

The Massaciuccoli Holocene pollen sequence and the vegetation history of the coastal plains by the Mar Ligure (Tuscany and Liguria, Italy)

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Abstract A 90 m deep core from the Massaciuccoli lake basin (Tuscany, Italy) offers new material for improving the knowledge of the Holocene vegetation history in the coastal plains in Tuscany and Liguria bordering the Mar Ligure (Ligurian sea). In this paper, an assessment of the upper part of the core is presented. During the Holocene, the area was covered by woodlands whose composition changed in time. Numerous oscillations of the tree taxa were recorded which can probably be connected to sea level variations that had a strong influence on the depth of the water table. Human impact is evident particularly at ca. 4200–2500 B.P. when traces of opening of the woodland accompanied by noticeable pollen percentages of *Vitis* could suggest an early agricultural practice favouring this native plant. The new data have been integrated with previous palaeobotanical and archaeobotanical research. The occurrence of coastal wetlands has been shown. Throughout the Holocene, Mediterranean evergreen vegetation is generally poorly represented; it becomes widespread only in the late Holocene, suggesting that its establishment was probably favoured by the management practices in the coastal plains, particularly land reclamations, starting from the Roman period.

Keywords Tuscany · Liguria · Coastal plains · Northwest Italy · Holocene · Pollen analysis

Introduction

The coastal plains of Liguria and northern Tuscany, facing the Mar Ligure (Fig. 1), have been the setting of several corings and archaeological excavations, but their vegetation history is still far from being well known. Previous palynological investigations carried out in the Ligurian and Tuscan coastal areas (Ferrarini 1969; Arobba et al. 2001, 2004; Guido et al. 2004a,b), in the lower Arno river valley (Galletti Fancelli 1971, 1979; Paoli and Cellai Ciuffi 1980, 1983; Abbate Edlmann et al. 1991, 1993; Mori Secci 1991; Begliomini et al. 2003; Mariotti Lippi et al. 2006) and also in the Massaciuccoli basin (Marchetti 1935; Marchetti and Tongiorgi 1936; Tongiorgi 1936; Grassi et al. 2000; Menozzi et al. 2003) have supplied much information regarding vegetational and climatic changes in this area during the Quaternary.

The Massaciuccoli lake basin (northwest Tuscany, Italy) has been considered for a long time the principal biostratigraphical archive for the study of the landscape evolution of that area. However, the complex history of the basin reduces the availability of suitable study sites. In fact, the area has been inhabited at least since the Middle and Upper Palaeolithic period (Cremonesi Grifoni and Tozzi 1994), subjected to repeated episodes of drainage starting from Roman times, and has also been influenced by quarrying activities. The silica sand extractions ceased only recently, and strongly affected the stratigraphy of the quarried areas (Mazzanti and Nencini 1994). This situation has limited the possibility of investigating the palaeoenvironment, since the stratigraphic sequences are damaged and the chronological sequence al-

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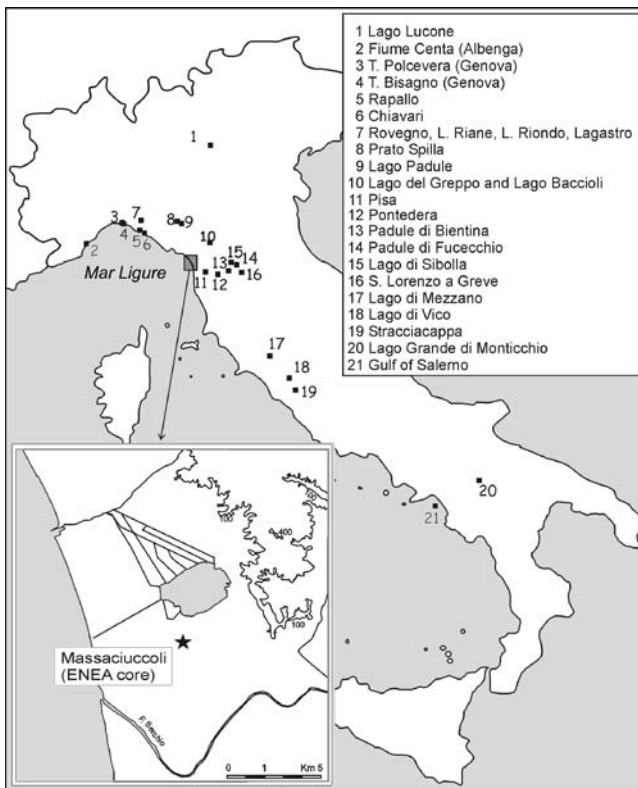


Fig. 1 Geographical location of the Massaciuccoli basin and the other sites mentioned in the paper

tered. For this reason, pollen analyses in the area must be preceded by historical study of the sampling site and geostratigraphic investigations of the sediments.

