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EVOLUTION OF VEGETATION AND CLIMATE IN THE VENETO-PO PLAIN DURING THE LATE-GLACIAL AND THE EARLY HOLOCENE USING POLLEN-STRATIGRAPHIC DATA*

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RIASSUNTO - *L'evoluzione del paesaggio vegetale e del clima nella Pianura Padano-Veneta durante il Tardiglaciale e l'Olocene antico, attraverso la stratigrafia pollinica* - Il Quaternario *Italian Journal of Quaternary Sciences*, **9**(2), 1996, 581-590 - Vengono discussi i risultati pollinici, alcuni dei quali integrati anche con datazioni radiocarboniche, di alcuni sedimenti situati prevalentemente nella Pianura Padano-Veneta, compreso un segmento di carota marina raccolta nel Mare Adriatico a largo di Chioggia, in gran parte inediti. Dopo il confronto con i diagrammi pollinici situati nella zona del Lago di Garda, vengono descritti altri diagrammi pollinici, dove si evidenzia, durante il Tardiglaciale, la presenza di una flora promiscua, rappresentata cioè contemporaneamente da entità microterme (*Pinus mugo, P. cembra, Picea, Larix, Betula nana,* ecc.) insieme, in alcune specifiche stazioni, a componenti del *Quercetum s.l.*, indentificabile con *Querco-Carpinetum* e ad entità termofile, steppiche ed a vegetazione ripariale ed acquatica. Sulla base della paleoidrografia, viene tentata l'interpretazione della presenza, durante il Tardiglaciale, del *Querco-Carpinetum,* che, durante l'Olocene, verrà a caratterizzare la vegetazione planiziale delle Pianura Padana. I risultati dei singoli siti studiati vengono messi a confronto tra loro in modo da poter avere un quadro sull'evoluzione della vegetazione e quindi del clima e dell'*habitat* durante il Tardiglaciale e l'inizio dell'Olocene nella Pianura Veneta.

ABSTRACT - *Evolution of vegetation and climate in the Veneto-Po Plain during the Late-Glacial and Early Holocene using pollen-stratigraphical data* - Il Quaternario *Italian Journal of Quaternary Sciences*, **9**(2), 1996, 581-590 - The results of pollen analyses – in some cases supplemented with radiocarbon dating – of sediments mostly from the Veneto-Po Plain, and a core segment from an off-shore borehole drilled in the Adriatic Sea off Chioggia are discussed. Most of these data are original and have not yet been published. After a palynological comparison using three pollen diagrams from the Lago di Garda area, other pollen diagrams are described, which show the presence of a promiscuous flora assemblage during the Late Glacial, owing to the contemporaneous occurrence of a cold climate vegetation (*Pinus mugo, P. cembra, Picea, Larix, Betula nana,* etc.), together with – in some specific stations – the components of *Quercetum s.l.*, attributable to *Querco-Carpinetum* and thermophilous, steppe, riparian and aquatic plant communities. On the basis of palaeohydrographic considerations it is hypothesised the presence of *Querco-Carpinetum* which, during the Holocene, would characterize the Po Plain vegetation. The data from the studied sites are compared to one another in order to get a comprehensive view of the vegetation evolution and, hence, of climate and environment evolutions during the Late Glacial and the early Holocene in the Veneto Plain.

Key words: Late-Glacial, Holocene, pollen analysis, *Querco-Carpinetum,* Veneto-Po Plain, NE-Italy
Parole-chiave: Tardiglaciale, Olocene, palinologia, *Querco-Carpinetum,* Pianura Padano-Veneta, Italia nord-orientale

1. INTRODUCTION

I have been undertaking palynological research for some years on sediments situated in NE-Italy; in some cases, pollen diagrams have been provided with radiocarbon dating.

In the present paper the results of original studies carried out in the Veneto-Po Plain and close to the Venetian Prealps, are given. These results, together with previous data (Accorsi *et al.*, 1984; 1989; 1991; Bertolani Marchetti, 1966-1967; Lona, 1957-1962a; 1957-1962b; Marchesoni, 1959; 1960; Marchesoni & Paganelli, 1960; Paganelli, 1961a; Pellegrini *et al.*, 1984; Sauro *et al.*, 1993), allow to put forward new hypotheses on the dynamics of vegetation during the Late-Glacial - Holocene.

In analysing the data, I shall merely consider the evolution of the forest and climate during the period of time between the Late-Glacial and the early Holocene — the time interval considered by this congress — though, for some sites, I shall also refer to vegetation connected with the Pleniglacial period and the recent Holocene. A critical study of the dynamics of forest vegetation in the Veneto-Po Plain from the last interglacial up to present days will be published in a short time.

2. RESEARCH SITES AND METHOD

Most of the sites discussed are situated in the Veneto region (Fig. 1): one is on the south-eastern coast of Lago di Garda, three are to the south of Monti Berici (in the province of Vicenza), one site is near Padova and two of them are in the Treviso province. Only one of the sites is in Friuli (Sacile) and one in southern Trentino (Linfano di Torbole). The last site refers to a sea-core drilling collected in the northern Adriatic Sea (*Mare Adriatico*), to the SE of Chioggia.

