DX

85360

POLLEN STRATIGRAPHY OF HOLOCENE PEAT SITES IN EASTERN LIGURIA, NORTHERN ITALY

GILLIAN MARY MACPHAIL

This thesis is submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy of the Council for National Academic Awards.

GEOGRAPHY SECTION

CITY OF LONDON POLYTECHNIC

November 1988

POLLEN STRATIGRAPHY OF HOLOCENE PEAT SITES IN EASTERN LIGURIA, NORTHERN ITALY.

G.M.MACPHAIL

ABSTRACT

This thesis presents the results of a research project designed to reconstruct the Holocene vegetation history of eastern Liguria. The study area lies within the northern Apennines, a region from which few detailed late Quaternary palaeoenvironmental records had been published and prior to this study no radiocarbon-dated pollen profiles had been reported. Presented here are the results of pollen-stratigraphical investigations (including pollen concentration and pollen preservation data) from six Holocene peat sites, augmented by twelve radiocarbon dates. The data provide a first regional assessment of the mid- and late Holocene vegetation succession in Liguria as well as a detailed examination of the problems of sampling and interpretation encountered.

The sites are situated at a range of altitudes between 831 m to 1481 m and consist of both infilled basins within drift deposits as well as shallow shelf sites. However most of the peat sequences began to form only 4000 to 5000 years ago. At three sites there are strong indications that peat formation only occurred after major disruption of local soils which locally may have been initiated by human (Chalcolithic) forest disturbances. Nevertheless there is also a lack of known early Holocene peat or lake sediments in much of north-western Italy suggesting widespread climatic conditions inimical to peat development during that period.

The biostratigraphical data indicate that _Abies_ forests were common at altitudes of over 1000 m during the mid-Holocene but these declined from approximately 2000 BP and subsequently, woodlands were dominated by _Fagus_. Certain pollen types suggest that these changes in forest composition could have been related to human activity, although forest clearance appears to have been restricted. The evidence overall suggests that there was major disruption of local soils during the mid- and late Holocene and it is suggested, therefore, that changes in soil moisture regimes possibly as a result of human disturbance, may have led to permanent changes in the vegetation cover.

Acknowledgments

This project was funded principally by the DES/British Academy through the award of a Major State Studentship. Further funding was provided by the Soprintendenza Archaeologica della Liguria and City of London Polytechnic. This financial assistance is gratefully acknowledged. I would also like to express my appreciation to Prof.Dr.W.G.Mook of the radiocarbon dating laboratory at Groningen, The Netherlands, for supplying free dating facilities and to the Soprintendenza Archaeologica della Liguria for providing funds for additional radiocarbon dates.

In particular I wish to thank those whose contribution helped to make the project a realistic proposition: Dr.J.J.Lowe (City of London Polytechnic) for overall supervision and his unceasing support and encouragement throughout the project; Dr.R.I.Macphail (Institute of Archaeology, University of London) for micromorphological analyses and for his continuous support both in the field and at home; and R.Maggi (Soprintendenza Archaeologica della Liguria) for his very extensive practical assistance in Italy.

I would like to express my appreciation for the help and practical assistance provided by the staff of the Geography Department, City of London Polytechnic; Prof.G.Meirion-Jones; the staff of the Cartographical unit, D.Shewan, R.Stephens and N.Hall for drawing all of the maps and diagrams; Dr.A.Haggett and Dr.R.Tipping for field assistance and pollen identifications; C.Burgues, G.Coston, V.Hargy and D.Candy for technical assistance.

In addition I would like to thank Dr.L.Barfield (Department of Archaeology, University of Birmingham) for useful discussions and his support in the early stages of the project; A.Clapham (Dept. of Botany, University of Glasgow) for macrofossil identifications; Dr.R.Scaife (Ancient Monuments Laboratory, English Heritage Commission) and Dr.P.D.Moore (King's College, University of London) for help with pollen identifications and helpful discussions; Dr.M.A.Courty (University of Bordeaux) and Dr.J.Greig (University of Birmingham) for providing extensive reading material.

Finally I would like to thank the numerous Italians who provided generous help and support throughout the project; C.Brizi, A.Cogorno, M.Colella, L.Maggi, R.Nisbet, F.Pitruzzella, M.del Soldato, I.Tiscornia and G.Viarengo for field and practical assistance; A.Betti, M.Catalisano and A.Maggi for their warm hostpitality; R.Nisbet (Universty of Turin) for useful discussions, reading the text of this thesis and for charcoal identifications; S.Somazzi and the staff of the Corpo Forestale dello Stato for permission to work at Agoraie and for field assistance; Don Leonardini for useful discussions and the Servizio Meteorologico at Genoa for supplying unpublished meteorological data.

CONTENTS

Appendices

FIGURES

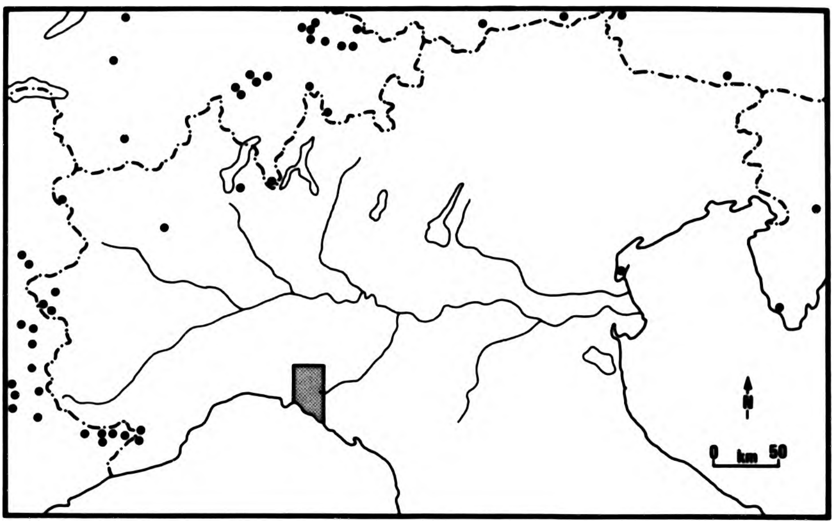
PART ONE: BACKGROUND TO THE PROJECT

CHAPTER 1: INTRODUCTION AND PREVIOUS WORK IN THE NORTHERN APENNINES

1.1 Introduction

There are few detailed palaeoenvironmental records from northern Italy and in particular there is a paucity of published accounts of radiocarbon-dated pollen-stratigraphy from the northern Apennines (see Figure 1). The region is critically located with respect to the migration routes of tree species and there are substantial archaeological remains suggesting major anthropogenic activity which could have had an impact on the vegetation and landscape during the Holocene. Thus the area is important in the understanding of vegetational successions during the Holocene in southern Europe. The original stimulus for this research project was provided by staff of the Soprintendenza Archaeologica della Liguria who have instigated the development of palaeoenvironmental research within the province of Liguria. The overall aim of the project was a reconstruction of the Holocene vegetation history of eastern Liguria (see Figure 1) and an assessment of the factors influencing vegetational successions. In view of the paucity of the published records for the northern Apennines that were available at the start of the project, the most urgent requirement was the establishment of a reliable data base for the region. Six sites have been investigated and the results obtained are a primary contribution.

Fig.1 Location of field area and nearest Holocene ^{14}C dated pollen sites.



The specific objectives of the research programme were:

(1) To identify sites in the Ligurian Apennines which contain Holocene peat and lake sediments.

(2) To establish detailed, radiocarbon-dated palaeobotanical records for those sites in order to reconstruct the regional vegetation and landscape history for the last 10,000 years.

(3) To assess and date those landscape and vegetation modifications considered to have been caused by prehistoric man.

(4) To compare such records with similar data available from sites in the north-western Mediterranean region in order to test wider regional models of landscape and climatic evolution in the region.

1.2 Previous work in the northern Apennines

There is a notable lack of precise information provided in the published pollen sequences from the northern Apennines (Chiarugi, 1936, 1950; Marchesoni, 1957; Ferrarini, 1962; Braggio Morucchio and Guido, 1975; Braggio Morucchio et al.,1978,1980; Bertoldi, 1980). In particular: (a) there have been no published reports of radiocarbon-dated pollen-stratigraphical data; (b) several of the diagrams, for example, those in Chiarugi (1936), Marchesoni (1957) and Ferrarini (1962), contain no data on non-arboreal pollen types; and (c) no pollen concentration and pollen preservation studies have yet been published for sites in the region.