A 90 m deep core (MSC) was obtained by ENEA (Ente per le Nuove tecnologie, l'Energia e l'Ambiente –Italian National Agency for New Technologies, Energy and the Environment) in an area of the basin not directly disturbed by human activity. The sedimentology and chronology of this core have been presented in previous reports (Antonioli et al. 2000; Lambeck et al. 2004).

This paper is devoted to the Holocene vegetation history of the site as shown from pollen analyses of the upper portion of the MSC core. The study of the lower part of the core, which reaches a depth of 90 m with a date of 130,000 B.P. at ca. 70 m (Antonioli et al. 2000), is still in progress.

The study area

The Massaciuccoli lake basin is situated on the coastal plain between the mouths of the rivers Arno and Magra, at sea level (Fig. 1). It is characterised by complex dune systems along the sandy coasts, and by numerous inland wetlands, today much reduced by repeated drainage works for agricultural land use. The area, which was formed in the Up-

per Pleistocene, is the result of the interaction of geological and palaeogeographical factors, mainly the varying sediment charge of the Arno-Serchio fluvial system, which created the Versilia plain. The territory has been affected by numerous marine ingressions, and has passed through lagoon and fresh water marsh phases (Federici 1993).

The climate is essentially Mediterranean, influenced by the proximity of the sea which moderates the temperatures. In the Arno floodplain near Pisa, 900 mm mean annual precipitation and 15 °C mean annual temperature have been recorded. Winds, principally blowing from the south-west, are also an important factor, especially concerning relative humidity values that never fall below 60% (Rapetti and Vittorini 1994).

The current flora and vegetation of this plain have been the subject of numerous studies (Corti 1955; Montelucci 1964; Ferrarini 1977; Gellini et al. 1986; Tomei et al. 1986; 1995; Arrigoni 1990; Vagge and Biondi 1999; Garbari 2000; Garbari and Cecchi 2000). The coastal sandy zone is characterised by pioneer halophytes and psammophytes (plants growing on sand) such as *Cakile maritima* and *Ammophila littoralis*. In the wetland areas *Phragmites australis*, *Cladium mariscus*, *Typha angustifolia* and *Carex elata* are the most common species. Proceeding inland, *Juniperus oxycedrus* subsp. *macrocarpa*, and *J. communis* appear on the dunes, followed by *Quercus ilex* woods. In the interdunal areas the vegetation is formed by *Quercus robur* and *Carpinus betulus*. Where the soil becomes damper, *Fraxinus oxycarpa* grows, or alternatively *Populus alba* together with *Alnus glutinosa* and *Ulmus minor*.

All of the floristic and vegetational investigations carried out in the Massaciuccoli lake basin indicate the high bioecological significance of the vegetation which is the result of past distributional and climatic factors. The area includes the last conservation niches for many plant species that were more generally widespread in the past and have almost completely disappeared from Italy today. For this reason, part of this diversified natural heritage has recently (1979, 1995) been included in the “Parco Regionale di Migliarino-San Rossore-Massaciuccoli”.

Materials and methods

The core was obtained in the Massaciuccoli basin (43 °48'N, 10 °19'E) by ENEA in 1998; the subsampling was carried out by Prof. Bonadonna's team at the Dipartimento di Scienze della Terra of the Università di Pisa (Table 1, Fig. 2).

In a previous research programme, pollen analyses were performed along all of the 90 m MSC core, with the aim of obtaining a general survey (Menozzi et al. 2003). In this paper, attention has been devoted to the upper 34 m of the core (Fig. 2), previously named MaSE II *pro parte* and MaSE-III,

Table 1 Lithostratigraphy of the Holocene portion of the Massaciucoli core (from Antonioli et al. 2000)

Depth (cm)	Description
0–33	Soil
33–100	Grey clayey silts
100–210	Grey clay with peaty layers
210–715	Grey clay alternate with silty and sandy layers; presence of organic matter and shells
715–800	Silty sands with abundant fragmented shells
800–900	Silt with sandy layers
900–2700	Middle and coarse sands alternate with levels rich in shells
2700–2920	Sandy silts and silty sands
2920–3400	Sandy silts alternate with sandy clay or silt with shells and to clay-organic layers, sometimes oxidised

which correspond to the last 10,000 years up to Roman times (Table 2). The samples were collected, where possible, every 10 cm, with a total of 67 samples. The discontinuities were caused by the nature of the sediments which were sometimes sandy or gravelly (Table 1, Fig. 2).