The deepest levels of these deposits refer to the Last Glacial Maximum, the Late-Glacial or the Holocene; however, none of the investigated sites gives a complete

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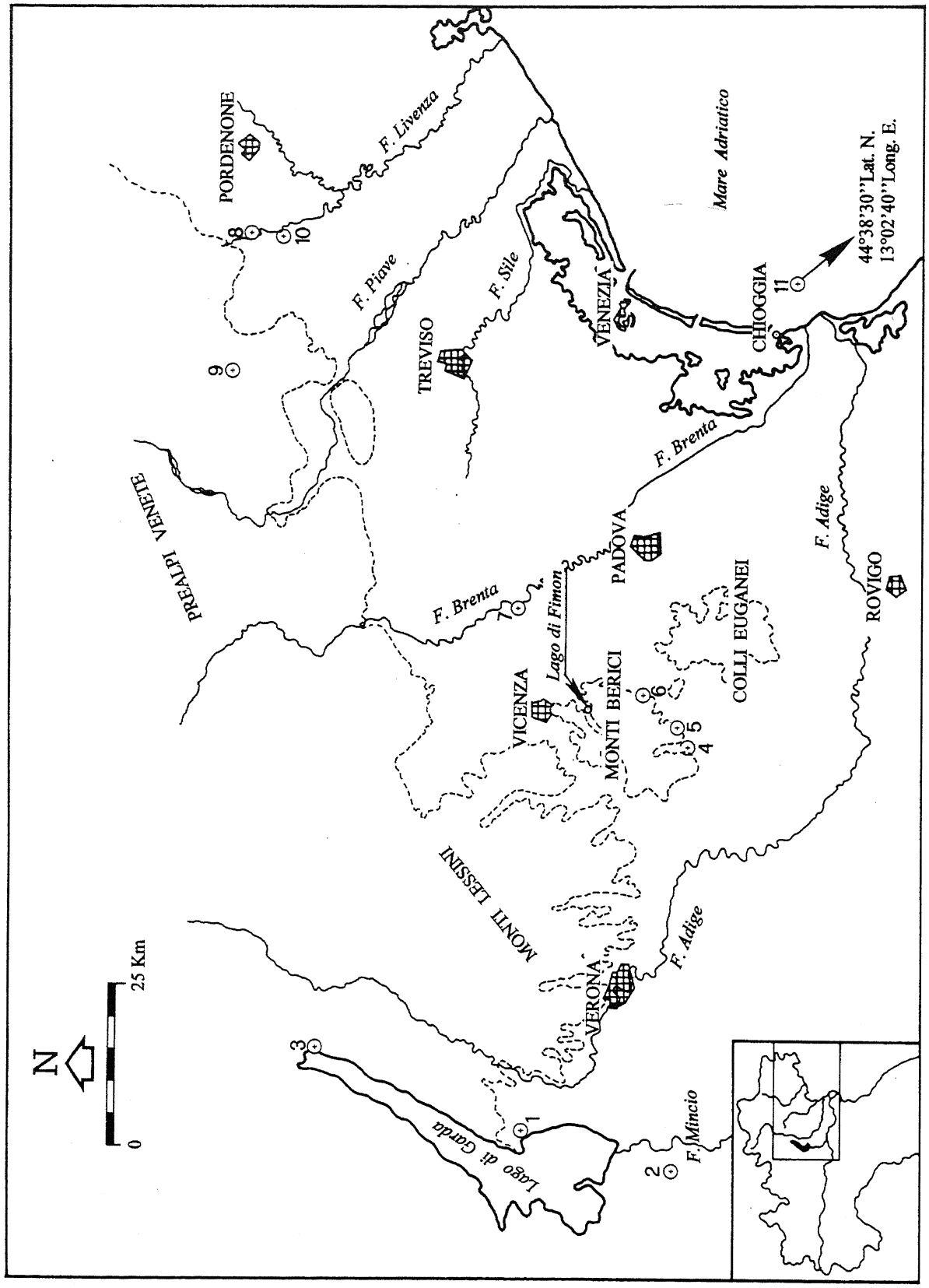
* Invited paper / *Comunicazione ad invito.*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Lago di Garda
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F. Adige
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PREALPI VENETE
TREVISO
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F. Livenza
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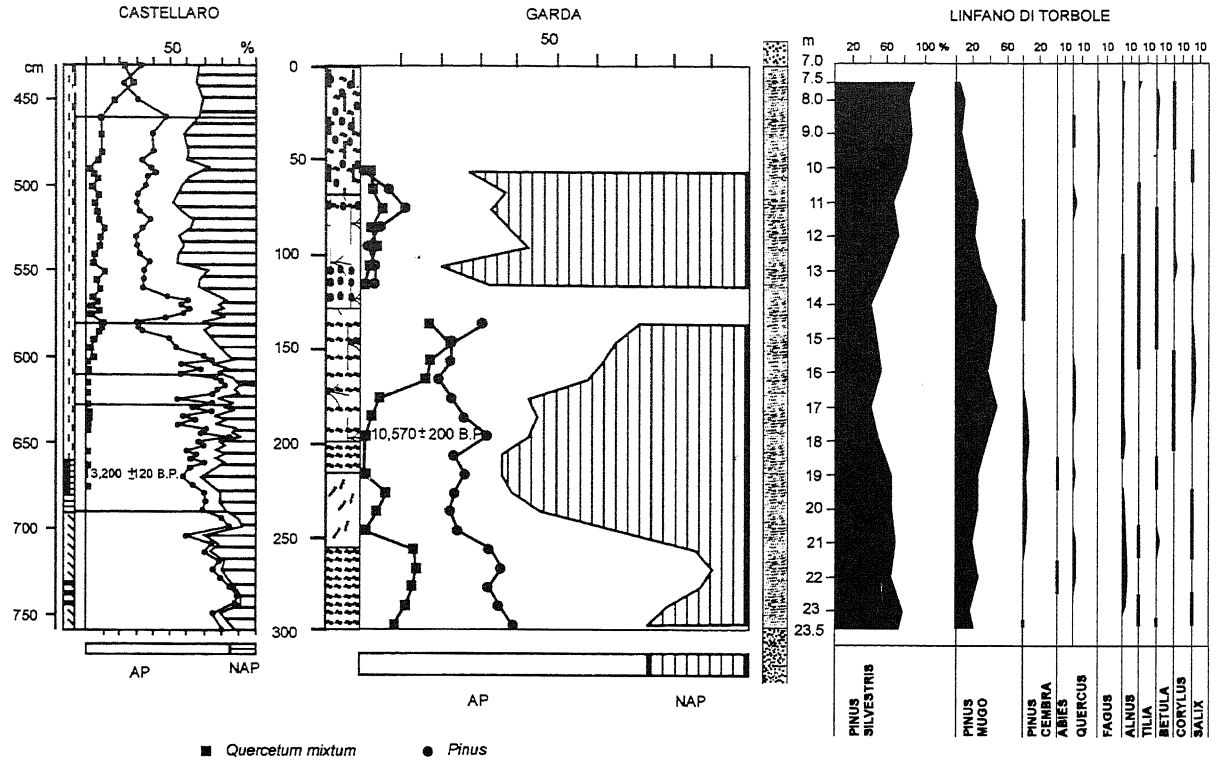