A model of vegetation developments in the northern Apennines was proposed by Chiarugi (1936, 1950) and this has been widely adopted by workers in the region as a basis for relative dating and correlation between sites. Chiarugi counted the major tree taxa from four sites in the northern Apennines. On the basis of those results he produced a single composite diagram and subsequently divided the Late and Post-glacial of northern Italy into two climatic zones:
(a) The "anatermico" characterised firstly by a *Pinus*-dominated period followed by a *Quercus* phase which Chiarugi considered to be broadly equivalent to the Late Glacial, Preboreal and Boreal periods during which continental-type climatic conditions were thought to be prevalent. (b) The "catatermico" corresponding to the Atlantic, SubBoreal and SubAtlantic periods of increasingly oceanic conditions

typified by an _Abies_ phase followed by a _Fagus_-dominated zone.

That the sediments from the four sites formed a stratigraphically-continuous sequence was never established by, for example, radiocarbon dating. In spite of this however, post-war palynologists working in the region have continued to treat Chiarugi's (1936) composite diagram as a single reference site and the "anatermico-catatermico" transition as a reference level for comparative dating. The proposed climatic phases were based solely on undated pollen-stratigraphic successions and there is no independant evidence to support the contention that similar changes in pollen values at different sites represent synchronous events. The possibility that the major pollen-stratigraphical changes are significantly diachronous throughout the northern Apennines needs to be examined, concurrently with an assessment of the impact of non-climatic parameters that may strongly influence local pollen-stratigraphical successions, such as altitude, exposure, local soil characteristics, pollen recruitment and survival, and the nature and intensity of anthropogenic land-use practises. In particular, very high _Abies_ frequencies are reported in the published pollen diagrams, but these almost invariably give way in the upper parts of the profiles to pollen spectra in which markedly increased _Fagus_ percentages are recorded. Indications of forest disturbances such as mineral inwash bands, increases in herb pollen, and the occurrence of _Castanea_ and _Corylus_ are reported for levels in which _Abies_ frequencies decline

(Chiarugi, 1936; Ferrarini, 1962; Braggio Morucchio *et al*., 1978;1980; Bertoldi, 1980) suggesting that the fragmentation of *Abies* forests in the northern Apennines and subsequent expansion of *Fagus* could have been strongly influenced by human forest clearances. To date and identify the causes of these forest changes is a major topic of interest in this study.

This thesis presents a detailed comparison of the *Abies* and *Fagus* records in pollen-stratigraphical successions obtained from several sites. The sites lie within the topographically diverse area of eastern Liguria (see Chapter 2) and their records have facilitated

(a) the identification of forest and landscape disturbance episodes,

(b) an assessment of the extent to which these phases coincide with major pollen-stratigraphical boundaries, and

(c) an evaluation of local climatic, topographic and site catchment influences on local vegetation history.

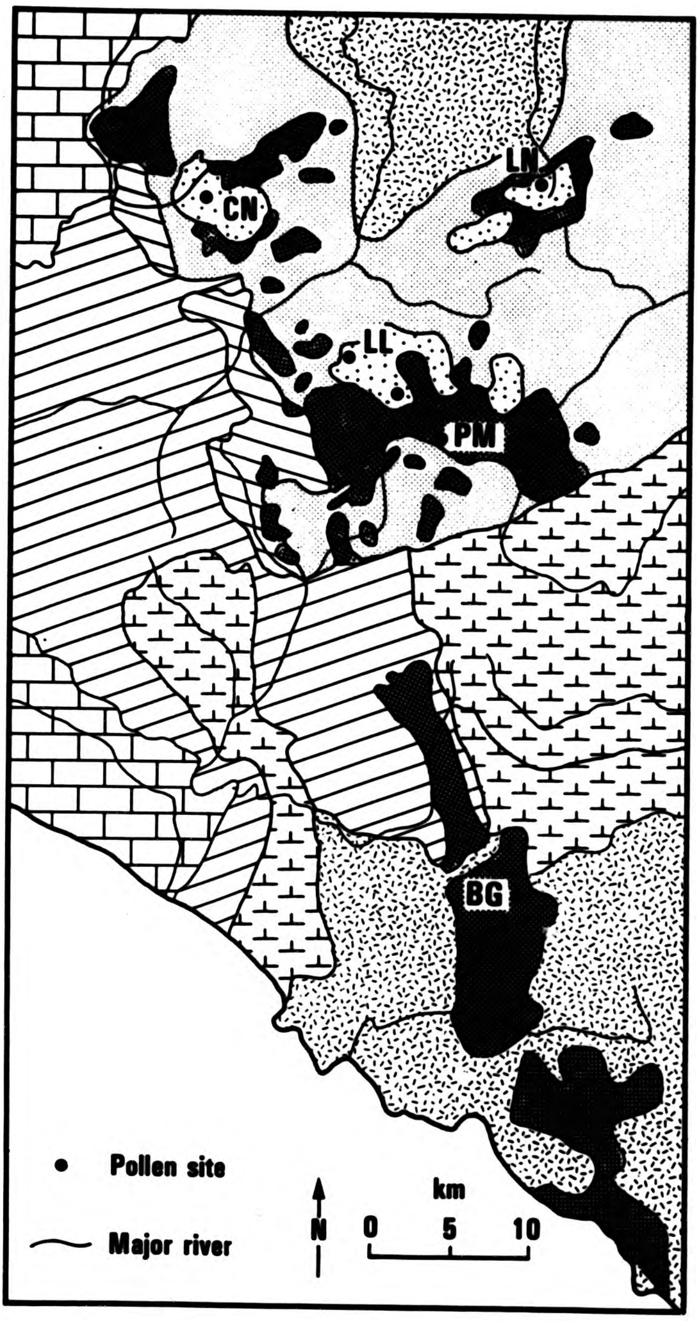
CHAPTER 2. THE STUDY AREA: PHYSICAL BACKGROUND

2.1 Geology.

The northern Apennines form an extensive mountainous region (Lat.44° Long.10°E) of which the Ligurian Apennines are the most easterly component. The area as a whole comprises a highly complex set of geological structures which are considered to have formed by repeated movements and changing directions of the African lithospheric plate with respect to the European plate (Moullade, 1978; Reutter et al.,1978; Naylor, 1982). The first orogeny occurred during the late Miocene when a series of thrust sheets were emplaced from SW to NE. Subsequent polyphase tectonic activity led to great variability in the major structural trends, exposure of crystalline basement rocks and intense folding and faulting of overlying sedimentary sequences.

Eastern Liguria is dominated by the NNW to SSE trending Bracco Unit the structural origin of which is still under review (Elter, 1975; Naylor, 1982). It consists of Upper Jurassic Ophiolites (see Figure 2) which comprise a complex of igneous rocks (basalts, serpentinites, gabbros and granites) that form the major massifs in the region. The Ophiolites are associated with a sedimentary cover of Palombini (alternating beds of grey micritic limestone and shale) and the Lavagna "shales" (alternating beds of argillo-schists with sandstones and limestones). Middle and Upper Cretaceous flysch sequences (Casanova sandstones) overly the Lavagna "shales" to the north and west of the Bracco Unit (Moullade, 1978; Marini and Terranova, 1980; Carta Geologica

Fig. 2 Generalised Geology.



Drift

Eocene and Palaeocene schists and sandstones

Casanova sandstones	Upper Cretaceous
Sandstones	Upper Cretaceous
Limestones	Upper Cretaceous
Lavagna shales	Mid Cretaceous
Palombini	Mid Cretaceous

Ophiolites

d'Italia, Sheet Nos. 83 and 95).

2.2 Physiography.

A series of thrust-faults and down-faulted blocks on the western (Tyrrhenian) side of the Apennines has resulted in major assymmetry of the Tyrrhenian and Adriatic slopes. In eastern Liguria the large-scale NW to SE structures are crossed transversally by a series of narrow steep-sided valleys where slope angles of at least 45° are common. Downfaulting of Pleistocene sediments (Gosseaume, 1979; Moullade, 1978) has given rise to a mountainous coastline along the Riviera di Levante which commonly rises to 800 m within 3 km of the coast. It is only in the interior, specifically on the Ophiolite outcrops, that the landscape is of a more open and rounded nature; the Ophiolite masses rise to a maximum of 1799 m at M.Maggiorasca with much of the watershed lying at 1400 to 1500 m.

2.3 Quaternary Landscape Evolution.

Studies of folded and faulted river terraces and palaeosols which have been ascribed to the "Mindel-Riss" interglacial, indicate significant late Quaternary neotectonic activity on the north-east margin of the Apennines (Cremaschi and Papani, 1975; Gruppo, 1976; Bernini et al.,1980). Modern seismic data (Moullade, 1978) has shown that western Liguria and the southern margin of the Po Plain are tectonically active at the present time although eastern Liguria is now tectonically stable.

