollen-stratigraphical changes identified in pollen zone PALB94.1E-II compares very well with the pollen-stratigraphical changes described in the previous section of this paper for the Prato Spilla 'C' and 'D' sequences. The initial expansions of *Quercus ilex* type, *Tilia, Ulmus* and *Corylus* and concomitant reductions in *Artemisia,* Poaceae and other herb taxa, match almost exactly the developments recorded during the Lateglacial Interstadial in the Prato Spilla sequences. Sub-zone IIb in the PALB94.1E profile, which is a clear 'revertance' phase characterised by re-increases in *Artemisia* and Poaceae, is therefore correlated with the Younger Dryas episode.

3) Tephra horizons provide marker chronostratigraphic horizons within the Lago Albano sequences. The basal volcanic debris in core 1E has been dated by K-Ar to 25 ± 5 ka BP, the Y1 Etna tephra (dated to ca. 14.2 ka BP) has been identified at 714 cm depth in the 1E profile,

---

(1) Reservoir age applied to these data = 570 years

and an Avellino ash horizon, dated to ca. 3.7 ka BP, has been recorded at 394.5 cm in the 1E profile as well as within the 3A/3B sequence (N. Calanchi *et al.*, unpublished data, PALICLAS project).

4) The Albano record can also be compared with the recently-published new results from Lago Grande di Monticchio in southern 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. Although there are differences in detail, the three-fold pollen zonation scheme described for the PALB94.1E profile from Lago 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-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, 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 Lago Albano PALB94.1E profile spans the Würmian maximum to late Holocene period (approximately the last 25,000 years or so), and that a distinct Younger Dryas signal can be discerned in the pollen-stratigraphical records from both Lago Albano and Lago Grande di Monticchio.

4. CENTRAL ADRIATIC

Much seismic and coring work has been undertaken in the Adriatic Sea in recent years by the CNR-IGM team at Bologna, with some of the more recent work contributing to the PALICLAS project referred to above. This work has established that the sedimentary infill on the southern flanks of the Meso-Adriatic Depression, a shallow basin separated from the deeper parts of the Mediterranean Ocean to the south by a narrow submarine spillway (Fig. 6), provide a continuous record spanning Oxygen Isotope Stages 1 and 2, and in some deeper pockets the sediment successions may extend as far back as 60 to 70 thousand years ago (Trincardi *et al.*, 1994). We present here pollen records that have been obtained from two boreholes in the Central Adriatic: RF93.77, situated on the southern flanks of the depression was drilled in a water depth of 152 m, and CM92.43, situated more centrally in the Meso-Adriatic Depression, at a depth of 252 m below present sea level (Fig. 6). Marine sediments are characteristically rich in coniferous pollen types, which can mask the statistical variations in other taxa, and so the pollen records from these sequences are calculated on a pollen sum of 200 'dryland' pollen types excluding *Abies, Pinus* and *Picea.* Radiocarbon dates, based on AMS measurements of foraminiferal tests, are available for both successions, and detailed studies of foraminiferal assemblages are also available (Asioli *et al.*, in press).

Core RF93.77 is divided into four pollen assemblage zones (Fig. 7). Zone RF93.77-I (799-620cm) is characterised by high *Pinus* (outside the pollen sum) and *Quercus* percentages, but also high *Artemisia* and Poaceae percentages occur at around 750 and 660 cm core depth. In pollen zone RF93.77-II (620-210 cm), *Pinus, Juniperus, Artemisia* and *Chenopodium* type are recorded in high values, along with Cyperaceae and Poaceae pollen, while pollen of angiosperm trees and fern spores are low in number. Zone RF93.77-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 RF93.77-IV (140-0 cm) consists of assemblages with high percentages of *Quercus* pollen percentages and continuous records for *Betula, Carpinus* and *Fagus.* From 60 cm upwards *Castanea* pollen are recorded continuously in low percentages.

It is clear from comparisons with the Lago Albano and Lago Grande di Monticchio pollen data referred to in the previous section that pollen zone *RF93.77-IV* represents the Holocene period, zone RF93.77-III corresponds to the last glacial-interglacial transition, and zone RF93.77-II to a part of the last (Würmian) cold stage. 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 the radiocarbon dates obtained from the profile (Table 1). There is no equivalent in the Albano sequence, however, for zone RF93.77-I in the Adriatic sequence. The assemblages in this zone compare reasonably well, however, with those published for the Monticchio sequence (Watts *et al.*, 1996) and dated to earlier than 25,000 calendar years ago. 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 (Table 1). However, whether Pollen Zone RF93.77-I represents the warm interval of Oxygen Isotope Stage 3 or that of the preceding warm interval of Oxygen Isotope Stage 5a is an equivocal point at present. Comparison of the pollen data with the Monticchio pollen diagram suggests the former, whereas isotopic data obtained from the RF93.77 core (D. Ariztegui, unpublished data, PALICLAS project) and the provisional determination and age estimates of three tephra layers suggest the latter. One tephra identified at 380 cm depth in the sequence has been assigned to the Y5 tephra widely recognised in Central Adriatic cores and dated to ca. 35 to 38 ka BP. A lower tephra layer (460 cm) is assigned to Paterne's C14 tephra and the third, from 790 cm in the profile is assigned to Paterne's C20 tephra (Paterne *et al.*, 1988). These last two are not dated directly, but their ages are estimated to ca. 41.5 and 70 ka BP respectively by comparison of isotopic profiles with the SPECMAP master chronology.