Each sample was treated according to the standard methodologies (Fægri and Iversen 1989). Pollen analysis was carried out with a light microscope, operating at 400–1000 \times . The grains were identified making reference to the literature (Punt et al. 1976–1996; Fægri and Iversen 1989; Andersen 1979; Moore et al. 1991; Reille 1992–1998) and to reference collections. Pollen concentration (APF = Absolute Pollen Frequency) was calculated according to Accorsi and Rodolfi (1975); the values of all the examined samples are given in Fig. 2. Pollen percentages are calculated from the total land plant pollen sum (TLP). Only the samples with

at least 250 identified grains are presented in the percentage diagram (Fig. 3), which was drawn using GpalWin (Goeury 1997).

In the diagram, hygrophilous and hydrophilous herbs include Juncaceae, *Filipendula* cf. *ulmaria*, *Anagallis* cf. *tenella*, *Lythrum*, *Glyceria* type, *Sparganium*, *Typha latifolia*, *Typha angustifolia* type, *Alisma*, *Butomus*, *Callitriche*, *Hydrocotyle*, *Myriophyllum* and *Potamogeton*.

Results

In the Holocene sequence, the APF values are variable, but generally low, ranging from approximately 100 to nearly 400,000 grains/g (Fig. 2). The state of preservation of the pollen grains was not always good. However, in the samples described below, the percentage of the unidentifiable grains is quite low, averaging around 3%.

The pollen diagram (Fig. 3) has been divided into seven pollen zones (PAZ), which will be discussed from the earliest to the most recent.

MSC1 (33.85–33.45 m; 9590 \pm 60 B.P. at 34 m) This sequence is characterized by significant percentages of AP that are mainly represented by deciduous *Quercus*, *Corylus* and *Alnus*. Other elements of the mixed oak woodland, like *Ulmus* and *Tilia*, are noteworthy, although they are present in low percentages. The conifers, mostly *Abies* and *Pinus*, are scarcely represented. *Q. ilex* shows a slight increase, always with low values (< 10%). Poaceae and Cyperaceae, the first with higher percentages, form the main part of the NAP component and follow a decreasing trend. Fern spores are recorded with low values.

Table 2 Radiocarbon dates from the Massaciucoli core according to Antonioli et al. (2000, *) and Lambeck et al. (2004, **)

Depth (m)	Marker	Dating method	Radiocarbon age uncal B.P.*	Radiocarbon age cal B.P.**
– 1.0	Marsh	conventional	2206 \pm 52	2227 \pm 99
– 2.1	Marsh	conventional	2716 \pm 37	2812 \pm 37
– 2.5	<i>Cerastoderma glaucum</i>	conventional	4122 \pm 53	4166 \pm 78
– 2.6	Wood	AMS	3827 \pm 40	4247 \pm 97
– 2.7	<i>Cerastoderma glaucum</i>	–	–	4660 \pm 115
– 3.0	Wood	–	–	4665 \pm 130
– 4.0	Wood	conventional	5405 \pm 58	6200 \pm 84
– 7.5	Marine shell	AMS	5471 \pm 41	5863 \pm 33
– 8.9	<i>Hinia</i> sp.	AMS	6194 \pm 47	6626 \pm 49
– 9.5	<i>Cerastoderma glaucum</i>	AMS	6530 \pm 50	7050 \pm 86
– 10.5	<i>Cerastoderma glaucum</i>	AMS	7135 \pm 47	7605 \pm 40
– 15.3	<i>Venus</i> sp.	AMS	7370 \pm 50	7813 \pm 53
– 15.8	Infralittoral shell	AMS	7385 \pm 44	7844 \pm 60
– 27.3	Infralittoral shell	AMS	7415 \pm 45	7870 \pm 53
– 29.5	Wood	AMS	8419 \pm 48	9422 \pm 91
– 29.9	Marsh	conventional	8866 \pm 58	9904 \pm 111
– 32.1	<i>Cerastoderma glaucum</i>	AMS	8970 \pm 50	9622 \pm 177
– 34.0	<i>Cerastoderma glaucum</i>	AMS	9590 \pm 60	10146 \pm 90

Fig. 2 Schematic representation of stratigraphy, chronological references, and pollen concentrations (APF) in the MSC core