Detailed geomorphological studies of the Ligurian Apennines have not yet been undertaken and there is a paucity of this type of data from the field area. As shown in Figure 2 glacial drift deposits on the north and north-west facing slopes of the highest mountains are indicated on the Carta Geologica d'Italia (Sheet No. 83). In those areas Sestini (1936) and Lo Sacco (1949,1982) have identified a number of possible moraines and glacial cirques which they attributed to the Würm (last) glacial stage. These features will be indicated where relevant in the site descriptions provided in Part 3.

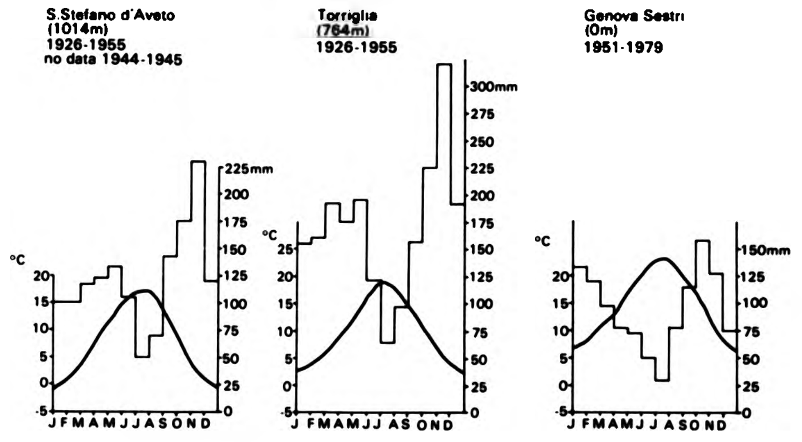
More detailed information has been provided by Federici and Tellini (1983) who mapped in detail the Quaternary deposits of the upper Parma valley. In that area the Parma glacier extended for 8 km from the watershed down to an altitude of 730 m. At lower altitudes (700 m to 400 m) in Emilia-Romagna screes have been mapped that were attributed to the Würm (last) glacial stage (Gruppo, 1976; Bernini et al.,1980). In Emilia-Romagna the period since the last glacial maximum has been characterised by rapid river incision (possibly by as much as 100 m), river capture, widespread erosion and recurrent landslides with an acceleration of erosion in recent times as a result of deforestation.

2.4 Climate.

The study area lies in the north-western Mediterranean which is the most favoured area for the formation of depressions in the Mediterranean, receiving 69% of all those encountered in the Mediterranean basin. These "Genoa" depressions originate as lee or wave depressions which form when northern air currents penetrate the Mediterranean region via gaps in the southern European mountain chains. Combined with the effects of local topography, they are responsible for the high rainfall totals experienced in the area (Meteorological Office, 1962; Cantu, 1977).

In winter when the position of the depressions are influenced by the central European high pressure system their trajectories are generally south-easterly but in summer they tend to follow north-north-easterly and north-easterly tracks when there is a pronounced trough in the upper wind patterns. At this time of the year thunderstorms occur ahead of and at the cold fronts of these depressions in northern Italy (Meteorological Office, 1962; Cantu, 1977).

Fig. 3 Temperature and Rainfall.



Compiled from Servizio Idrografico(1966a,b) and unpublished data supplied by the Servizio Meteorologico,Rome

Long-term climatic records are not readily available from the field area. However rainfall and temperature data from one station within the immediate vicinity (Santa Stefano d'Aveto, Lat.44°33'N Long.9°27'E) and two from elsewhere in eastern Liguria are summarised in Figure 3. Annual precipitation is high in the region as a result of the "Genoa" depressions and local topography, with annual amounts of rainfall being 1145 mm at sea level (Genoa, Lat.44°24'N 8°56'E) rising to over 2000 mm in some of the mountains which border the sea (Torriglia, 44°31'N 9°10'E). Maximum atmospheric instability caused by land and sea temperature differences occurs in autumn when rainfall values are highest particurly during the month of November. Fine settled weather generally occurs during the summer months due to the effect of the Azores anticyclone although there is still some atmospheric instability during this season and monthly rainfall values remain significant particuarly at inland stations (S.Stefano d'Aveto, Torriglia). A second maximum is experienced in spring due to the convergence of onshore winds with katabatic winds blowing from the snow-covered mountains which overlook the sea (Meteorological Office, 1962).

The prevailing winds in the field area are northerly and north-easterly. However wind directions are modified locally due to topographic effects and the differential heating of land and sea in summer (Meteorological Office, 1962). During spring and summer months the predominantly northerly winds are modified diurnally by southerly sea breezes which become particularly pronounced by the afternoon of each day. For example, at Passo dei Giovi (Lat.44°33'N 8°56'E) southerly winds account for 73% of the summer breezes recorded at 4.00 p.m as compared to 16% at 7.00 a.m (Servizio Meteorologico, pers.comm).

North and north-east facing slopes of the Apennines which are exposed to northerly winds experience 100 to 200 cm of snow as compared to less than 50 cm on the south-facing slopes (Cantu, 1977). In the higher mountains snow falls on at least 40 days in the year as compared to an average of only two days at Genoa (Servizio Meteorologio, pers.comm).

2.5 Soils

The soils of the field area have been mapped at a scale of 1:5,000,000 (FAO-Unesco, 1981) and the entire area has been described as being covered by base-rich, stoney brown earths (Eutric Cambisols). Locally however, in a region of great topographical diversity, soils are highly variable according to lithology, slope angle, exposure, altitude and the history of land-use. Detailed micromorphological investigations in the northern Apennines have demonstrated the importance of soil truncation and colluviation processes during recent and prehistoric times (Cremaschi et al..1982: Macphail, 1987) and it is probable that much of the present-day soil cover has been influenced by such processes. However there are few of these types of studies in the region and there is a need for systematic investigations of both present-day soils and the variations which may have occurred in the past. As all of the pollen sites investigated in this research programme are located on serpentinite rocks (see Figure 2) the specific characteristics of the serpentinite soils and vegetation are considered below.

2.6 Serpentinite soils and vegetation

The Ophiolite formation of eastern Liguria (see section 2.1) includes ultramafic rocks rich in ferromagnesian minerals which have promoted the development of serpentinite soils and vegetation communities in the area. Ultramafic or serpentinite rocks vary greatly in chemical and mineralogical composition but often are composed of the minerals olivine, pyroxenes, horneblende and secondary alteration products. Iron and magnesium are always relatively high and silicon relatively low (Proctor and Woodell, 1971).

Soils developed on the Apennine serpentinites are poor in K_2O, Na_2O, MnO, F_2O_3 and Calcium, and high in Magnesium (Veniale and van der Marel,1963). The pH's of immature soils are high, between 7 and 8 (Veniale and van der Marel, 1963), while mature soils are neutral and slightly acid (Macphail, 1987). Clay content in serpentinite soils is highly variable some being exceedingly rocky and stoney while others have a very high clay content (Proctor and Woodell, 1971). An investigation of the clay mineralogy of an Apennine serpentinite soil by Veniale and van der Marel (1963) demonstrated that weathering of serpentinite nodules produced a fine mineral of the montmorillinite group with a corresponding increase in cation exchange capacity.

In the field area serpentinite soils are frequently shallow (30 to 40 cm), stoney and freely-draining on steep, active slopes whereas deeper (up to 140 cm) silty and sandy loams have developed on the interfluves where they form moderately leached, weakly formed argillic brown earths (Macphail, 1987).

The serpentinite soils in the field area frequently support a dense woodland cover comparable to that found on other types of bedrock (see section 2.7) but there have been no detailed published studies of these woodland communities on serpentinite substrates. Instead investigations of the Apennine serpentinite vegetation, for example, Pichi-Sermolli (1948) and Martini and Orsino (1969), have focused on the herb and grass communities. The vegetation types have been placed in a sequence which assumes that the richer communities of deeper soils are more mature and evolved than those developed on shallow soils. In bed-rock soils and those on slopes affected by mass-movements the plants are typically pioneer species able to withstand dry conditions such as the coarse grasses Bromus erectus and Brachypodium pinnatum and low-growing herbs Plantago holosteum and Helianthemum nummarlarium. Richer grass and heathlands develop on deeper soils with Bromus erectus, Brachypodium pinnatum, Festuca ovina as well as several types of Leguminosae, Cistus salvifolius and Calluna vulgaris.

Other factors in addition to soil depth, are also likely to influence floristic diversity in the area. Systematic investigations of such factors, however have not yet been published. For example the effect of varying climatic conditions at differing altitudes was discussed only very briefly by Martini and Orsino (1969) and there have been no studies of the superficial deposits (see section 2.3) and the modifying influence that they may have exerted on the vegetation and underlying bedrock lithology. At least in Scotland it has been demonstrated (Carter et al..1987) that the erosion of drift soils resulted in an expansion of open and relatively impoverished vegetation communities on shallow, skeletal serpentinite soils where water shortage may have been a critical factor in limiting plant development. In the field area disruption of drift soils overlying serpentinite bedrock has been demonstrated by R.I.Macphail (Appendix C) and it is likely that these soil changes would have had a profound influence on the local vegetation cover in the past.