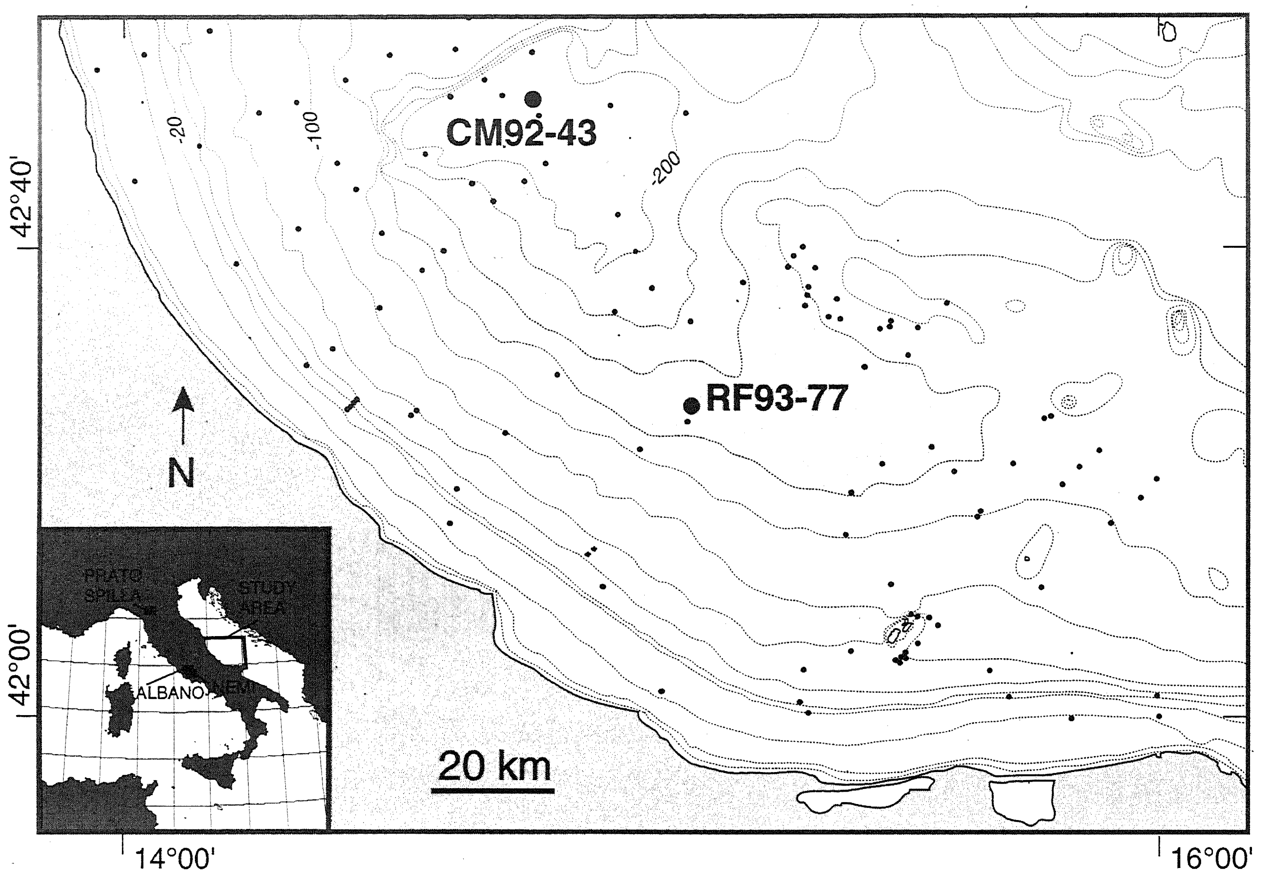

Fig. 6 - Bathymetry and location of boreholes in the Meso-Adriatic depression, Central Adriatic.
Batimetria e posizione dei carotaggi nella depressione Meso-Adriatica, Adriatico centrale.

One important point to emerge from these conclusions, as far as the present paper is concerned, is the 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 pollen percentages. This is followed by a reduction in *Quercus* percentages and re-increase in *Artemisia* and Poaceae, this phase occurring between ca. 185 and 150 cm depth (Fig. 7). Radiocarbon dates limit this phase to sometime between 11,990 ± 60 and 10,160 ± 90 radiocarbon years BP (Table 1). 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, to some extent, Prato Spilla. 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).