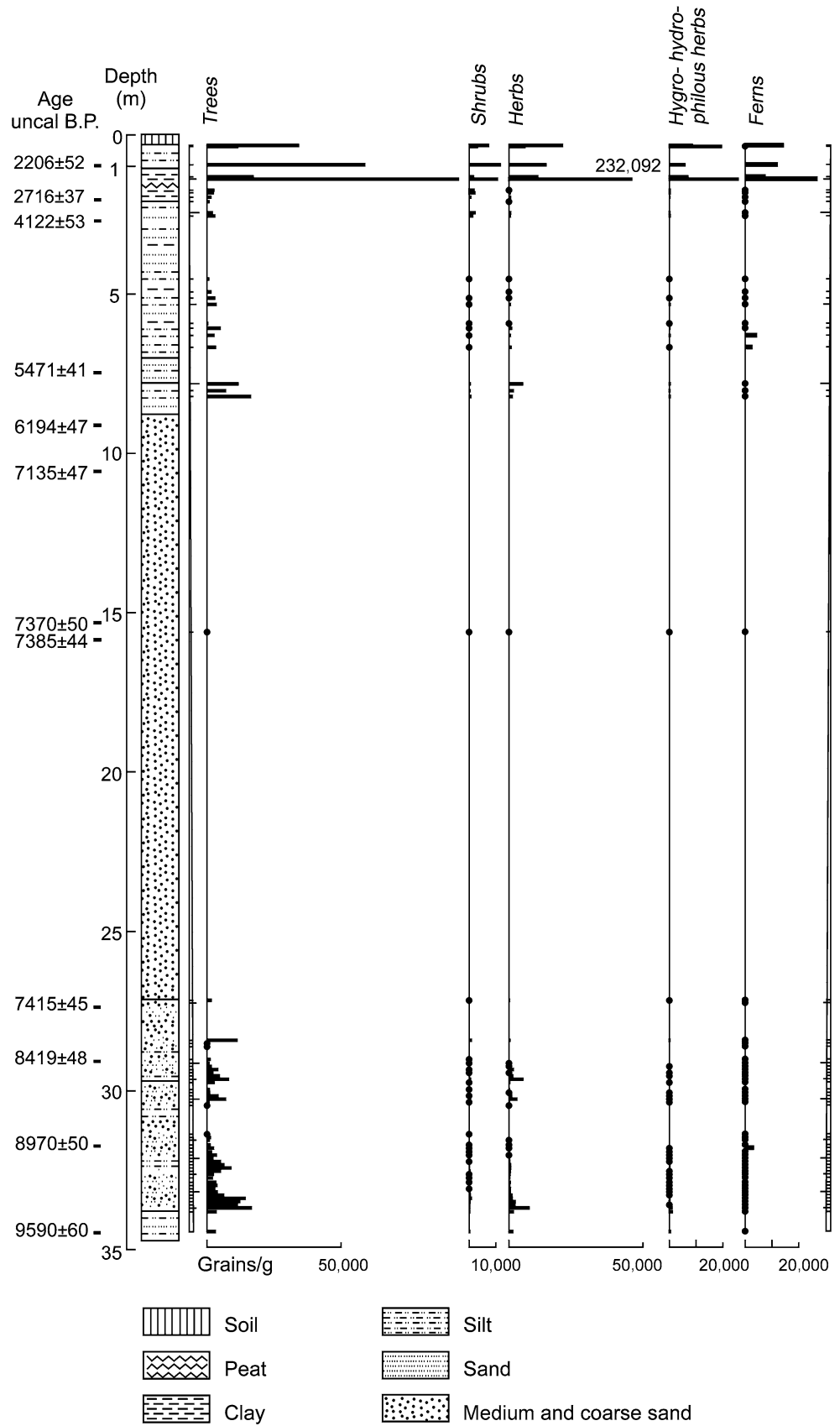
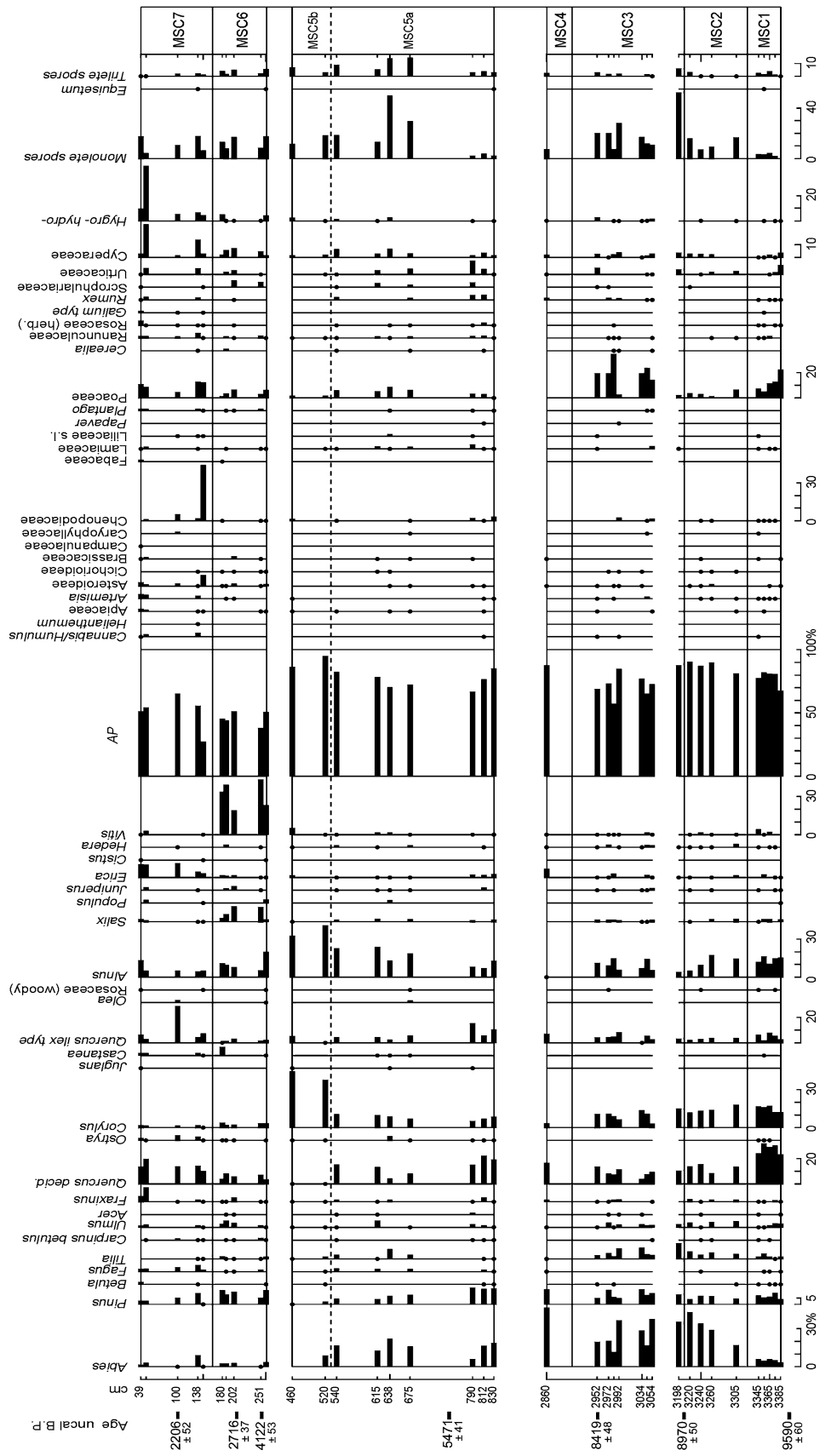