2.7 Present-day vegetation and land-use

Tomaselli (1970) adopted a a generalised model of the vegetation of Italy based on the identification of broad vegetation zones occurring at the various altitudes. The vegetation zones were:

(a) a Mediterranean zone corresponding to the Olea-Ceratonian and Quercion ilicis alliances;

(b) a Submediterranean zone dominated by Quercion pubescenti petraeae and Fraxino-Carpinion formations;

(c) a Montane zone consisting of the Geranio-Fagion and Fagion Sylvaticae alliances at lower altitudes and Vaccinion-Piccion in higher areas;

(d)a Subalpine and Alpine zone consisting of the Vaccinion-Piccion and Rhodereto-Vaccinium alliances.

This scheme encompasses the whole complex of the Italian mountains and climatic variations from the Alps in northern Italy to the south of Italy where the Mediterranean influence is dominant. Within the field area there is a complex of physiographic, lithological and historical factors and as a consequence there are considerable departures from this generalised model. Nevertheless the model provides a convenient means by which the vegetation can be described, and the vegetation zones present in the field area together with relevant historical details are discussed in the following passage.

Montane Zone

The Montane zone in eastern Liguria extends from altitudes of about 1000 m up to and including the main watershed of the Ligurian Apennines and is characterised by the Fagetalia sylvaticae association, a widespread forest type of the mountains of southern Europe. It can be dominated almost exclusively by Fagus sylvatica although there may be considerable variety of ground cover (Barbero,1970). Within the study area an understorey of Vaccinium myrtilis is widespread and more locally Luzula and Cardamine species or Trochiscanthes nodiflorus and Geranium nodosum are prevalent (Oberdorfer and Hofman, 1967; Gentile, 1974). Much of the Ligurian beech forest was formely coppiced on an 8 to 14-year cycle (Gola, 1912). In sheltered localities this management practise led to the development of a species-rich canopy which included Fagus sylvatica, Corylus avellana, Sorbus aria, Carpinus betulus, Laburnum anagyroides with an understorey of Convallaria majalis, Anemone trifoliata, and Polygonatum species. During the present century the decline of traditional management practises has resulted in a modern vegetation which is characterised by ageing coppice woods interspersed with very rapidly regenerating stands of beech saplings and young trees. Conversely, tree-cutting on the least sheltered parts of the water-shed may have led to severe exposure and a reduction in tree regeneration (Gola, 1912; Orsino, 1969). The modern vegetation of the watershed is typically a fragmented and stunted open woodland dominated entirely by Fagus and separated by bare and rocky soils bearing heath and grassland communities.

Submediterranean Zone

The Submediterranean Quercetalia pubescentalis zone in eastern Liguria extends from approximately 200 to 1000 m altitude. Oberdorfer and Hofman (1967) broadly divided the zone into a Quercus petraea-Carpinus betulus association on clay-rich soils and an association dominated by Quercus pubescens, Fraxinus ornus and Ostrya carpinifolia on calcareous soils. Within the field area Castanea sativa was formerly cultivated on a large-scale and in the modern vegetation it frequently forms mixed associations with Quercus pubescens, Ostrya carpinifolia and Alnus species up to 1000m (Orsino, 1969). Destruction of the Quercus woodland has lead to the development of dry heathlands dominated by Calluna vulgaris and Erica species, or grasslands dominated by Bromus and Trifolium species (Oberdorfer and Hofman, 1967). These grass and heathlands were formerly widely exploited as pastures for cattle (Gola, 1912; Orsino, 1969) but changing economic conditions, rural depopulation and a decline in traditional peasant-farming practises have led to the abandonment of many pastures since the later part of the 19th century, a process which has been accelerated in the post-war period. As a consequence of this, formerly wide-spread pastures have now been colonised by rapidly growing arboreal species particuarly Castanea sativa, Corylus avellana, Ostrya carpinifolia, Quercus pubescens and Alnus species.

Mediterranean Zone

The Mediterranean zone in the field area is limited to a narrow coastal strip up to an altitude of 200 m (Oberdorfer and Hofman, 1967) and is dominated by species typical of Mediterranean maquis such as Quercus ilex, Erica arborea, Arbutus unedo and Pistacia lentiscus. However, intensive land-use of the coastal area has now reduced this vegetation type to small fragments partly as a result of building construction and partly by overgrazing which has led to the development of garrigue dominated for example by Thymus vulgaris, Cistus albidus and Euphorbia spinosa.

Studies of locally available documentary records have indicated that during the historical period, the vegetation of eastern Liguria underwent considerable modification as a result of agricultural and industrial activities (Moreno, 1971, Gatti, 1976). During the twelfth, thirteenth and fourteenth centuries Cistercian and Benedictine monasteries introduced Castanea, Vitis and Olea cultivation to many areas where native woods were destroyed. By the sixteenth century the woodlands of the Submediterranean zone may have been reduced to 20 to 30% of the land area (Moreno, 1971) although widespread forests probably remained in the Montane zone. During the 17th century major deforestation of higher mountains took place as a result of charcoal-making, iron-working and glass-making in those areas. Major erosion of the steeper slopes was reported to have occurred during the 18th and 19th centuries (Gola, 1912; Moreno, 1971) and during the 20th century, major slope stabilisation schemes have been realized by the widespread planting of Pinus pinaster, which now forms an important element of the vegetation in the Mediterranean and Submediterranean zones.

2.8 Prehistory

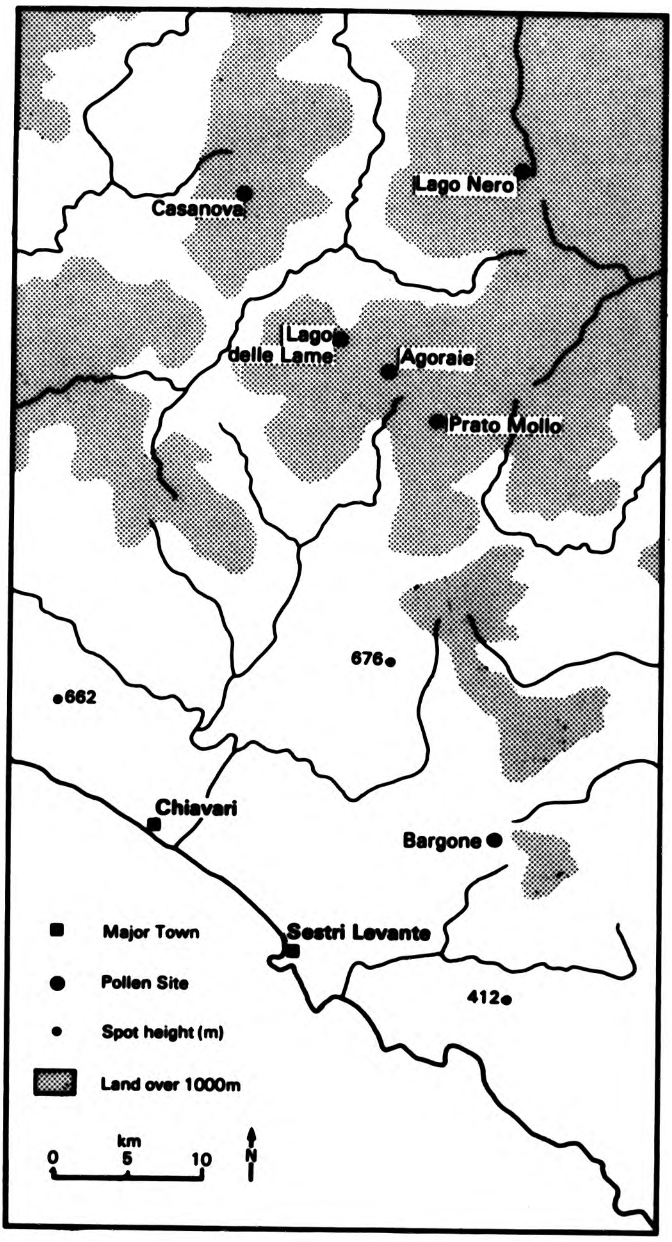
Flint artefacts found throughout eastern Liguria provide evidence of human occupation within the area during the late Quaternary. However the study of prehistory is frequently limited by a shortage of in situ archaeological sites with a secure stratigraphical and dating control. In the field area where steep, eroded slopes are common, this problem is particularly serious and flint scatters are often found within colluvium or on the soil surface where erosion has led to the mixing of flint assemblages. A brief outline of the available archaeological evidence from the field area is presented in this section; where artefacts occur close to the pollen sites they will be noted in Part Three.