A higher resolution pollen-stratigraphic sequence for the last glacial-interglacial transition, as well as a more comprehensive set of radiocarbon dates, have been obtained from core CM92.43 in the Adriatic. This core, raised from a water depth of 250 m from a more central part of the Meso-Adriatic Basin than core RF93.77, is 975 cm long, but it clearly does not extend as far back in time as the RF93.77 sequence. The core succession has been divided into four pollen zones (Fig. 8). Zone CM92.43-I (950-620 cm) has high *Pinus, Artemisia* and Poaceae 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, so that the base of the CM92.43 sequence is likely to be considerably less than 25,000 years in age. Zone CM92.43-II (620-500 cm) shows increasing values for *Quercus* pollen percentages and much reduced values for *Juniperus, Artemisia* and Chenopodiaceae. Poaceae values fluctuate and do not show a straightforward pattern. Zone CM92.43-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 CM92.43-II and CM92.43-III together span the last glacial-interglacial transition, an interpretation which is fully supported by 11 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.*, in press). Zone CM92.43-IV (500-0 cm) consists of assemblages dominated by *Quercus,* but also containing relatively high percentages of *Abies, Fagus* and *Betula,*

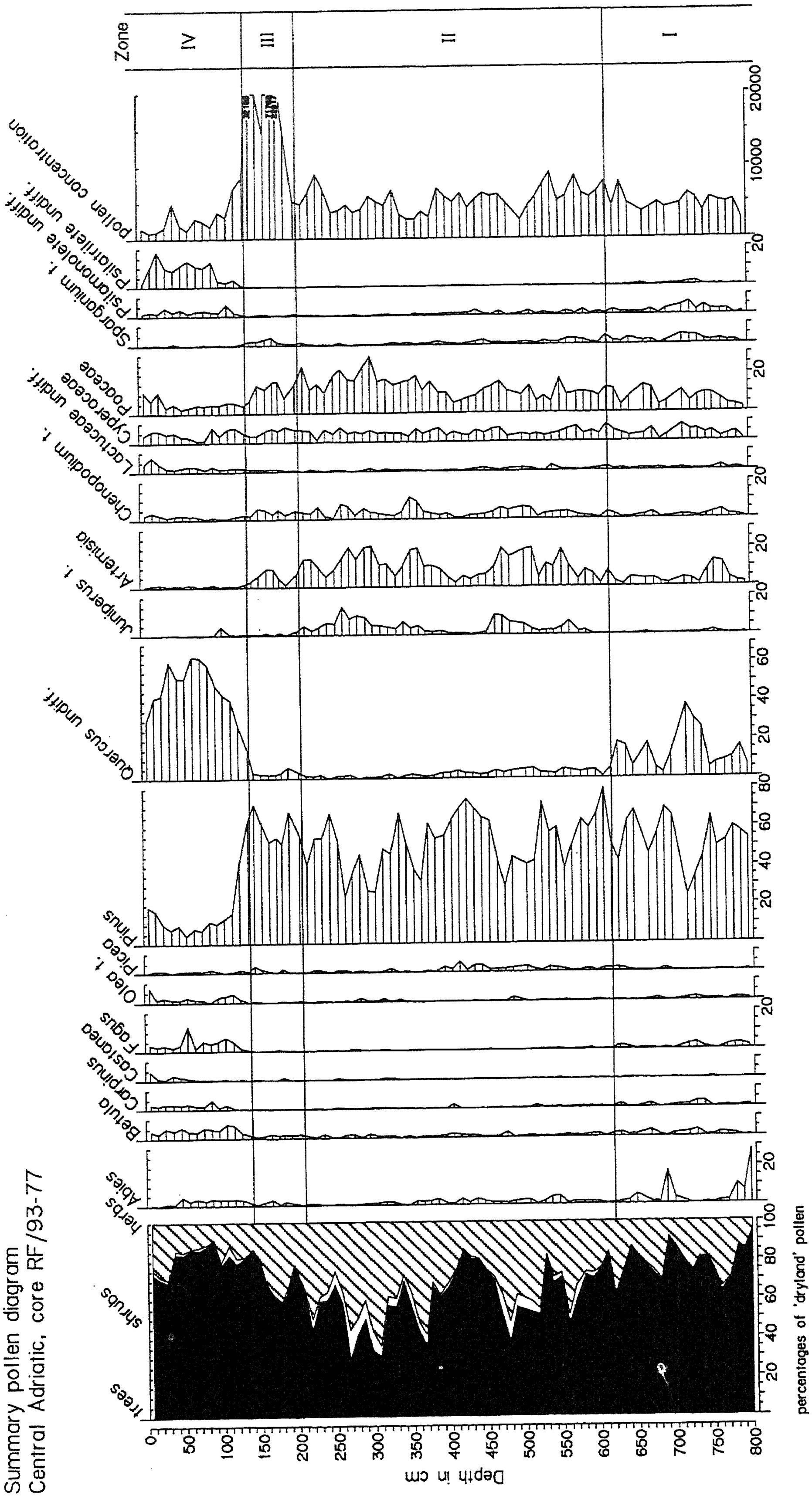

Fig. 7 - Percentage pollen diagram (principal taxa only) for the core sequence RF93.77 in the Central Adriatic. Pollen sum excludes *Abies*, *Pinus* and *Picea*. *Carotaggio RF93.77, Adriatico centrale. Diagramma pollinico percentuale (solamente taxa principali). La somma pollinica non comprende* Abies, Pinus *e* Picea.