Fig. 3 Pollen diagram of the Holocene MSC core (selected taxa)



MSC2 (33.05–32.20-m; 8970 ± 50 B.P. at 32.10 m) The onset of the second PAZ is marked by increasing values of *Abies*. *Quercus* is present at lower percentages than in MSC1; *Corylus* and *Alnus* decrease in the upper part of the zone. NAP percentages are always very low and represented by Poaceae and Cyperaceae. Fern spore percentages become more significant.

MSC3 (31.98–29.52-m; 8419 ± 48 B.P. at 29.52 m) The zone formed by sterile sandy levels (Table 1) is characterized by oscillating AP percentages. *Abies* follows an overall decreasing trend. Deciduous *Quercus* values are low, as are other elements of the mixed oak woodland; *Alnus* percentages oscillate. There are high values of Poaceae and a peak of fern spores in the lowest sample, and these then maintain relatively high values.

MSC4 (29.20–27.34 m) In the overlying sandy silts, the analysed samples show very low concentration values. Only one sample (28.60 m) has a sufficient APF and has significant values of *Abies* pollen and, to a lesser degree, deciduous *Quercus*.

MSC5 (8.30–4.60-m; 5471 ± 41 B.P. at 7.50 m) The AP percentages decrease at first, then increase. In the lower part (subzone a: 8.30–5.40 m), *Abies*, *Pinus*, *Quercus*, and *Alnus* are important. *Pinus* and *Q. ilex* type show an opposite trend to *Alnus*. NAP, mainly Poaceae, decreases after a slight increase. Wetland and freshwater plants (such as Cyperaceae and *Potamogeton*) are also recorded. Fern spores show a peak in the middle of this subzone.

The upper part (subzone b: 5.20–4.60 m) is characterized by high percentages of *Corylus* and *Alnus*, while all other tree taxa drop to very low values. *Abies* disappears in the uppermost level.

MSC6 (2.60–1.80-m; 3827 ± 40 B.P. at 2.60-m to 2716 ± 37 B.P. at 2.10 m) Throughout the zone, AP values are formed almost only by *Alnus*, *Salix* and *Vitis*, the latter with two peaks of high percentages. The occurrence of *Castanea* is noteworthy.

MSC7 (1.45-m–39 cm; 2206 ± 52 B.P. at 1 m) The first sample shows the lowest AP value of the whole diagram and a peak of Chenopodiaceae and Asteraceae. The following samples have increased AP due to the contribution of *Q. ilex* type and *Erica*. Elements of the deciduous woodlands seem to be more or less established. At 42 cm, hygrophilous and aquatic plants show a peak, while *Q. ilex* type and *Pinus* decrease.