Fig. 2 - The Castellaro (after Bertoldi, 1968), Garda (after Sauro *et al.*, 1983; Paganelli, unpubl.), and Linfano di Torbole (after Venzo *et al.*, 1958) schematic pollen diagrams used for a comparison.

Confronto tra tre diagrammi pollinici schematici relativi a Castellaro (da Bertoldi, 1968), Garda (Sauro et al., *1983; Paganelli,* inedito), *e di Linfano di Torbole (da Venzo* et al., *1958).*

climatic and forest history up to modern times. In the text, each site is indicated by a number in brackets; in the map (Fig. 1) only the numbers are quoted .

The term AP is used to indicate trees and shrubs, while NAP refers to herbaceous plants.

In the pollen diagrams (Fig. 3 and Fig. 4), the term *Quercetum s.l.* (*sensu lato*) is adopted instead of *Quercetum mixtum* (more frequently used by palynologists) because *Quercetum mixtum* generally indicates an oak forest with *Quercus pubescens* Willd., whereas *Quercetum s.l.* has to be considered a potential *Querco-Carpinetum* that is characteristic of the Po Plain vegetation during the Holocene. In spite of this, the deciduous oak cannot unfortunately be determined at the species level on the basis of pollen morphology (for instance the *Quercus robur*-group includes pollen grains of *Q. petraea, Q. robur* and *Q. pubescens*) and the occurrence of other plant taxa allows to characterize the different deciduous oak forests. Therefore, in the curve of *Quercetum s.l.* the pollen grains of *Acer, Tilia, Ulmus, Carpinus betulus, Fraxinus, Corylus, Frangula alnus,* etc. have been included besides the pollens of the *Quercus robur*-group.

The three pollen diagrams from the Lago di Garda area are shown together in Figure 2. It must be noted that the diagrams from Castellaro and Garda include both AP and NAP, while that from Torbole contains AP only.

For the Monti Berici area, the only pollen results from Orgiano (4) (Fig. 3) are given because the other pollen diagrams [Case Cappellare di Sossano (5) and Villaga-Barbarano railway station (6); Paganelli, unpubl.] are both very similar to the Orgiano ones also as to radiocarbon ages.

The chronology (Mangerud *et al.*, 1974; Renault-Mis-kowsky & Petzold, 1989?; Panizza, 1985) of single pollen diagrams was made on a palynological basis, sometimes extended by radiocarbon dating in conventional radiocarbon age (B.P.).

Fig. 1 - Map of the palynologically investigated sites. 1: Garda; 2: Castellaro; 3: Linfano di Torbole; 4: Orgiano railway station; 5: Case Cappellare di Sossano; 6: Villaga-Barbarano railway station; 7: Carturo sul Brenta; 8: Sacile; 9: Revine di Vittorio Veneto; 10: Palù di Francenigo; 11: submarine core recovered at the depth of 42 m b.s.l. about 30 km to the SE of Chioggia.

Mappa dei siti studiati a livello palinologico. 1: Garda; 2: Castellaro; 3: Linfano di Torbole; 4: stazione di Orgiano; 5: Case Cappellare di Sossano; 6: stazione di Villaga-Barbarano; 7: Carturo sul Brenta; 8: Sacile; 9: Revine di Vittorio Veneto; 10: Palù di Francenigo; 11: carota sottomarina raccolta a circa 30 km a SE di Chioggia, alla profondità di 42 m.

3. RESULTS AND DISCUSSION

A study of a river-lake deposit situated at 15 m a.s.l. and with an erosional phase intercalated between 120 and 130 cm at Garda (Fig. 2) in the Lago di Garda area (province of Verona), in the western zone of the Veneto-Po Plain was carried out (Sauro *et al.*, 1983; Paganelli,