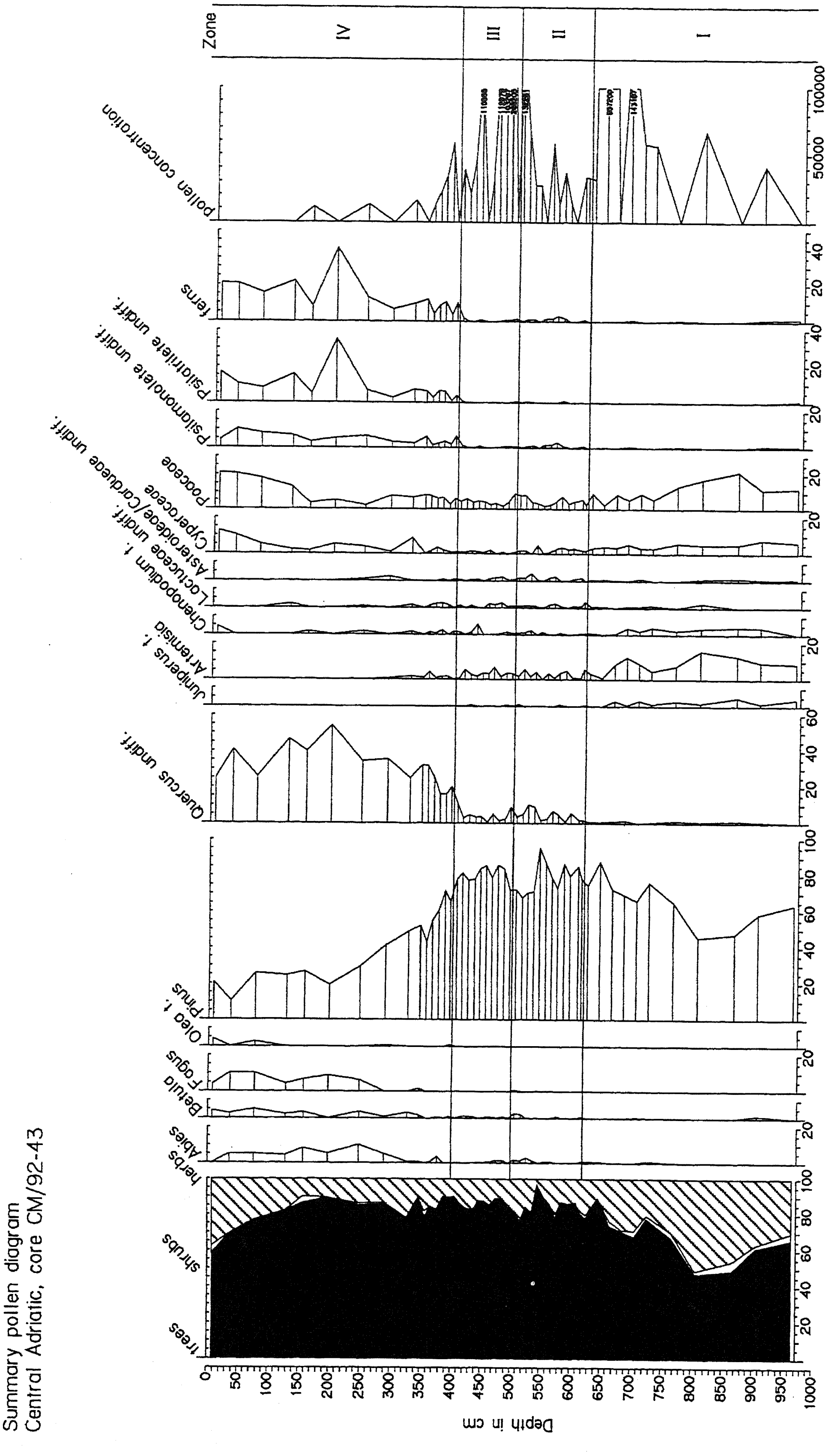

Fig. 8 - Percentage pollen diagram (principal taxa only) for the core sequence CM92.43 in the Central Adriatic.
Carottagio CM92.43, Adriatico centrale. Diagramma pollinico percentuale (solamente taxa principali).

with some *Carpinus* and (towards the top of the sequence) *Olea*. This zone clearly equates with the Holocene period.

5. DISCUSSION

It has been shown that a clear Younger Dryas signal can be discerned in the sediment sequences obtained from two small kettle hole basins in the northern Apennines, the bottom sediments of two volcanic crater lakes in Central (Albano) and southern (Monticchio) Italy, and two core records from sea bottom sediments in the Central Adriatic. Moreover, there is a remarkable degree of consistency between all of these records with respect to the pollen-stratigraphic successions that they record for the last glacial-interglacial transition as a whole. In addition to the indications of vegetational revertance that are equated with the onset of the Younger Dryas phase, the lower boundary of the Lateglacial Interstadial (Bølling-Allerød interval) and the start of the Holocene are also distinctive marker horizons in each profile. Where radiometric and other chronological information is available, they support this general interpretation. It seems clear, therefore, that pollen stratigraphy provides a very useful framework for the correlation of sequences spanning the last glacial-interglacial transition throughout peninsular Italy.