Discussion

The oldest samples (MSC1; Fig. 3), representing the beginning of the Holocene, show a tree cover mainly of deciduous *Quercus*, *Corylus*, *Tilia* and *Ulmus*. *Alnus* is also well represented, while conifers, particularly *Abies*, are scarce. The

Poaceae values show the contemporary occurrence of open areas.

Earlier studies (Marchetti 1935; Marchetti and Tongiorgi 1936; Tongiorgi 1936; Alessio et al. 1965; Menozzi et al. 2003) suggest that a cold continental climate, which determined the development of woodlands dominated by *Abies* and *Pinus sylvestris/mugo* was established in the Late Pleistocene. Significant percentages of *Abies* and *Pinus mugo/sylvestris* pollen were still found at the onset of the Holocene in Pisa (Trinci 2003). However, mesophilous and Mediterranean taxa also occurred in the area, showing the existence of at least some temperate climate habitats, which might have played the role of refuge areas. The finding of *Menyanthes trifoliata* seeds (Marchetti and Tongiorgi 1936) shows the presence of wetlands, also indicated by freshwater plant pollen at the base of the Holocene (Trinci 2003).

Around 9000 B.P., the MSC core (MSC2) has high values of *Abies* pollen, suggesting the spreading of this conifer when the oak woodland was reduced and the open areas mostly disappeared. The subsequent oscillations of the AP values (MSC3) denote a rather variable landscape in which the tree cover alternately expanded and retreated, each time modifying its composition. This suggests a period of environmental instability, probably related to fluctuations of the water table. This is above all indicated by the oscillations of *Alnus* and Poaceae. A peak of both *Abies* and deciduous *Quercus* (MSC4) precedes the occurrence of a thick sand layer caused by a marine ingression (Figs. 2 and 3) in the Massaciuccoli basin.

At higher altitudes, the presence of significant percentages (> 10%) of *Abies* are reported, starting from 11,500–10,500 B.P. in the northern Apennines (Terhürne-Berson et al. 2004). Particularly in the Ligurian Apennines, *Abies* is recorded from 10,600 B.P. together with *Quercus robur* type and *Ulmus* (Branch 2004). Starting from 10,000 B.P., the presence of significant percentages of both *Abies* and deciduous trees like *Quercus*, *Corylus*, *Ulmus* and *Tilia* were also recorded in the Appennino Parmense (Prato Spilla, Watson et al. 1994), and in the Tuscan-Aemilian Apennines (Lago Padule, Lowe et al. 1994a). In the Ligurian woodlands, *Abies* became the dominant element between 8600 and 6700 B.P. (Branch 2004); in the Tuscan-Aemilian Apennines, *Abies* shows high values after 9000 B.P., together with a drop of the *Quercus-Tilia-Ulmus* curve (Lago del Greppo and Lago Baccioli, Bertolani Marchetti et al. 1994).

In central Italy around 10,000–8000 B.P., *Abies* is sporadically recorded with low percentages, while *Quercus* and other broadleaved trees are dominant in the spectra (Lago di Vico, Magri and Sadori 1999; Stracciaccappa, Giardini 2006). In the same period in southern Italy, noticeable percentages of *Abies* are recorded, even if broadleaved trees were prevalent (Lago Grande di Monticchio, Allen et al. 2002; Gulf of Salerno, Russo Ermolli and di Pasquale 2002). However,

interpreting the relationship between the northern and southern Italian mountain plants is a difficult task, because of the different and peculiar vegetation histories of the two geographical areas.

Between about 7500 and 5500 B.P. the MSC pollen sequence is interrupted by a thick sand layer from a marine ingression that took place between 10,400 and 6600 B.P. (Figs. 2 and 3; Antonioli et al. 2000; Table 1). This gap in the vegetation history is partially filled by Ligurian coastal data (Cornara et al. 1996; Montanari et al. 1998; Brandolini et al. 2002), from cores of continental sediments in the city of Genova (Liguria), at the mouth of the streams Bisagno and Polcevera (Fig. 1). These analyses show that between 8500 and 5500 B.P., the coastal vegetation was characterised by woodlands in which *Abies* was abundant, together with *Pinus*, deciduous *Quercus*, *Ulmus*, *Tilia*, *Alnus*, etc. A substantially similar scenario results from the analysis carried out at the mouth of the river Centa (Fig. 1; Arobba et al. 2001). In France, *Abies* spread between 7200 and 5200 B.P. in the western Alps and Provence (Digerfeldt et al. 1997). A study in the Alpes Maritimes in southeast France places the onset of significant percentages of *Abies* at the beginning of the Atlantic period (Nichol-Pichard and Dubar 1998).