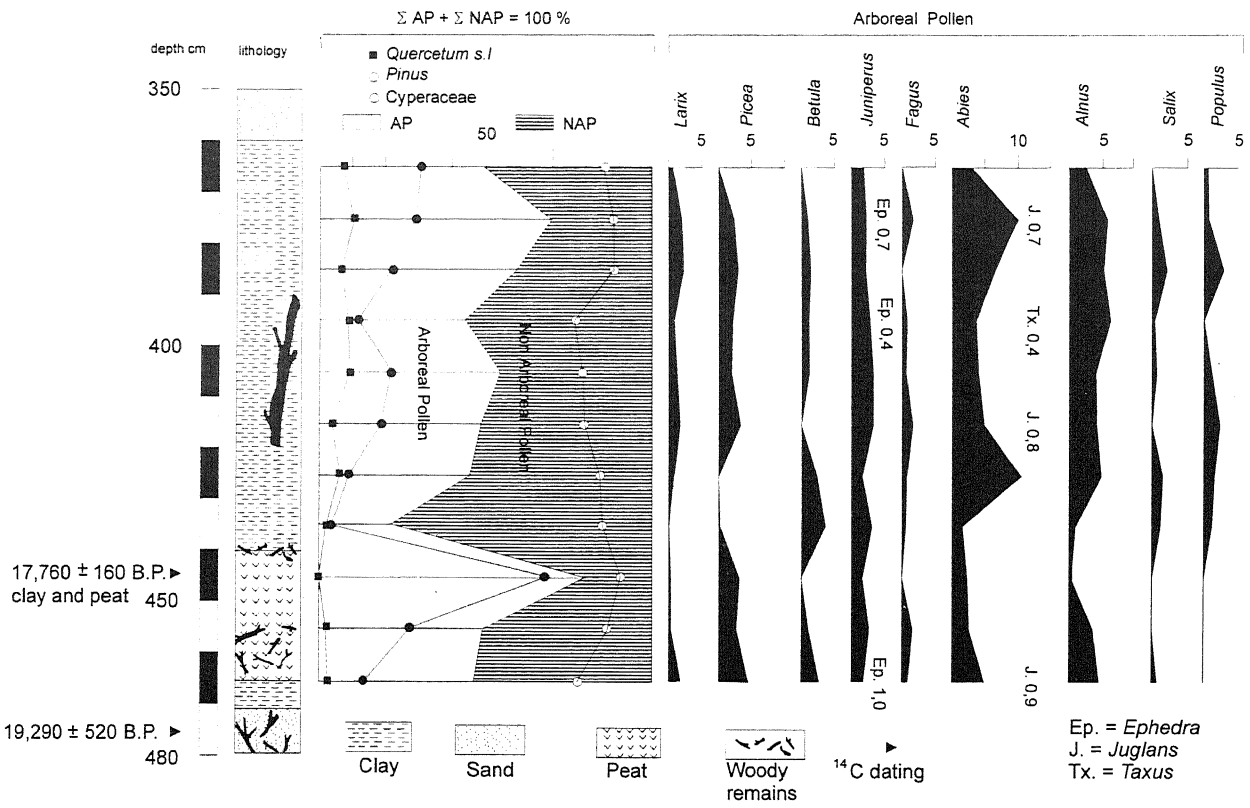

Fig. 3 - Orgiano, to the south of Monti Berici: schematic pollen diagram.
Diagramma pollinico schematico di Orgiano, a sud dei Monti Berici.

unpubl.). A radiocarbon age determination on a trunk in growing position in the middle of the stratigraphic series, gave an age of 10,570±200 years B.P., corresponding to the Younger Dryas. A pollen analysis (Paganelli, unpubl.) showed that the sediment spans over a period between the Allerød oscillation and the Pre-Boreal; erosion has cancelled the climatic and forest history between the Boreal and the Early Sub-Atlantic. In the diagram the Late-Glacial interval shows taxa from a cold climate including subarctic taxa (such as *Pinus mugo, P. cembra, Picea, Larix, Betula nana,* dwarf forms of *Salix, Selaginella selaginoides,* etc.), from dry climates (*Juniperus, Ephedra fragilis*-type, Chenopodiaceae, Caryophyllaceae, *Artemisia,* etc.) with riparian components (*Salix, Alnus*), as well as from humid habitats (Juncaceae, Cyperaceae, *Selaginella selaginoides* and *Alnus*).

The Allerød oscillation, at the base of the diagram, is highlighted by a prevalence of the AP curve with a marked presence of oak forest components and *Pinus* (prevalently *P. sylvestris,* although if *P. mugo* and *P. cembra* are represented as well); the AP curve considerably decreases in the Younger Dryas interval, and increases again during the Pre-Boreal interval.

In the Lago di Garda area (Fig. 1) palynological data are available from two other sites, whose history started in the Late-Glacial: the sequences of Castellaro and Linfano di Torbole (Fig. 2).

The sequence of Castellaro is situated to the south of the lake, at approximately 100 m a.s.l. (Bertoldi, 1968), while the Linfano di Torbole sequence lies at 71.70 m a.s.l., to the north of the lake. The Castellaro deposit comprises a continuous record from the pre-Bølling to modern times (Bertoldi, 1968); a radiocarbon date gave an age of 13,200±120 B.P., predating the Bølling oscillation. The Linfano di Torbole pollen record shows a forest continuous record from the Allerød oscillation to the Pre-Boreal (Venzo *et al.*, 1958). To compare the pollen diagrams of these 3 stations, which are situated along the SW-NE axis of the lake (Fig. 1), we have to consider the portion between 700 and 500 cm for the Castellaro sequence, the sediments up to the erosional phase (120-130 cm) for the Garda sequence and the entire Linfano di Torbole sequence.