Pollen stratigraphy also appears to provide a sound basis for correlation between marine and continental successions, a conclusion also reached by Rossignol-Strick (1995) for the eastern Mediterranean region, though the evidence reported here for Italy and the Adriatic appears to be much more sharply defined. Furthermore, the pollen-stratigraphical records obtained from the Meso-Adriatic Depression are consistent with those based upon foraminiferal data (Asioli *et al.*, in press) as well as with dinoflagellate and palynological data obtained from other parts of the Central and Southern Adriatic (Jorissen *et al.*, 1993; Zonneveld & Boessenkool, 1996). Although these latter records seem more complex than, and are difficult to compare directly with, those reported in this study, they nevertheless show evidence for abrupt cooling of the Adriatic during the Younger Dryas, an interpretation that is supported by radiocarbon dates based on shells and benthic foraminifera (Zonnefeld, 1995). The data from Italy and the Adriatic as a whole suggest that the abrupt climatic cooling of the Younger Dryas impacted equally strongly on both the continental and marine realms, and, as far as can be judged from the stratigraphical and chronological information currently available, the changes appear to have been more or less synchronous.

In broad terms, therefore, the climatostratigraphic scheme for Italy outlined above, of climatic warming during the Lateglacial Interstadial (Bølling-Allerød interval, dated approximately from 13-12.5 to 11 radiocarbon years BP (14.5-12.4 calibrated radiocarbon years BP) followed by the marked cooling of the Younger Dryas episode, resembles that inferred for several parts of oceanic NW Europe (see *e.g.* Lowe *et al.*, 1994a; Walker, 1995; Lowe & NASP Members, 1995). However, while the climatic history of oceanic NW Europe during the last glacial-interglacial transition appears to have been dominated by changes in surface water temperature and associated atmospheric circulation in the North Atlantic (*e.g.,* Lowe *et al.*, 1995a, 1995b; Peteet *et al.*, 1995), it is thought that other factors (*e.g.* proximity to Scandinavian ice sheet, continental air masses in eastern Europe) over-rode the Atlantic influences in other parts of Europe. Thus the pattern of climatic changes in Europe during the last glacial-interglacial transition was far from uniform (Lowe & NASP Members, 1995; Coope & Lemdahl, 1995). It is for this reason that we have divided the records from Italy and the Adriatic into two broad climatostratigraphic phases only, using the informal terms 'Lateglacial Interstadial' (*sensu* Lowe & Gray, 1980) and Younger Dryas, and avoided the traditional and more comprehensive terminology of Mangerud *et al.* (1974). The application of the latter scheme is more problematic, since the terms are often used in different senses (climato-stratigraphic, biostratigraphic, chronostratigraphic), and the scheme has been found to be misleading or inadequate even in the context of the Scandinavian evidence, for which it was originally defined (Wohlfarth, 1996). Compatibility of climatostratigraphic records between different parts of Europe should not therefore be assumed, but should be measured, using objective assessments of the timing and magnitude of the climatic variations inferred. This is often difficult to achieve, however (see below). Strictly speaking, even the term 'Younger Dryas' may be misleading in a Mediterranean context, since the timing, duration and magnitude of the cold reversal recognised in Mediterranean records need not necessarily be conformable with interpretations of the evidence from other parts of Europe.

If, however, it can be shown that climatic changes during the last glacial-interglacial transition in Italy and the Adriatic, and perhaps even the eastern Mediterranean region (Bottema, 1995; Rossignol-Strick, 1995), really did parallel those of oceanic NW Europe, then this would mean that either the Atlantic influences extended into the Mediterranean region, or that both the North Atlantic and Mediterranean regions were responding to common climatic forcing mechanisms. This is clearly an important issue to resolve, since it has a bearing on the overall mechanisms proposed to explain not only the Younger Dryas cooling event, but also other climatic perturbations during the last glacial-interglacial transition (*e.g.* Broecker *et al.*, 1989; Berger, 1990; Jansen & Veum, 1991; Keigwin & Lehman, 1994).

A precise comparison between the last glacial-interglacial transition records from the Mediterranean region and those from NW Europe, however, is difficult to achieve at present for the following two principal reasons.