Flint assemblages ascribed to the Middle and Upper Palaeolithic periods have been recovered from both cave and open sites where local jasper resources were probably utilised for flint manufacture (Vicino,1983). In contrast, there is no evidence of human occupation of cave sites during the Mesolithic period but instead, large groups of Mesolithic artefacts have been found on the highest slopes of the major mountains, most notably M.Aiona (1701m) and M.Maggiorasca (1799m)(Baffico et al.,1983; Biaggi and Maggi, 1984; Biaggi and Nisbet, 1986) where they may represent nomadism and summer hunting activities. Lower altitude Mesolithic flint assemblages may relate to the exploitation of outcrops of jasper and flint (Baffico et al;1983).

Evidence for the Neolithic is sparse in the field area but considerably more information is available for the Chalcolithic (Copper Age). During this period settlements were located on hill-tops ("castellari") ranging in altitude from 100 to 1100m both near to the sea and in the interior (Maggi, 1983,1984). Recent excavations of "castellari", burial and mining sites at altitudes of below 800 m have provided important information indicating major human activity in the region from about 4500 yrs BP (Maggi, 1984; Maggi et al.,1985). Carbonised cereal grains have furnished evidence of cultivation at lower altitudes while flint scatters on the highest slopes of M.Aiona (see Chapter 10) indicate human exploitation of the upper mountain zones for hunting and possible seasonal occupation of summer pastures by domesticated animals (Maggi et al., 1989 in press).

During the Bronze Age there was continuity of site occupation and agricultural systems established during the

Fig. 4 Location of Pollen sites.



preceding Copper Age (R.Maggi, pers.comm.). At this time terraces were constructed for agricultural purposes. By the Iron Age a network of settlements had been established on the "castellari" and ridges which run parallel to the coast. Widespread cultivation and pastoralism were practised with possible transhumance into the interior (Melli, 1983). At this time the ports of the Ligurian coast became urbanized as trade with Central Italy and southern France increased. These patterns were not substantially changed by the Romans for whose presence in the area there is relatively little evidence.

2.9 Study site locations

The locations of the six sites reported in this study are shown in Figure 4. Local site details are provided in Part Three. All sites are situated on serpentinite bedrock, five of which are located close to or within the present-day Montane vegetation zone. The highest sites, Prato Mollo and Lago Nero are situated close to the major watershed of the Ligurian Apennines at about 1450 m. The former has a south-facing exposure and is located close to several major Chalcolithic and Mesolithic flint scatters while the latter has a north-west facing exposure. Agoraie lies within hummocky moraines on the north-west facing slopes of M.Aiona at 1329 m and is surrounded by beech woods. Casanova and Lago delle Lame are both located at approximately 1000 m, close to the present-day boundary of the *Fagus* and *Quercus*-dominated vegetation zones although Lago delle Lame is situated within drift mounds and surrounded by dense forest, while Casanova is surrounded by heath and grassland and lies close to multi-period flint scatters. In contrast to the inland sites, one site named Bargone, is situated close to the coast at an altitude of 831 m within the Submediterranean zone. Here the present-day vegetation is open heath and grassland.

PART TWO: METHODS

CHAPTER 3: FIELD METHODS

3.1 Site location and selection

The principal aim of the field investigations was to obtain sediment sequences from several sites at different altitudinal and climatic ranges in order to examine the variability of Holocene vegetational stages throughout the Ligurian Apennines.

Potential sites were identified from a number of sources: much information was provided by local researchers with an extensive knowledge of the region particuarly R.Maggi and colleagues at the Soprintendenza Archaeologica della Liguria; some information was extracted from the limited geomorphological literature, available geological maps (1:100,000) and previously published general literature. A large number of potential sites were visited of which six were found to contain significant peat deposits and these were sampled (see Figure 4). Three sites (Bargone, Casanova and Prato Mollo) were located as a result of local knowledge, one site (Agoraie) by reference to previously published literature and two (Lago delle Lame and Lago Nero) as a result of field reconnaissance. Other sites examined were rejected as they were lakes formed within steep-sided rock basins with no marginal sediment formation, while certain peat deposits reported in the literature were found to be alluvial infill of possible glacial cirques. A lack of lowland basins within which organic sediments could accumulate and which could be sampled using the available manually operated equipment excluded the possibility of selecting sites at lower altitudes. Therefore a large proportion of the sites selected for detailed study were located in high altitude areas (above 1000 m) in lake basins in which peat deposits were found to have accumulated.

<u>3.2 Sediment sampling</u>

The deepest point of each site was established by systematic probing initially at 10 to 15 m intervals and then closing to 5 to 2 m intervals depending on the presence of subsurface wood or rocks and the highly irregular surface of the underlying weathered bedrock of some sites. The deepest deposits were selected on the assumption that this would provide the oldest sediments, the most continuous sequence of deposits for the site and the highest degree of resolution in the pollen sequences.

One exception was made to this general rule; it had already been noted that several previously sampled sites consisted of comparatively recent peat deposits overlying impenetrable green silts and gravels. It was possible to penetrate these mineral deposits at Lago delle Lame (Chapters 6 and 9) and they were found to contain considerable quantities of macrofossils, some of which were believed to be charcoal. In order to investigate the sequence of events prior to the onset of peat formation at this site, the sediments were sampled at the point of maximum penetration into the mineral sediments. This was at the expense of a deeper, possibly disturbed peat sequence elsewhere on the site.

Several sampling strategies were adopted according to the nature of each site and the available peat coring equipment. Closed chamber samplers were preferred but on two sites an open chamber "Dutch" gouge was used. The various sampling strategies are ranked here according to the considered reliability of the sampling method.

1) Box monoliths (1 m length and 10 cm width): in the case of the shallow peat sites (Prato Mollo and Lago Nero) it was possible to excavate pits and cut out large undisturbed sediment samples.

2) Russian corer (1 m length and 5 cm internal diameter): this was used to core the sediments at Casanova from two adjacent holes with no overlap and with the help of experienced operators.

3) Russian corer (0.5 m length and 5 cm internal diameter) and Hiller borer: the site at Agoraie was sampled using the Russian borer from adjacent boreholes with 20 cm overlaps but the bottom 30 cm of stiff basal peats and underlying minerogenic deposits were sampled with a Hiller borer. Materials obtained with the Hiller were subsampled in the field.

4) "Dutch" gouge (1 m length and 6 cm width): Bargone and Lago delle Lame were cored using this equipment in order to obtain intact cores in the absence of an operational closed chamber sampler. Maximum precautions against contamination were taken using alternate cores of 1 m length and 0.5 m

overlaps. In the laboratory the outer 4 cm of sediment was discarded and a sample removed from the centre of the core was used for preparation of pollen samples. In spite of these precautions, contamination may be evident in the Bargone diagram probably due to younger material being carried down profile, against which the open chamber provided no protection. This problem will be discussed in Chapter 11.

Cores were extruded in the field, labelled, placed in clean plastic guttering and wrapped in adhesive film and silver foil. The cores were transported back to the U.K within one week of sampling, or were stored in a cool cellar and brought to Britain within three weeks of sampling.

Samples for radiocarbon dating from Agoraie, Bargone, Casanova and Lago delle Lame were removed by multiple sampling using a 60 cm chamber piston corer of 5 cm diameter. A large peat monolith for radiocarbon dating was extracted from Lago Nero. Prato Mollo was sampled in the field from a cleaned peat section at critical points in the lithostratigraphy. The Prato Mollo samples were packed in clean polythene bags and sent to the radiocarbon dating laboratory at Berlin. All other samples for dating were treated as described in section 4.8.

CHAPTER 4: LABORATORY METHODS

The peat cores were stored at 2-3°C prior to subsampling and sediment description. The surface was cleaned and described following Faegri and Iversen (1975) and Munsell colours were determined on moist sediment under artificial light. Subsampling for pollen was initially at 10 cm intervals and after construction of skeleton pollen diagrams subsamples from closer intervals of 5 cm or less were taken from the sections of the cores which contained evidence for major vegetation changes.

4.1 Chemical preparation techniques

The preparation techniques described by Moore and Webb (1978) were followed as far as possible but certain problems made it necessary to modify some of those methods.

A. Reflocculation

After treatment with KOH the organic sediments demonstrated a marked tendency to reflocculate in all mediums including water. This "clumping" reduced the effectiveness of acid treatments, particuarly acetolysis, so that many pollen grains were obscured by matrix material, it was impossible to satisfactorily concentrate the pollen and it was necessary to count up to five slides for a single count.

Therefore experimentation was undertaken to resolve the problem. The methods attempted and their results are summarised below:

1. HCl. No effervescence was observed on addition of cold 10% HCl or on subsequent heating and this treatment made no difference to ensuing "clumping". Treatment with HCl after the addition of Lycopodium tablets as

recommended by Francis and Hall (1986) was also found to make no difference.