It can be seen that the forest evolves gradually from south to north during the Late Glacial. I shall, however, merely point out two interesting aspects. The first concerns the evolution of the *Quercetum mixtum* curve. During the pre-Bølling period at Castellaro (Fig. 2) the vegetation appeared to be basically xerophilous with some birch, bushes or shrubs like *Juniperus, Hippophae rhamnoides* and *Ephedra.* The landscape was thus a tundra with scattered shrubs and trees. Thermophilous plants are entirely absent; *Quercetum mixtum* only sporadically appears at the beginning of the Bølling period, whereas, towards the end of this oscillation, it is more frequent, hence forming in the diagram a closed curve. During the Allerød period *Quercetum mixtum* is decidedly abundant. At Garda (Fig. 2) the oak forest (*Quercetum mixtum*) is well represented from just the beginning of the sequence (Allerød period). On the contrary, low per-

centages of pollen from deciduous oaks, together with *Tilia* and *Corylus,* were found at Linfano di Torbole (Fig. 2) during the Allerød period. It can therefore be concluded that the oak forest was established almost contemporaneously in the area south of the lake, while at Linfano di Torbole the *Quercus* curve is still discontinuous during the Pre-Boreal. Even if an oak forest was absent in the Linfano di Torbole area, there were favourable conditions for its establishment. In fact, the *Pinus sylvestris* forest, with its vegetational dynamism, represents the first stage of what would have evolved into a forest during the Holocene. *Pinus sylvestris* must be considered the real pioneer in forest reconstruction. Following climatic improvements and different edaphic conditions, it will be substituted by or associated with thermophilous and/or mesophilous broad-leaved trees. The second aspect is to understand the contemporary and remarkable presence of the oak forest during the Allerød period at Castellaro and Garda. I feel that we should recall the sheltered areas (*refugia*) which, in the Lago di Garda zone, were located on the Baldo chain and Giudicarie Mountains. This hypothesis is supported by a pollen analysis recently carried out on materials from Isera, near Rovereto (Calderoni *et al.*, 1996) which showed a well represented *Quercetum mixtum* in the deepest level that is attributable to pre-Bølling or Bølling periods.

To the S of Monti Berici, studies were made on a deposit cropping out near Orgiano (Fig. 3), at Case Cappellare di Sossano, and at the Villaga-Barbarano railway station (4, 5 and 6 in Fig. 1), all at 19 m a.s.l. (Paganelli *et al.*, 1988). Radiocarbon age determinations on core samples showed that the deepest levels in the three cores are almost contemporary, their age varying from 19,550±210 B.P. and 19,140±610 B.P., thus in the field of the upper part of the Last Glacial Maximum. It is worth noting that Orombelli (1983) hypothesises, on the basis of radiocarbon ages from Pontida (15,750±360 B.C.), that the greatest glacial expansion took place between 18,000 and 16,000 B.C. in the Alpine zone in Italy. The pollen analysis for one of the three deposits on the Plain (Orgiano, Fig. 3) confirms the presence of cold climate plants, *i.e.* of Euro-Siberian taxa such as *Picea, Pinus mugo, P. cembra, Larix, Alnus viridis* etc., and of arctic-alpine plants such as *Betula nana,* dwarf species of *Salix,* and *Selaginella selaginoides* together with pollen grains from riparian plants (arboreous species of *Salix, Populus, Alnus glutinosa, Sambucus,* etc.). The occurrence of pollen of cold climate plants on the Plain, during the Pleniglacial and Late Glacial, is not a new discovery, as it is well known that wood and other macroscopical remains of these taxa (*Pinus mugo, Picea* and *Betula*) were found in the Veneto-Po Plain and in Versilia (Tuscany) (Paganelli, 1984). The finding in all the pollen spectra (even if in reduced percentages), of pollen grains from mesophilous broad-leaved trees, such as *Quercus* of the deciduous type, *Carpinus betulus, Acer, Ulmus, Fraxinus, Frangula alnus, Tilia, Ligustrum,* and *Corylus,* is more striking. Some taxa represent the components of a mesohygrophilous forest — *i.e.* of the present *Querco-Carpinetum* — which would have later developed and characterized the vegetation of the Po Plain during the Holocene. Pollen grains from *Quercus* (deciduous) and *Carpinus betulus* are always present along the whole Orgiano profile (Fig. 3); the pollen percentage of *Carpinus* ranges from 1.1 to 5.4%.

AP do not always dominate over NAP, due to the still dry and harsh climate. The pollen diagrams also suggest a plain rich in waterways, marshes, ponds and lakes, because of the presence of riparian plants and hygro-hydrophilous NAP, such as abundant Cyperaceae, Potamogetonaceae, Nymphaeaceae, *Myriophyllum, Typha latifolia,* and *T. angustifolia, Sparganium,* Juncaceae, Gramineae of aquatic type [*Phragmithes australis* (Cav.) Trin.], etc. The diagrams also show pollen of *Juniperus, Hyppophae rhamnoides, Ephedra distachya*-type and *E. fragilis*-type, *Artemisia,* Chenopodiaceae, Caryophyllaceae, *Helianthemum,* non aquatic Gramineae, etc., which all together witness for a landscape dominated by a dry open vegetation.

At this point a question arises: how the contemporary presence of hygro-hydrophilous and xerophilous vegetation is explained? Referring to the Würm glaciation, Mancini (1962) explains this fact with the presence, in the Po Plain, of soils containing a superficial water table and of sandy areas where xerophilous plants could stand. From the Mancini's paper, a clear and detailed picture of a polyvalent, heterogeneous vegetational landscape emerges.

The stratigraphic column of Orgiano (Fig. 3) is complete with two radiocarbon dates: one referring to wood at the base of the column (conventional age equal to 19,290±520 B.P.; analysis nr. 3877), the other to a more superficial peaty clay sample corresponding to an age of 17,760±160 B.P. (analysis nr. H 587)[1].

The general increase in the curves of *Pinus, Quercetum s.l., Larix, Abies, Picea* — to mention the more characteristic taxa — in the Orgiano pollen diagram indicates a phase of climatic improvement. This phase may be identified with the warm Lascaux oscillation, from 16,000 to 14,000 years B.C., a time interval which coincides with the most recent radiocarbon date obtained at Orgiano; however, the pollen curves highlight this warm pulse a bit later.