a) *Dating limitations:* It follows from the previous section that regional climatic variations must be dated very precisely, in order to test the degree of synchroneity between regional data-sets. So far, most of the investigations in the Mediterranean region have relied upon radiocarbon dating to provide a chronological framework. The problems associated with attempts to date events that occurred during the last glacial-interglacial transition using the radiocarbon dating method are now very well known (*e.g.* Lowe, 1991; Wohlfarth, 1996). In an effort to attain a more reliable dating control, efforts have been made to extend dendrochronological calibrations into the Lateglacial period (Becker & Kromer, 1993; Kromer & Becker, 1993), to use sites with varved sediments to provide independent estimates of the calendar age of Lateglacial sediments (*e.g.* Goslar *et al.*, 1995a, 1995b; Hajdas *et al.*, 1995a, 1995b), and to calibrate AMS radiocarbon dated terrestrial plant macrofossils using the Stuiver & Reimer (1993) calibration scheme (Lowe *et al.*, 1995a). None of these approaches have yet been successfully applied in the Mediterranean region, although the laminated sediments of the Lago Grande di Monticchio sequence appear to provide the potential for establishing calendar ages for Lateglacial events in southern Italy (Watts *et al.*, 1996). Precise comparisons between Mediterranean sequences is presently not possible, because the radiocarbon dates obtained from terrestrial sequences have been mostly based upon bulk sediment samples, which are invariably subject to 'reservoir' and mineral carbon errors (Lowe, 1991; Björck *et al.*, 1995; Wohlfarth, 1996), while the marine dates have been obtained from foraminiferal and other fossil material employing an estimated reservoir age for the Adriatic. It is not clear whether a consistent correction has been applied to all radiocarbon dates obtained from marine fossils, nor whether the reservoir age has remained constant during the past 14,000 years. In summary, therefore, only approximate comparisons between sites can be made at present, and precise comparisons will require a different approach to the dating of the Mediterranean sequences.

b) *Non-quantified climatic reconstructions:* The interpretations of the Mediterranean data presented in this paper are almost entirely based upon non-quantified (relative) estimates of climate variation. The experience of the palaeoclimatic research undertaken in northern Europe during the last 20 years or so, which has relied heavily on such subjective assessments of pollen-stratigraphical data, has revealed the problems inherent in such an approach. It can lead to spurious correlations between sites and circular argument when attempting to reconstruct the pattern and timing of climatic variations (see *e.g.* Walker *et al.*, 1994; Lowe *et al.*, 1994a; Lowe & NASP Members, 1995). A more objective assessment may be gained by employing methods that provide quantified estimates of past climatic variations. In NW Europe, the principal technique employed so far has been the analysis of coleopteran remains using the Mutual Climatic Range (MCR) method (Coope & Lemdahl, 1995). To date, very few such studies have been undertaken in the Mediterranean region (De Beaulieu *et al.*, 1994), and only one study has been undertaken in Italy — that at the Prato Spilla 'D' sequence. Quantitative climatic reconstructions based upon the coleopteran data from Prato Spilla 'D' site suggest a maximum average temperature for the warmest month of 9° to 13°C, an average winter minimum between -16° to -2°C, and an annual range of 15 to 25°C during the Younger Dryas (Ponel & Lowe, 1992). These figures imply a reduction in average maximum temperatures for the warmest month of between 2 and 6°C, which compares reasonably well with inferences obtained from sites in NW Europe (*e.g.* Walker *et al.*, 1993). Some attempts have been made to derive quantified climate estimates from palynological data using pollen-climate response surfaces (Watts *et al.*, 1996; Juggins & Lowe, unpublished), but these are seriously limited by the fact that there are no modern analogues for the majority of the pollen assemblages encountered in the Lateglacial successions from Italy (see Huntley & Prentice, 1993; and Huntley, 1993, for discussion of this problem). Much more effort needs to be made to obtain reliable quantified estimates of past climatic variations from Italy, and indeed from the Mediterranean region in general, before precise comparisons with NW European palaeoclimatic data can be effected.

Although, therefore, it is tempting to conclude that palaeoclimatic developments in Italy and the Adriatic were very similar in pattern and timing to those in parts of NW Europe, we are very far from being able to establish this with any degree of confidence. Improvements are required in the dating of events and in the objective estimation of the magnitude of climatic variations inferred, before such assumptions can be rigorously tested. Indeed, if such comparisons are to be made, cognizance must be taken of the fact that climatic variations during the last glacial-interglacial transition appear to have been much more complex in parts of NW Europe than were envisaged in the Mangerud *et al.* (1974) scheme. Thus several climatic oscillations (at least 2, and possibly 3 or more) appear to have occurred during the Lateglacial Interstadial, while the Younger Dryas cold episode seems to have consisted of at least two distinct climatic phases in some regions, and at least one climatic oscillation affected several parts of northern Europe during the first millenium of the Holocene (Walker, 1995). Where these changes can be quantified, they appear to show a remarkable degree of compatibility with the Greenland ice core records (Lowe *et al.*, 1995a). It is possible that the Italian sequences, when studied at a much higher degree of stratigraphic resolution, may provide evidence for an equally complex climatic history. The Prato Spilla 'C' and 'D' sequences, for example, both show significant variations in arboreal and non-arboreal pollen percentages within the part of the record assigned to the Lateglacial Interstadial (Figures 2 and 3), while several fluctuations can also be seen in Zone CM92.43-II (620-500 cm) in the Meso-Adriatic record (Fig. 8). Minor oscillations in *Quercus* and *Fraxinus* during the early Holocene, accompanied by renewed increases in *Rumex* and Compositae, can be detected in the Prato Spilla 'D' record. Whether these variations are significant for the region as a whole and, what is more, correlate closely with events in NW Europe, remains to be established. What this paper has shown, nevertheless, is that important records of high stratigraphic resolution and rich fossiliferous content exist in Italy and adjacent marine basins, and these are providing new insights into the history of climatic changes in the western Mediterranean region during the last glacial-interglacial transition.