2.Erdtman's Acetolysis as described by Moore and Webb (1978) was performed twice; an initial treatment of 2 minutes was followed by a further treatment lasting approximatley one minute. Some marginal improvement was observed but the amount of matrix material left on the slides was still considered unacceptable.

3.Godwin's acetolysis with and without oxidation using sodium pyrophosphate (Kerney et al..1980). Marginal improvement.

4.Oxidation using Nitric acid (Jalut, 1977). No improvement.

5.Pre-soaking of the peat sample with KOH for up to 7 days. No change.

6.Sieving with a smaller mesh size (150 m). This resulted in loss of large pollen grains for example Abies, and did not reduce the "clumping".

After several experiments it was apparent that flocculation created a reduced surface area that could be attacked by the acetolysis solution, thus rendering the procedure ineffective. Therefore sodium hexametaphosphate and sodium carbonate (Calgon) was added to the sediment at critical stages in the procedure with an immediate improvement in the results. Eventually Calgon was adopted as part of the standard preparation procedure as follows:

1. A volume of sediment was measured by displacement in 10% KOH in a 10 ml measuring cylinder and Lycopodium tablets (Stockmarr, 1971) were added.

2. The sediment and tablets were transferred to a pyrex boiling tube (50 ml) which was filled with KOH and placed in a boiling bath for 40 minutes.

3. The sediment and suspension were washed through a 10 um sieve, described in detail by Tipping (1984). Previous experience had shown that full deflocculation had not always occurred at this stage in the procedure and for this reason a coarse sieve size was not used until stage 5.

4. The sample was returned to the boiling tubes with KOH for a further 20 to 40 minutes. This second treatment was found to be necessary in order to remove all humic acids from the sediment.

5. The sediment was washed through a nest of sieves of 180 um and 10 um with large quantities of distilled water. It was then transferred to centrifuge tubes, centrifuged once and decanted.

6. At this stage between 1 to 2 ml of Calgon was added, mechanically stirred and centrifuged. Experience had showed that at least this amount should be used and with some sediments it was necessary to use up to 7 ml. A qualitative assessment of the required amount could be determined by the degree of stickiness encountered when using the mechanical mixer.

7. HF and HCl treatments followed by two washings in water as outlined by Moore and Webb (1978).

8. Calgon was added for a second time, centrifuged and decanted. Amounts varied according to the stickiness of the sediments but were usually of a similar order to those in stage 6.

9. Glacial acetic was added and Erdtman's Acetolysis carried out as described by Moore and Webb (1978).

10. The sample was washed twice in water and about 4 ml of NaOH was added to the first washing. It was found that a few drops as recommended by Moore and Webb (1978) was insufficient to prevent reflocculation in the mounting medium.

The greatest problem encountered in the use of this method was the difficulty of accurately estimating the required quantity and strength of Calgon. It was found that a standard 40% solution was ineffective in the treatment of some samples and that it was necessary to use a 60% solution in those cases. Conversely, addition of too much Calgon could result in sloppiness of some sediments. This was sometimes a problem when using silicon oil as a mounting medium, as the sediment did not always adhere to the glass vials it is necessary to use at the end of the procedure. This problem could be overcome by evaporation of the acetone instead of decanting. Finally it was found that Calgon deteriorated after approximately two months which rendered it ineffective, and it was necessary to only use a fresh solution. Given these conditions it was possible to retain an even solution at all stages of the procedure and it was possible to make counts of many levels where the pollen concentrations were exeedingly low.

B. Mineral sediments

The highly minerogenic basal sediments at Lago delle Lame were treated with KOH and washed through coarse and fine sieves as in stages 1 to 5 above but the sediment retained on the fine sieve contained considerable quantities of green silt which could not effectively be removed by treatment with HF. In order to resolve this problem the sediment was placed in water and the silt and organic fractions were separated from each other by pouring off the lighter organic material which floated above the heavier silt. The remaining mineral sediment was examined microscopically for pollen and organic material and the separation was considered satisfactory when none was observed. Marked colour differences between the two fractions and the large, heavy silt size both contributed towards an acceptable division of the organic and mineral components. The method was rejected in the preparation of sediments from other sites because the finer and lighter silt size prevented a satisfactory separation of the two fractions.

4.2 Mounting medium

During the early stages of the project samples from

Agoraie, Prato Mollo and Lago Nero were mounted in silicon oil (Andersen, 1960). A fluid medium was preferred at this stage in order to facilitate examination of pollen types not normally encountered in the British Isles and which were sometimes deteriorated. Nevertheless the application of Acetone during the dehydration procedure intensified the problem of sediment "clumping" and so for this reason combined with the difficulties of retrieving unknown or problematic grains in a fluid medium, preparations from Casanova, Bargone and Lago delle Lame were mounted in glycerol jelly. This change in mounting medium resulted in a great improvement in the clarity of pollen grains, a corresponding increase in the speed of counting, and more rapid retrieval of grains for reference or identification.

4.3 Pollen concentrations

In order to provide an estimate of pollen concentrations Lycopodium tablets (Stockmarr, 1971) were added at the earliest stage of the preparation as described above. It is a simple, easily available method and Lycopodium clavatum is not a common constituent of the Italian flora. Any sediment loss is assumed to have contained equal proportions of both fossil pollen and exotic spores unlike volumetric and weighing methods (Davis, 1965; Jorgensen, 1967) which cannot take account of the loss of pollen grains during preparation. In addition the adopted method avoids the difficult question of complete homogenisation of glycerol-exotic pollen suspensions (Beninghoff, 1962; Tipping, 1985).

4.4 Pollen counting

Pollen counting was on a Vickers (ML1300) binocular microscope at a magnification of x 400 with regular examination of problematic grains at x 1000 and under phase contrast when necessary. Slides with low pollen concentrations were scanned initially at x 200. Non-pollAniferous levels were defined as those with fewer than about 25 grains per slide.

Pollen concentrations were generally low and for each sample it was necessary to count at least half of each slide, and more usually it was normal to count one to one and a half slides. For this reason it was assumed that any non-randomness in the distribution of pollen on slides was unlikely to have produced bias in the pollen counts.

4.5 Pollen identification

Pollen identifications were based on reference to type slides available in the pollen reference collection at City of London Polytechnic with additional reference material collected in the field area. Extensive use was made of the keys and photographs in the published literature namely Erdtman et al. (1961), Aubert et al. (1959,1962), Planchais (1962), Faegri and Iversen (1975), Accorsi and Forlani (1976), Arobba (1976), Paoli and Ciuffi (1976), Punt and Clarke, (1976,1980,1981,1984), van Zeist and Bottema (1977), Moore and Webb (1978), Braggio Morucchio and de Vincenzi (1980,1981), Stevenson (1981), and Andrew (1984). Dr.P.Moore (King's College, University of London), Dr.R.Scaife (Ancient

Monuments Laboratory, Historic Buildings and Monuments Commission) and colleagues at City of London Polytechnic were also consulted. Nevertheless there remain several pollen types for which it has not been possible to make any identification. These pollen types are grouped as "Unknowns" (see Appendix A) but nowhere reach more than 2% of the count at any one level.

4.6 Pollen sum

The pollen sum commonly adopted by workers in Italy has been based on total arboreal pollen (Chiarugi, 1936; Ferrarini, 1962; Braggio Morucchio and Guido, 1975,1980) but since this project aimed to examine the history of the total vegetation cover, that approach was rejected. Conversely the pollen sum frequently used in south-western Europe has been based on total pollen, aquatics and spores (de Beaulieu, 1977; Jalut, 1977; Triat-Laval, 1978). When this method is adopted however, some variations in tree pollen values can be an artefact of a percentage method which includes locally over-represented taxa. In order to avoid that problem the pollen sum used throughout this project is 300 "Total Land Pollen" (T.L.P.) except for levels with particuarly low concentrations where counts of 200 to 250 were adopted. These levels are indicated on the pollen diagrams. T.L.P. includes the total of all trees, shrubs and herbs recorded, while Cyperaceae, aquatics and spores are calculated as a percentage of T.L.P plus their own sum. All calculations were made using a package of pollen programmes supplied by

A.Haggart (City of London Polytechnic) for use with an Apple II computer.

4.7 Pollen preservation

Deteriorated pollen groupings were recorded in the following hierarchical order after the work of Cushing (1964,1967), Birks (1970) and Lowe (1982): (a) corroded (b) amorphous (c) split and (d) crumpled grains as defined by those authors. A hierarchical division was adopted because, in the presence of large numbers of broken conifer grains, it was useful to identify those levels which also exhibited other types of deterioration particuarly corroded and amorphous characteristics. Thus a split conifer which was also corroded was recorded in the corroded class.