Further northwards, about 20 km NW of Padova there is the site of Carturo sul Brenta, situated at 20 m a.s.l.: radiocarbon age determinations carried out on a birch root in growing position, gave the age of 18,850±200 B.P. (Pellegrini *et al.*, 1984; Paganelli, unpubl.). The palaeovegetational history recorded by the Carturo sul Brenta sediments ranges between a Last Glacial Maximum final phase (sediments from the riverbed of Fiume Brenta) and a Late Glacial phase (sediments collected on the right bank of Fiume Brenta, and included between gravel and sand strata). The Carturo deposit contains pollen from microterm plants (*Pinus mugo, P. cembra, Larix, Picea, Betula* including *B. nana, Alnus viridis,* etc.). Fragments of wood of *Betula pubescens, Pinus cembra* and *P. sylvestris* (Castiglioni *et al.*, 1981) found down-

(1) Both analyses were performed at the Laboratoire d'Hydrologie et de Géochimie Isotopique of Paris-Sud University directed by prof. J.C. Fontes.

stream of the sampling site of the Carturo deposit, confirm the pollen determination. Components of the meso-hygrophilous *Quercetum s.l.* can also be found together with pollen of steppe plants (*Ephedra, Juni-perus, Hippophae rhamnoides, Artemisia,* Chenopodia-ceae, Caryophyllaceae).

The Carturo deposit may be considered as more or less contemporary with that of Sacile in the province of Pordenone (Marchesoni & Paganelli, 1960), situated about 25 m a.s.l. In fact, the analysed Sacile uppermost level was palynologically attributed to the Last Glacial Maximum. The Sacile pollen spectrum, limited to the only AP, shows prevalent *Pinus* pollen (90%) and a low percentage (2% only) of oak forest components. This may be significant for a better understanding of the spatial different evolution of forest landscape in the Veneto Plain.

The next example refers to two stations in the Treviso area: Fornaci di Revine, near Vittorio Veneto in the Venetian Prealps, and Palù di Francenigo, ca. 4 km to the south of Sacile in the plain.

The Fornaci di Revine deposit (9 in Fig. 1), where subfossil trunks of *Larix* were discovered, is situated at 234 m a.s.l. An interdisciplinary research aimed at the reconstruction of the palæoenvironment was undertaken (Casadoro *et al.*, 1976). Radiocarbon dating carried out on two trunks, gave ages of 14,765±135 B.P. and 14,370±115 B.P., which correspond to the Oldest Dryas interval. The pollen diagram (Paganelli & Moretto, 1976) shows a prevalence of cold climate vegetation (also confirmed by the occurrence of larch forest *in loco*), with subarctic species (*Betula nana* and fruticose willows). But the diagram also indicates a relatively high percentage of oak forest (up to 16%), with *Corylus, Quercus* of deciduous type, *Carpinus, Ulmus, Tilia, Ostrya, Acer* and *Fraxinus.*

Finally, the deposit of Palù di Francenigo (Fig. 4), at 23 m a.s.l., describes (Paganelli, unpubl.) the vegetation history between the Early Atlantic period and modern times; this is supported by a peat radiocarbon dating of 5,700±80 B.P. (analysis Rome-384). The pollen diagram shows a forest consisting since the beginning, of prevalent taxa of *Quercetum s.l.* with *Picea* (15.7%); it is possible that the spruce pollen came from the surrounding mountain slopes. Human activity is recorded in the upper part of the pollen diagram.

To conclude this synthesis, I would like to add the pollen results (Paganelli, unpubl.) from a peat level 87÷104 cm thick found in a off-shore core approximately 30 km to the SE of Chioggia at the depth of 42 m. The pollen spectrum (Table 1) shows a high percentage of AP (74%) [mostly pines (41%), with predominant *Pinus sylvestris* (37%)], very low percentages of *P. mugo* and *P. cembra,* components of *Quercetum s.l.* (about 12%), and scarce occurrence of *Picea, Fagus, Betula.* The high AP percentage suggests that woodland had already established in the Paleo-Po valley. The period of formation of this level may date back to the Würm glaciation or to the Late Glacial.

Table 1 - Sporomorph percentages in a 87÷104 cm thick peat level from an off-shore core drilled at the depth of 42 m approximately 30 km to the SE of Chioggia.

Percentuale di sporomorfi rinvenuti in un livello (cm 87-104) di una carota sottomarina prelevata a circa km 30 a SE di Chioggia, a 42 m di profondità.

AP: 74.2%	**NAP**: 25.8%
Pinus sylvestris L. 36.9%	Gramineae 15.3%
Pinus mugo Turra 3.7%	*Typha latifolia* L. 6.4%
Pinus cembra L. 0.6%	Liliaceae 2.9%
Abies 4.5%	Cichorioideae 0.8%
Picea 1.9%	Caryophyllaceae 0.2
Betula 0.8%	Chenopodiaceae 0.2%
Juniperus 0.2%	
Quercus sp. (Deciduous) 2.7%	
Carpinus betulus L. 4.3%	
Acer 0.2%	
Tilia 1.9%	
Fraxinus 1.6%	
Ulmus 1.0%	
Corylus 2.1%	
Castanea 1.9%	**Pteridophyta**: 64.0%, of the Σ(AP+NAP)
Alnus 1.0%	*Thelypteris palustris* Schott 62.1%
Salix 2.3%	*Dryopteris filix-mas* (L.) Schott 1.9%
Ericaceae 6.6%	
	Very abundant fungal spores