ACKNOWLEDGEMENTS

We thank Clare Watson, who undertook some of the palynological investigations of core CM92.43, Nick

Branch who prepared the TILIA files and diagrams, and Justin Jacyno for the artwork. Thanks also to Sam Evans for Italian translations and for more general assistance.

REFERENCES

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

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

Becker B. & Kromer B., 1993 - *The continental tree-ring record: ^{14}C calibration and climatic change at 11 ka.* Palaeogeogr., Palaeoclimat., Palaeoecol., **103**, 67-71.

Berger W.H., 1990 - *The Younger Dryas cold spell - a quest for causes.* Palaeogeogr., Palaeoclimat., Palaeoecol., **103**, 67-71.

Bertoldi R., 1980 - *Le vicende vegetazionali e climatiche nella sequenza paleobotanica würmiana e post-würmiana di Lagdei (Appennino settentrionale).* Ateneo Parmense Acta Naturalia, **16**, 147-175.

Björck S., Wohlfarth B. & Possnert G., 1995 - *^{14}C AMS measurements from the Late Weichselian part of the Swedish Time Scale.* Quat. Intern., **27**, 11-18.

Bottema S., 1995 - *The Younger Dryas in the Eastern Mediterrranean.* Quat. Sci. Rev., **14**, 883-892.

Broecker W.S., Kennett J.P., Flower B.P., Teller J.T., Trumbore S., Bonani G. & Wolfli W., 1989 - *Routing of meltwater from the Laurentide ice sheet during the Younger Dryas cold episode.* Nature, **341**, 318-321.

Coope G.R. & Lemdahl G., 1995 - *Regional differences in the Lateglacial climate of northern Europe based on coleopteran analysis.* J. Quat. Sci., **10**, 391-395.

De Beaulieu J-L., Andrieu V., Lowe J.J., Ponel P. & Reille M., 1994 - *The Weichselian Late-glacial in southwestern Europe (Iberian Peninsula, Pyrenees, Massif Central, Northern Apennines).* J. Quat. Sci., **9**, 101-108.

Goslar T., Arnold M., Bard E., Kuc T., Pazdur M.F., Ralska-Jasiewiczowa M., Rozanski K., Tisnerat N., Walanus A., Wicik B. & Wieckowski K., 1995a - *High concentration of atmospheric ^{14}C during the Younger Dryas cold episode.* Nature, **377**, 414-417.

Goslar T., Arnold M. & Pazdur M.F., 1995b - *The Younger Dryas cold event – was it synchronous over the North Atlantic region?* Radiocarbon, **37**, 63-70.

Hajdas I., Zolitschka B., Ivy-Ochs S., Beer L., Bonani G., Leroy S., Negendank J., Ramrath M. & Suter M., 1995a - *AMS radiocarbon dating of annually laminated sediments from Lake Holzmaar, Germany.* Quat. Sci. Rev., **14**, 137-143.

Hajdas I., Ivy-Ochs S.D. & Bonani G., 1995b - *Problems in the extension of the radiocarbon calibration curve (10-13 kyr BP).* Radiocarbon, **37**, 75-79.

Huntley B., 1993 - *The use of climate response surfaces to reconstruct palaeoclimate from Quaternary pollen and plant macrofossil data.* Phil. Trans. Roy. Soc. London, series B - Biol. Sci., **341**, 215-223.

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

Jansen E. & Veum T., 1991 - *Evidence for two-step deglaciation and its impact on North Atlantic deep-water circulation.* Nature, **343**, 612-616.

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

Keigwin L.D. & Lehman S.J., 1994 - *Deep circulation change linked to Heinrich Event I and Younger Dryas in a mid-depth North Atlantic core.* Paleoceanography, **9**, 185-194.

Kromer B. & Becker B., 1993 - *German oak and pine ^{14}C calibration 7200-9400 BC.* Radiocarbon, **35**, 125-137.

Lowe J.J., 1991 - *Stratigraphic resolution and radiocarbon dating of Devensian Lateglacial sediments.* Quat. Proceed., **1**, 19-26.

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., Ammann B., Birks H.H., Bjrck S., Coope G.R., Cwynar L., De Beaulieu J-L., Mott R.J., Peteet D.M. & Walker M.J.C., 1994a - *Climatic changes in areas adjacent to the North Atlantic during the last glacial-interglacial transition (14-9 ka BP): a contribution to IGCP-253.* J. Quat. Sci., **9**, 185-198.

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

Lowe J.J., Coope G.R., Harkness D.D., Sheldrick C. & Walker M.J.C., 1995a - *Direct comparison of UK temperatures and Greenland snow accumulation rates, 15-12,000 calendar years ago.* J. Quat. Sci., **10**, 175-180.

Lowe J.J., Coope G.R., Lemdahl G. & Walker M.J.C., 1995b - *The Younger Dryas climate signal in land records from NW Europe.* In: Troelstra S.R., Van Hinte J.E. & Ganssen G.M. (eds.), *The Younger Dryas.* Roy. D. Acad. of Science, Amsterdam, 3-25.