4.8 Sampling for radiocarbon dates

Field sampling of materials for radiocarbon dating was described in Chapter 3 (3.2). In the laboratory all cores were matched biostratigraphically by constructing skeleton pollen diagrams (100 T.L.P.) and cross-correlating between cores. Whenever possible cores and sampled horizons were also matched lithostratigraphically. Sample slices of 5 to 10 cm were cut from each core, wrapped in clean polythene and placed in clean polythene boxes. The samples were then posted to the Centre of Isotope Research, Groningen, The Netherlands.

4.9 Charcoal

Several types of carbonised material were recorded during this project. Firstly macroscopic charcoal pieces of approximately 1 to 2 cm length were removed from the peat section at Prato Mollo (see Chapter 7) and were identified by Nisbet (1989, in press). Secondly, a micromorphological investigation by R.I.Macphail (see below) of the basal sediments at the same site indicated the presence of in situ burned peat levels and finally, microscopic charcoal was observed in pollen preparations.

A major problem of charcoal identification in pollen preparations was the presence of large quantities of black amorphous organic material and black opaque mineral particles, both of which could be mistaken for charcoal. Therefore the recognition of charcoal, as confirmed by R. Scaife (Ancient Monuments Laboratory) was confined to black, opaque angular fragments which had clearly been carbonised, and to black opaque spheres in the size range 15 to 40 um, similar to the smoke microspherules described by Patterson et al. (1987) and Griffin and Goldberg (1979).

Various methods of charcoal measurement have been reviewed by Patterson et al. (1987) who concluded that similar results were obtained when using either number or area measurements. They also suggested that relative changes in charcoal abundance could be assessed quickly by counting all charcoal particles encountered during routine pollen analysis. During the investigations reported in this thesis it had been noted that charcoal was present in very specific parts of the cores, particuarly the basal sediments from Prato Mollo and Lago Nero as well as in several samples in the Casanova sequence. The point-count method of Clark (1982) is time-consuming when charcoal content is low (Patterson et al.,1987) as for example in many samples from those sites, and therefore this method was not employed. Instead the relative changes in charcoal frequencies were ascertained by recording the number of charcoal particles encountered during routine pollen counting (Tolonen, 1985; Patterson et al., 1987) and expressing the results as a percentage of the corresponding pollen sums (T.L.P).

4.10 Macrofossils

During this project it was found that there was insufficient time for routine macrofossil analyses and a systematic study of this type of material was not undertaken. However large fragments of wood (2 to 8 cm) and other macrofossils were found in the peat cores from Lago delle Lame and Casanova. These were removed from the cores after completion of pollen counting and were identified by A.Clapham (Department of Botany, University of Glasgow) (see Appendix B). All identifications were carried out on a stereomicroscope (x 50 magnification) and an epi-illuminating microscope with reference to the keys and photographs in Schweingruber (1978).

4.11 Loss on ignition

Loss on ignition was undertaken in order to provide a rough estimate of the amount of organic matter in the peat cores. The method used was based on that outlined by

Bengtsson (1979).

1) Fresh samples were removed from the peat cores and dried at room temperature for at least three days. Dried samples were then ground to a fine powder.

2) Clean crucibles were ovendried and the weight of each crucible was determined (A).

3) The samples were transferred to the crucibles and were oven-dried for at least 2 hours at a temperature of 105°C. The weights of the samples and crucibles were determined (B).

4) Crucibles and samples were placed in a muffle furnace for at least 4 hours at a temperature of 500-550°C. In order to avoid ash losses by violent burning ignition was started at a low temperature.

5) Crucibles and ignited samples were allowed to cool to room temperature in a dessicator. The weight of ash and crucible was determined (C).

6) Loss on ignition was calculated as follows: $\frac{B-C}{B-A}$ and expressed as a percentage of dry weight.

12. Soil Micromorphology

Micromorphological analyses of the basal peats and underlying minerogenic sediments at Prato Mollo and Lago Nero were carried out by R.I.Macphail (Institute of Archaeology, University of London) in order to appreciate the events leading up to the onset of peat formation at those sites (see Appendix C). An undisturbed block of sediment was removed from the Prato Mollo peat monolith used for pollen sampling. A second block from Lago Nero was removed from an exposed peat face adjacent to that of the peat monolith. These samples were impregnated with crystic resin, described according to Bullock et al. (1985) and interpreted according to Courty et al. (1989, in press). See Appendix C.

CHAPTER 5: POLLEN DIAGRAM CONSTRUCTION

5.1 Relative pollen diagrams

The pollen diagrams presented in this thesis are constructed so that the information appears consistently in the following order (from the left-hand edge):

1) Vertical scale showing depth below surface in cm.
2) Generalised lithostratigraphic column.
3) A representation of the cores used and the extent of overlap where relevant.
4) Loss on ignition values expressed as a percentage of dry weight.
5) Position and sample thickness of radiocarbon dates.
6) Pollen curves for the principal taxa defined as those with a minimum value of 2% T.L.P for any single level. Minor taxa with values of less than 2% T.L.P. which may have some "indicator" value or which conform to a pattern within the stratigraphical succession are shown in the diagram as spots. Tables containing all percentage data not included in the pollen diagrams together with the total number of taxonomic divisions identified for each pollen spectrum, are supplied in Appendix A. Pollen types are organised as far as possible in order of appearance and are arranged from left to right as trees, shrubs, dwarf shrubs, herbs, Cyperaceae, aquatics and spores. Conforming with many European pollen diagrams (e.g de Beaulieu, 1977) summary diagrams are in a central position following the tree types. In common with workers in southern Europe tall shrubs such as Corylus have been grouped with the trees while dwarf shrubs have been grouped with herb types.

7) Microscopic charcoal expressed as a percentage of the pollen sum (T.L.P).

8) Indeterminable pollen expressed as a percentage of T.L.P.

9) T.L.P. sum if below 300 grains per pollen spectrum.

10) Pollen assemblage zones. As discussed by de Beaulieu, (1982) pollen analysts in southern Europe have typically adopted bio-assemblage zones established in north-west Europe (e.g Mangerud, 1975) on the assumption that vegetation changes throughout Europe were synchronous events. In southern Europe however, it has not always been possible to establish biostratigraphical criteria with which to differentiate one zone from another (de Beaulieu, 1982). Therefore local pollen assemblage zones have been adopted throughout this project and are based on the observed pollen stratigraphy and changes in one or more of the major pollen taxa.

5.2 Pollen concentration diagrams

Pollen concentration data are expressed as grains x 1000 per cm^3 of sediment and are presented in the following order (from the left hand side):

1. Pollen concentrations of the major taxa.
2. Summary concentrations of the following taxonomic groupings: (a) trees, (b) herbs, (c) total land pollen, (d) total pollen, Cyperaceae, spores and aquatics.
3. Pollen concentration zones based on major fluctuations in the curves for total pollen and spore concentrations. These are compared to pollen assemblage zones displayed on the

right hand edge of the diagram.

5.3 Pollen preservation diagrams

Pollen preservation data are presented as follows:

1. Total deteriorated grains expressed as a percentage of all recorded pollen, spores and indeterminable pollen.
2. Corroded, amorphous, split and crumpled grains expressed as a percentage of total recorded pollen, spores and indeterminable pollen.
3. Deteriorated *Abies* grains for those sites where there are discernible variations in the preservation characteristics of *Abies* (Lago delle Lame, Prato Mollo, Lago Nero and Agoraie). These are expressed as a percentage of the total *Abies* recorded. Corroded and amorphous *Abies* grains are expressed as a percentage of the total recorded *Abies*.
4. Pollen preservation zones identified on the basis of variations in the curves for deteriorated total pollen, spores and indeterminable pollen. These variations are observed in the data from Lago delle Lame, Casanova and Bargone.