5. CONCLUSIONS

Last Glacial Maximum and Late Glacial pollen diagrams show a very heterogeneous vegetation, indicative of quite different climatic and edaphic requirements: for instance, cold climate plants of Euro-Siberian type and even arctic-alpine plants were present together with thermophilous taxa, as well as steppe plants together with hygro-hydrophilous taxa. During this time interval, particular climatic and edaphic conditions occurred, owing to the glaciers which spread towards the plain. It is worth recalling that, during the last Pleniglacial, the coast line of the Adriatic sea was ca. 200 m below the present one (Colantoni *et al.*, 1989), so that the shore was situated on the edge of the meso-Adriatic depression, approximately at the Pescara ridge. However, this situation should be evaluated also on the basis of subsidence phenomena occurring in the Adriatic sea during the Late Glacial and Holocene. Thus, due to the migration of the sea towards the Pescara ridge, its mitigating effect on temperature should have been attenuated in the Veneto area. Moreover, Padania and the Paleo-Po valley were crossed by a diffuse network of waterways, forming ponds and small lakes, whereas the emerged land had already been colonised by forests, as suggested by the pollen spectrum of site no. 11 (Table 1).

During the last Pleniglacial, the forest vegetation was restricted to the plain and the marginal areas near the mountains. Since that time, some of the stations have shown evidence of a potential *Querco-Carpinetum* (indicated in the present paper as *Quercetum s.l.*) which is characteristic, in all its variants, of the climax vegetation of the Po Plain. This type of vegetation, however, was at the time not yet consolidated due to the particular climatic and edaphic conditions.

All available palynological data suggest that the distribution of *Quercetum s.l.* during Pleniglacial and Late Glacial times in the Veneto-Po Plain was different and limited with respect to the present one. Pollen grains of deciduous oak (*Quercus robur*-group) and *Carpinus betulus* are present in all the pollen spectra where *Quercetum s.l.* was found. On the contrary, the other taxa

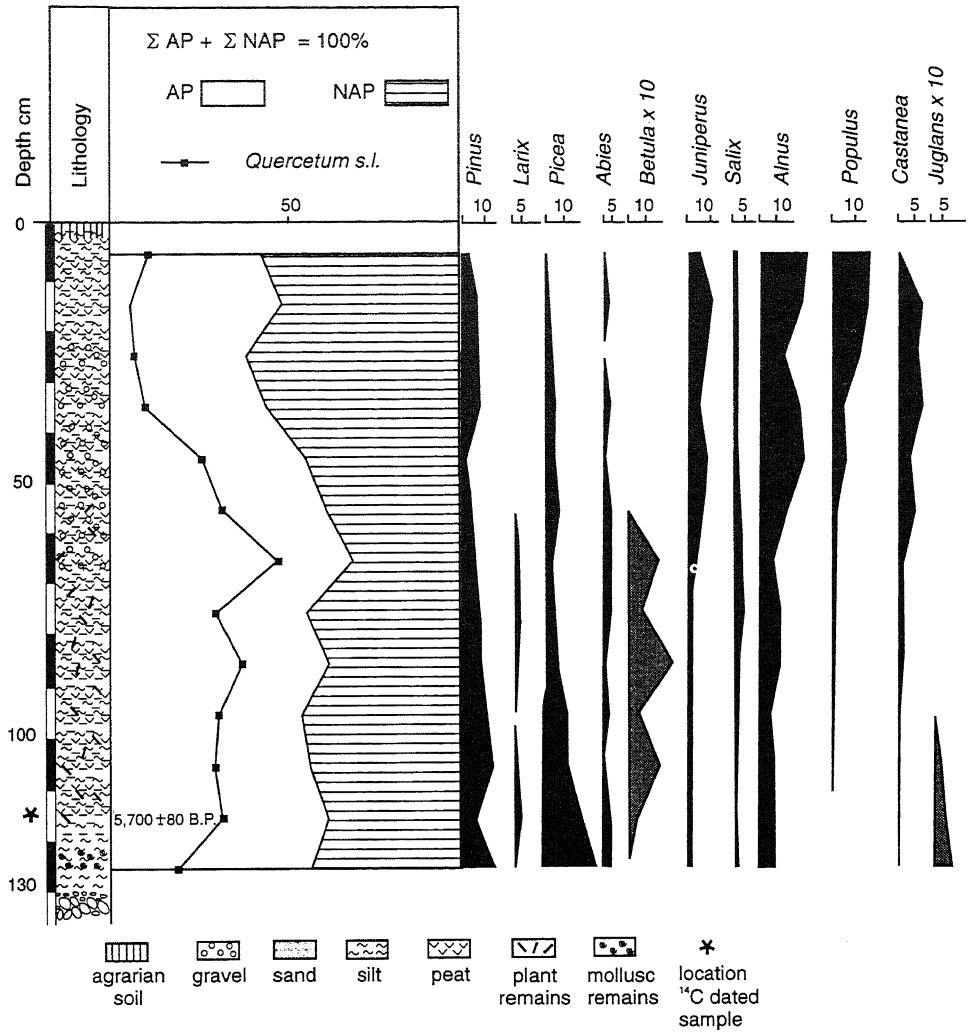

Fig. 4 - Schematic pollen diagram of Palù di Francenigo.

Diagramma pollinico schematico di Palù di Francenigo.

(*Acer, Tilia, Ulmus, Carpinus betulus, Fraxinus, Corylus, Frangula alnus,* etc.) occur sporadically and in lower percentages. At Orgiano (Fig. 3), for instance, the oak pollen percentage ranges between 2 and 4.7%; that of hornbeam between 1.1 and 5.8%. Similar percentages were found at Case Cappellare di Sossano and Villaga-Barbarano. Much lower values of oak and especially hornbeam were, on the contrary, recorded at Carturo sul Brenta. According to Huntley & Birks (1983) "hornbeam pollen is found in scattered sites in south east Europe during the Late Glacial. Pollen values are consistently low (< 3%)".