Lowe J.J. & Gray J.M., 1980 - *The stratigraphic subdivision of the Lateglacial of North-west Europe: a discussion.* In: J.J. Lowe *et al.* (eds.), *Studies in the Lateglacial of North-west Europe.* Pergamon Press, Oxford & New York, 157-175.

Lowe, J.J. & NASP Members, 1995 - *Palaeoclimate of the North Atlantic seaboards during the last glacial/interglacial transition.* Quat. Intern., **28**, 51-62.

Lowe J.J. & Watson C., 1993 - *Lateglacial and early Holocene pollen stratigraphy of the northern*

Apennines, Italy. Quat. Sci. Rev., **12**, 727-738.

Mangerud J., Anderson S.T., Berglund B.E. & Donner J.J., 1974 - *Quaternary stratigraphy of Norden, a proposal for terminology and classification.* Boreas, **3**, 109-126.

Niessen F., Lami A. & Guilizzoni P., 1993 - *Climatic and tectonic effects on sedimentation in Central Italian volcano lakes (Latium) – implications from high resolution seismic profiles.* Lecture Notes in Earth Sciences, **49**, 129-148.

Paterne M., Guichard F. & Labeyrie J., 1988 - *Explosive activity of the South Italian volcanoes during the past 80,000 years as determined by marine tephrochronology.* J. Volc. Geoth. Res., **34**, 153-172.

Peteet D.M., Lowe J.J., Jansen E., Van Hinte J.E., Van Weering Tj., Troelstra S.R. & Ganssen G.M., 1995 - *Northern hemisphere record and surface temperatures.* In: Troelstra S.R., Van Hinte J.E. & Ganssen G.M. (eds), *The Younger Dryas.* Netherlands Acad. of Science, Amsterdam, 209-215.

Ponel P. & Lowe J.J., 1992 - *Coleopteran, pollen and radiocarbon evidence from the Prato Spilla 'D' succession, N. Italy.* C.R. Acad. Sciences, Paris, **315**, ser. II, 1425-1431.

Reille M. & Lowe J.J., 1993 - *A re-evaluation of the vegetation history of the eastern Pyrenées (France) from the end of the last glacial to the present.* Quat. Sci. Rev., **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.* Quat. Sci. Rev., **14**, 893-916.

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

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

Turner C. & Hannon G.E., 1988 - *Vegetational evidence for late Quaternary climatic changes in southwest Europe in relation to the influence of the North Atlantic Ocean.* Phil. Trans. Roy. Soc. London, B **318**, 451-485.

Van der Kaars S., Lowe J.J., Accorsi A., Bandini M., Mercuri A. & Torri P., 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, 283.

Walker M.J.C., 1995 - *Climatic changes in Europe during the last glacial/interglacial transition.* Quat. Intern., **28**, 63-76.

Walker M.J.C. & Lowe J.J. (eds.), 1993 - *Records of the Last Deglaciation around the North Atlantic.* Quat. Sci. Rev., **12**, 597-738.

Walker M.J.C., Coope G.R. & Lowe J.J., 1993 - *The Devensian/Weichselian Late-glacial palaeoenvironmental record from Gransmoor, East Yorkshire, England.* Quat. Sci. Rev., **12** , 659-680.

Walker M.J.C., Bohncke S.J.P., Coope G.R., O'Connell M., Usinger H. & Verbruggen C., 1994 - *The Devensian/Weichselian Late-glacial in North-west Europe (Ireland, Britain, North Belgium, The Netherlands, Northwest Germany).* J. Quat. Sci., **9**, 109-118.

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

Watts W.A., 1980 - *Regional variation in the response of vegetation to Lateglacial climatic events in Europe.* In: J.J. Lowe *et al.* (eds.), *Studies in the Lateglacial of North-west Europe.* Pergamon Press, Oxford & New York, 1-22.

Watts W., 1986 - *Stages of climatic changes from full glacial to Holocene in northwest Spain, southern France and Italy: a comparison of the Atlantic coast and the Mediterranean Basin.* In: Ghazi A. & Fantechi R. (eds.), *Current Issues in Climate Research.* D. Reidel, Dordrecht, 101-112.

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

Wohlfarth B., 1996 - *The chronology of the last termination: a review of radiocarbon-dated, high-resolution terrestrial stratigraphies.* Quat. Sci. Rev., **15**, 267-284.

Wohlfarth B., Björck S., Possnert G., Lemdahl G., Brunnberg L. Ising J., Olsson S. & Svensson N.O., 1993 - *AMS dating Swedish varved clays of the last glacial/interglacial transition and the potential difficulties of calibrating Late Weichselian 'absolute' chronologies.* Boreas, **22**, 113-128.

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

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

Ms received : Oct. 11, 1996
Sent to the A. for a revision: Nov. 21, 1996
Final text received: Dec. 10, 1996

Ms. ricevuto: 11 ott. 1996
Inviato all'A. per la revisione: 21 nov. 1996
Testo definitivo ricevuto: 10 dic. 1996