Starting from 5500 B.P. (MSC5), the Massaciuccoli sequence indicates a landscape composed of coniferous and broadleaved woodlands, with occasional open areas. Later, high percentages of *Corylus* could indicate the occurrence of woodland clearance, presumably a signal of human activity. More inland areas had a thin tree cover, dominated by deciduous *Quercus*, *Ulmus*, *Fraxinus* and *Acer*, as is shown by the archaeobotanical investigations at Pontedera dated to the Neolithic period (Fig. 1; Abbate Edlmann et al. 1991, 1993) and by analyses carried out on cores from the Bientina marsh, the Padule di Fucecchio and Lago Sibolla (Fig. 1; Paoli and Cellai Ciuffi 1980, 1983, 1984). The slight development of the woodland may be the consequence of damp soils or may result from woodland clearance for agricultural purposes, or both. Indeed, cultivating practices are revealed by numerous plant macrofossil remains from Neolithic and Bronze Age archaeological sites in the Pisa area (D'Amato Avanzi 1953; Nisbet 1987; Mori Secci 1991). Northwards, at the same time (about 5000 B.P.), pollen analysis carried out in Liguria near Chiavari shows the presence of a Mediterranean maquis mainly composed of *Erica* cf. *arborea* (Fig. 1; Guido et al. 2004a). Although the anthropogenic indicators are not present in high values, this kind of vegetation may be a consequence of long-term human action.

At Massaciuccoli, high percentages of *Vitis* together with low AP values were found between approximately 4200 and 2700 B.P. (MSC6). These two contemporary features could suggest an early agricultural practice, at least favouring this native plant. The analyses show the presence of *Salix* and *Alnus* in coincidence with both of the *Vitis* peaks (Fig. 3)

and hint at the occurrence of swamp woods in which the grapevine grew wild in the form of a climber. Therefore, it could be hazardous to suggest that the grapevine was actually being cultivated, in the absence of significant percentages of anthropogenic indicators and/or archaeological evidence; a less ambitious interpretation could be that some form of management practice in the area, such as woodland clearance, indirectly favoured the spread of *Vitis*, and then its cultivation or management followed. At Pontedera, not far from Pisa, stored wild *Vitis* seeds were found in a Neolithic (5500 B.P.) archaeological site (Mori Secci 1991). Pollen analysis of deposits referred to the upper Holocene (Grassi et al. 2000) shows a strong development of wetland vegetation and the spread of human-induced habitats in the Massaciuccoli lake.

Investigations of coastal-marine sediments in Liguria have recorded the appearance and spread of fruit trees such as *Olea*, *Juglans* and *Vitis*, since at least 2500 B.P. (Guido et al. 2004c).

A decrease in the tree cover is recorded between 3800 and 3500 B.P. in central Italy (Lago di Mezzano, Sadori et al. 2004) and is interpreted as having been triggered by a climatic change towards drier conditions, successively intensified by human action; at the same time low percentages of *Vitis* occur. *Vitis* pollen probably related to agricultural practices was detected at Lago di Vico only after ca. 2630 B.P. (Magri and Sadori 1999). In northern Italy, there is a reduction of deciduous woodlands and the presence of *Vitis* micro- and macroremains around 2000 and 1100 B.C. (Lago Lucone, Valsecchi et al. 2006) and at the onset of the Bronze Age (Terramara di Montale, Mercuri et al. 2006).

Pollen analysis of a valley mire in southwest Spain showed two *Vitis* events at approximately 4500 and 3500 B.P. The first event, accompanied by *Salix*, was interpreted as a spontaneous expansion, while the second event, accompanied by disturbance indicators, was interpreted as being a signal of cultivation (Stevenson and Moore 1988). In Greece an increase in *Vitis* pollen shortly after 3500 B.P. is interpreted as a spread of the swamp woods where *Vitis* was growing (Crete, Bottema and Sarpaki 2003). The authors remark on the high pollen productivity and dispersal of wild vines and the under-representation of the cultivated forms. An intermediate pollen productivity is supposed to have occurred during the transition from the dioecious wild form to the hermaphrodite cultivated grapevine. A slight increase in *Vitis*, cautiously read as a signal of an agricultural phase, contemporary with the Celto-Ligurian civilization, was detected in southern France around 2000 B.P. (lower Rhone valley, Andrieu-Ponel 2000).

At Massaciuccoli, *Vitis* disappears together with a drop in the AP percentage mainly due to a large quantity (45%) of Chenopodiaceae. Since determination of Chenopodiaceae pollen at a lower taxonomic level is not always possible, interpreting this event unequivocally is hard. However, it

is important to keep in mind that the site is located in an area adjacent to the coast that represents a natural habitat of many of the *Chenopodiaceae*. Consequently, their peak could be considered as a signal of an enlargement of brackish environments in the Massaciuccoli lake basin, also according to the fluctuation of the shoreline (Lambeck et al. 2004; Fazzini and Maffei 2000).