If the pollen records from the area to the S of Monti Berici and from Carturo sul Brenta to the N of Padova, which are attributable to the last Pleniglacial or Late Glacial, are compared with the pollen spectra from a) the peaty sediment collected off-shore from Chioggia; b) the deposits from the Verona (Accorsi *et al.*, 1984; 1989; 1991; Sauro *et al.*, 1993) and Padova provinces — Arquà Petrarca included (Lona, 1957-1962a; Marchesoni & Paganelli, 1960); c) those from the Venetian Lagoon (Motta di Volpego, Bertolani Marchetti, 1966-1967); and d) from Friuli including Sacile (Marchesoni & Paganelli, 1960), a forest very diversified from one area to another can be identified. In my opinion, such a diversification may depend upon climate and soil moisture conditions. In the areas where springs are found, as in the northern part of the province of Padova (Carturo sul Brenta), or where there is a superficial water table and/or flooding may take place, as in the case of the plain near Monti Berici or, probably, in the Paleo-Po valley (pollen spectrum of the off-shore core drilling from the Adriatic Sea, 11 in Fig. 1 and Table 1), *"refugia"* for *Quercetum s.l.* were present, whereas in the other aforementioned areas where such conditions did not exist, the forests were populated by prevalent conifers, conforming to the climate of that time.

In my opinion, paleovegetation was greatly influenced by hydrological conditions. As a matter of fact, according to Oberdorfer (1957) and Marchesoni (1959), the Po Plain climax vegetation had to be *Quercetum petraeae,* the climate being sub-Mediterranean; yet we find *Querco-Carpinetum* as the result of edaphic features. Marchesoni (1959), in describing the forest history of the Po Plain, realized that the diffusion of *Querco-Carpinetum* was linked mainly to the presence of a superficial water table. On the basis of pollen profiles and present day vegetation, Pignatti (1976) concluded that the climax vegetation in the Po Plain is *Querco-Carpinetum.*

As to the spreading of a plain oak forest in the Po Plain, various theories have been hypothesised. According to Marchesoni (1959), it occurred at the start of the Boreal period, following the alpinisation of the *Fagus* and *Abies* belt, while Bertolani Marchetti (1969-1970) thinks that it occurred during the Atlantic period. Marchetti *et al.* (1993) are of the same opinion on the basis of pollen evidence from sediments near Cremona. In my opinion, presumably *Quercetum s.l.* began to spread from *"refugia"* during the Late Glacial, *i.e.* during the first warm Bølling and Allerød oscillations and continued up to the Holocene

Climatic Maximum when reached its maximum spreading, and when a remarkable snow melting occurred.

The Holocene deciduous forest of the Po Plain is considered to be a mixed oak forest ("*Eichenmischwald = Quercus, Tilia, Ulmus*") by Keller (1931), who carried out a pollen research on pre-alpine peat-bogs, from Piedmont to Friuli. A synthesis of pollen studies carried out on the southern and southeastern Alps, between Torino and Trieste, was made by Schneider (1985), who indicates the plain deciduous forest as: *Quercetum mixtum* for the Alleröd period, *Quercetum mixtum-Corylus* from the late Pre-Boreal to Atlantic period, *Quercetum mixtum-Alnus-Carpinus* from Sub-Boreal to early Sub-Atlantic, and *Quercetum mixtum-Alnus-Ostrya* in the remaining Sub-Atlantic period. Therefore, a different meaning can be given to *Quercetum mixtum* as mentioned by the above mentioned Authors on the basis of recent pollen evidence, at least as regards the paleovegetation of the Po Plain.

Recent pollen results show that, following climate improvement, the meso-hygrophilous taxa growing in the areas of *Quercetum s.l.* expanded with different expansion rates, mainly depending on the dispersion capacity of single fruit.

Taxa characterizing present-day *Querco-Carpinetum* were already present in the Veneto-Po Plain during the Late Glacial, as evidenced by the Orgiano, Case Cappellare di Sossano, and Villaga-Barbarano station pollen records, as well as those of Lago di Fimon in Monti Berici (Keller, 1931; Lona 1957-1962b; Durante Pasa, 1972), and of sediments collected off-shore from Chioggia (see nos. 4, 5, 6 and 11 in Fig. 1 and Table 1).

Before man impact, the Veneto Plain was largely occupied by forest vegetation. The edaphic conditions played a very important role in determining the distribution of the different forest components: *Querco-Carpinetum* occurred on fertile well-drained land, *Querco-Ulmetum carpinifoliae* on humid soils, *Alnetum glutinosae* and *Carici-Fraxinetum* on marshy, peaty, or periodically flooded soils (Pignatti, 1976). Riparian vegetation grew along the rivers and hygro-hydrophilous plants were present in ponds and small lakes.

It can be concluded that the plain oak forest represents the remain of the Colchic vegetation that developed during the Riss-Würm interglacial period (Bertolani Marchetti, 1964; Lona & Venzo, 1956; Mancini, 1962; Marchesoni, 1960; Paganelli, 1961b; 1984; Sercelj & Culiberg, 1984; Sordelli, 1896; Venzo, 1955), which, for northern Europe, corresponds with the Eemian (Menke & Tynni, 1984; Sibrava *et al.*, 1986; Behre, 1989; Pons *et al.*, 1989; Mangerud, 1989). Therefore, the *Querco-Carpinetum* forest was the expression of a particular edaphic situation, characterised by soils with a very superficial water table, which could easily be flooded and become marshy. These features would have been later modified by human impact, when man began to cut the forests and drain waterlogged soils, to obtain ground for grazing, cultivation of economic plants and construction of human and, much later, also industrial settlements.

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