Research data show that a cooler climatic phase began during the Etruscan epoch (Lamb 1995), causing the spread of *Fagus* in the area, at lower altitudes than the present ones. Unfortunately the dating of this event is not clear. The spread of *Fagus* was hypothesized by Negri (1927) and confirmed by investigations carried out on the Apuane coastal plains (Ferrarini 1969) and in the Pisa cores (Trinci 2003). A similar condition is also suggested by the analyses in the most ancient sediments, of uncertain date, at the archaeological site of Pisa San Rossore, where the subsequent *Fagus* decline coincides with the expansion of deciduous *Quercus* (Begliomini et al. 2003; Mariotti Lippi et al. 2006). At the same time in the Apennines, decreasing pollen percentages of *Abies* were recorded, until its disappearance in the late Middle Ages (Lowe et al. 1994b; Guido et al. 2004c).

At Pisa San Rossore, the integration between pollen and sedimentological data has allowed some inferences on the dynamics of the warm Roman period and indicates that the area was affected by century-scale hydroclimatic crises triggering catastrophic floods (Mariotti Lippi et al. 2006).

Around 2400 B.P., the coastal plain of eastern Liguria in the surroundings of Rapallo was characterized by swampy woodlands dominated by *Alnus*, *Cyperaceae*, *Juncaceae* and abundant aquatic plants (Fig. 1; Guido et al. 2004a). *Abies* was widespread in the surrounding hills, its pollen reaching 30% of the total. This is probably the sign of an unexploited coastal wetland, at the mouth of a small stream. Similar wetlands were widespread in western Liguria, as observed at the mouth of the river Centa (Fig. 1; Arobba et al. 2004).

The top part of the sequence (MSC7) represents approximately the last 2000 years and is characterised by an increase in Mediterranean evergreen taxa suggesting a drying up of the area. This may be attributed to the human attempts to make new land available for agricultural purposes by draining wetlands. However, this situation must not have lasted for a long time, since hygro-hydrophilous trees and especially herbs become more abundant, reaching their highest values.

Conclusion

The general outline emerging from the Massaciuccoli core suggests that at the beginning of the Holocene the area was mainly covered by deciduous woodlands, in which *Quercus*, *Corylus* and *Alnus* were dominant. Then *Abies* spread and reached high values between about 9000 and 7500 B.P. After

this, the pollen record is interrupted by a thick sandy layer resulting from a marine ingress (Antonioli et al. 2000).

At about 5500 B.P. deciduous woodlands, which were reduced in the most recent levels, again covered the area. Numerous vegetational oscillations were recorded, although there was not evidence of drastic changes. These oscillations can probably be connected to the sea level variations that would have had a strong influence on the local water table, rather than directly to global climatic changes. Furthermore, the MSC pollen record does not show evidence of the arid phases revealed by other south-western European sequences (Jalut et al. 2000). Particularly, no clear arid phase is detectable in the late Holocene, around 4500–4000 B.P., as recently observed in Mediterranean islands (Perez-Obiol and Sadori 2006). The Massaciuccoli basin is, indeed, a poorly drained area with low sensitivity to climate changes; these did not determine all the plant extinctions observed elsewhere, probably because of the mitigation effect of the sea and the shelter of the mountains, which in this area run parallel to the coastline, at a very short distance from it. This peculiarity is confirmed by its refuge role for relict plants, such as the elements of the *Sphagno-Droseretum rotundifoliae* Tomei et al. (1997).

The occurrence of high percentages of *Vitis* pollen for an apparently long period (starting from ca 4200 B.P.) is interpreted as a possible clue of an early management of the wild plant.

The data suggests that during the Holocene, along this part of the coast, thermophilous evergreen plants are scarcely represented. The spread of Mediterranean evergreen vegetation in the study area was probably often favoured by exploitation of deciduous woodlands, land reclamation, or other human activities. This is also suggested by the recent history of the area indicating that each time human management decreases, swamp conditions become newly established (Barsanti 2006). Human impact as an important factor in the Late Holocene spreading of the sclerophyllous vegetation in moister northern Mediterranean regions was also considered by Reille and Pons (1992).

All the investigations carried out along the coast of the Mar Ligure have shown the past presence of coastal wetlands which have allowed the preservation of macro- and microremains thanks to which we attempt to read the vegetation history of the area today. *Alnus* swamps must have been widespread in the damp environments behind the dunes along the coastal plains, and especially near river mouths. These environments have practically disappeared today, and even along the major water-courses they are strongly reduced. The reduction of these wetlands seems to have advanced parallel with the beginning of farming in the area, when the people were attempting to drain portions of the swamps for cultivation by the construction of drainage canals. This process became much more pronounced in historical times, after the

Roman period, and especially after the Middle Ages, up to the last century (Ceccarelli Lemut et al. 1994; Cori and Lombardi 1994).

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