PART THREE: LOCAL SITE DETAILS: RESULTS

CHAPTER 6: THE SITES AGORAIE AND LAGO DELLE LAME

6.1 Agoraie(Lat.44°29'N Long.9°28'S)

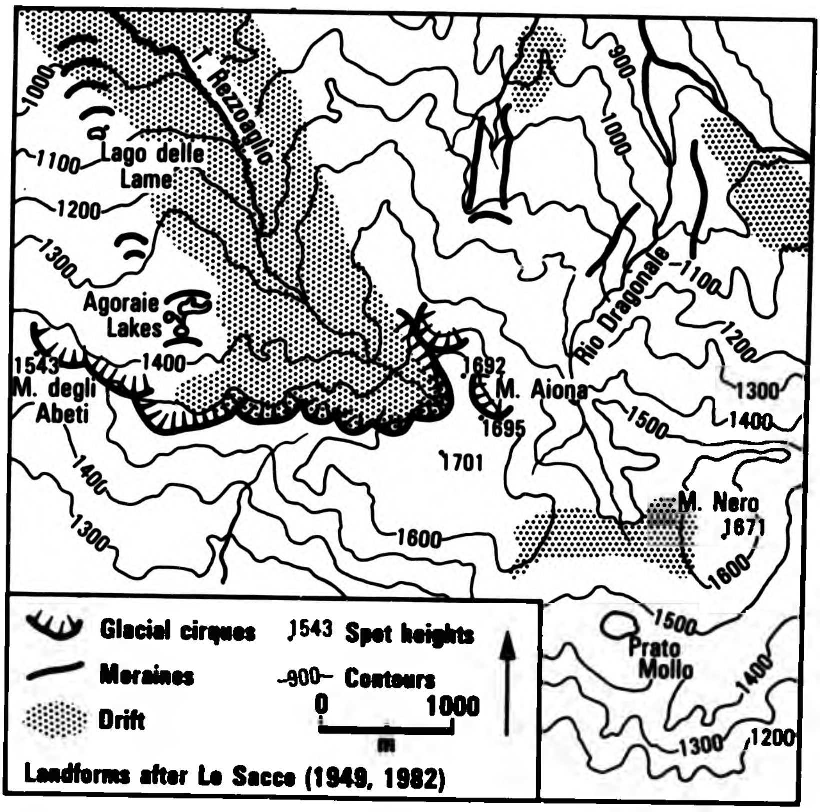
The Agoraie lakes form a series of four small infilled kettle holes situated between 1329 m and 1333 m on the north-west facing slope of M.Aiona (Figures 5 and 6). Drift mounds enclose the basins to the south and west and the whole area constitutes a nature reserve now managed by the Forestry Service. Two small streams enter the upper site, Lago degli Abeti, from the south-east and south-west and flow into Agoraie di Mezzo and Agoraie di Fondo by a series of interconnecting streams.

The results of an earlier investigation of the sediments at Agoraie di Mezzo were published by Braggio Morucchio and Guido (1975). However their pollen diagram lacks detail, particuarly for non-arboreal pollen types, and no radiocarbon dates were reported, so a more detailed study of the deposits at Agoraie was considered necessary.

The upper site is a small lake with no marginal sedimentation. The two sites named Agoraie di Mezzo are basins (approximately 75 m diameter) and infilled with peat of maximum depths 360 cm and 570 cm overlying gravels. Silt bands were observed within the peat of the shallower of the two sites. The deepest sediments of maximum depth 682 cm were found within the broadest of the basins (100 m diameter), Agoraie di Fondo, and this was selected for detailed study.

A stream enters the site from the south, flows across the mire surface in a diffuse fashion and leaves the site by an outlet in the north-western corner. Minor streams also enter the site from the west and north-west.

Fig. 5 Location of the peat sites Agoraie,Lago delle Lame and Prato Mello.

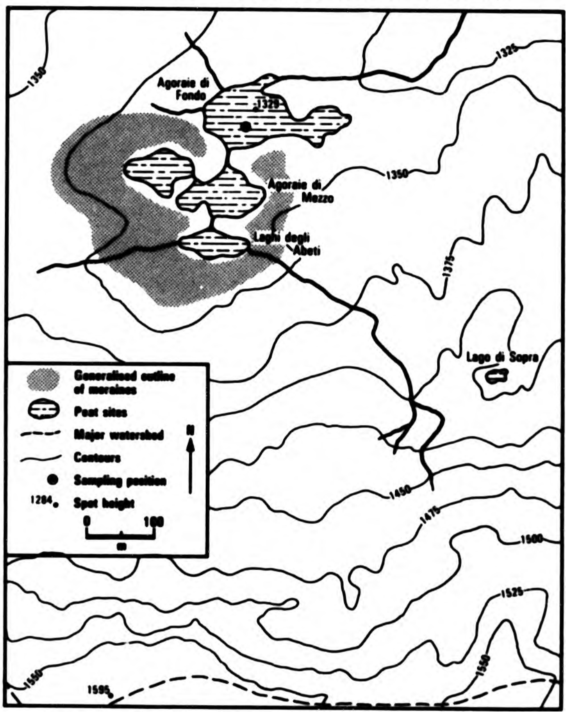


<u>Vegetation</u>

The vegetation of the mire surface is dominated by <u>Carex rostrata</u> and <u>Menyanthes trifoliata</u> with <u>Potamogeton natans</u> in water deeper than approximately 45 cm. A narrow fringe of drier vegetation of the <u>Molinio-Juncetea</u> and <u>Nardo-Callunetea</u>

classes (Aita _et al_..1979) occurs around the edges of the site. These include a wide variety of grasses and herbs of which the commonest constituents are _Nardus stricta_. _Molinia caerulea_ and _Juncus effusus_ with _Potentilla erecta_. _Filipendula ulmaria_. _Sanguisorba officinalis_. _Caltha palustris_ and _Ranunculus repens_. This narrow belt of fringing vegetation was reported (Aita _et al_..1979) to have been broader prior to 1950 at which time the water-table was raised artificially which resulted in an expansion of _Carex rostrata_ across the site.

Fig. 6 The peat site at Agoraie and surrounding area (position of moraines according to field observation).



Picea abies was planted on the local moraines earlier this century. These form mature coniferous stands with little ground cover which extend to the edges of the site. In contrast the rocky, steeper slopes in the area are dominated by rapidly-growing young *Fagus sylvatica* with an understorey dominated by *Vaccinium myrtilis*. Woodland edge vegetation is richer and more varied including *Sorbus aucuparia*, *Acer pseudoplatanus*, *Laburnum* cf. *alpina* and *Alnus incana* with *Calluna vulgaris*, *Melampyrum* spp., *Geranium nodosum*, *Euphrasia* spp., and *Epilobium angustifolium*.

On the more exposed parts of the water-shed the *Fagus* woodland is more open and of stunted appearance, and finally gives way to low grass and herb communities (including dwarf juniper, Cyperaceae spp., Gramineae spp., *Vaccinium myrtilis*, *Scabiosa* spp., *Euphrasia* spp. and *Potentilla erecta*) separated by bare, rocky outcrops and periglacial debris.

Lithostratigraphy

A transect of boreholes established that the deepest part of the basin was located towards the central south-east. It was also noted that a number of ephemeral silt bands occurred within the sediments at the northern end of the basin. The following generalised lithostratigraphy is based on observation of the sediments recovered from the deepest borehole:-

Depth from surface in cm

0-150	Poorly compacted root layer; not sampled.
150-330	Very dark greyish brown (10YR 3\2), fibrous unhumified peat becoming more humified towards the base; lower boundary sharp.

330-340	Dark brown (7.5YR 3\2) peat with fine rootlets; lower boundary sharp.
340-430	Very dark greyish brown (10YR 3\2) diatomite; woody detritus at 356-360 cm and charcoal fragments (0.5 cm) at 399,406 and 416 cm. Diffuse lower boundary.
430-460	Dark brown (7.5YR 3\2) unhumified wood peat; well-rotted wood fragments (2 to 3 cm), fine rootlets; sharp lower boundary.
460-471	Very dark greyish brown (10YR 3\2) diatomite; diffuse lower boundary.
471-682	Dark brown (7.5YR 3\2) detrital peat; wood and twigs (1 cm), bark and fine rootlets. Lower boundary very sharp.
685-690	Green (greener than 5Y) sand, gravel and weathered bedrock.

In addition sand and silt was observed in the sieves during pollen preparations of samples from depths 320 to 335 cm.

Pollen Assemblage Zones (Figure 7)

AG1: Abies-Fagus-Quercus PAZ (depths 680 to 330 cm, 42 spectra)

Tree pollen frequencies are typically over 70% TLP although individual levels fluctuate between 52% and 94% TLP. Abies dominates the pollen spectra with frequencies typically between 30% and 50% although the curve fluctuates erratically with values varying between 18% and 68%. Fagus is generally below 20% TLP but frequencies are higher in the early and central parts of the zone. Conversely Quercus values vary little and do not exhibit the fluctuations typical of the curves for the other major taxa. Other woody taxa, particuarly Ulmus, Tilia, Pinus, Alnus and Corylus are present throughout the zone at low frequencies while Juglans is recorded only in the uppermost horizon. Herb pollen spectra are dominated by very high but fluctuating

Filipendula values which vary between zero and 36% in contiguous samples and which alternate with a similarly eccentric Cyperaceae curve. Other herbaceous taxa generally account for 10% to 20% of land pollen although individual spectra fall to 6% TLP. Ericaceae and Gramineae are represented at low frequencies throughout the zone but in general, individual herbaceous taxa are recorded sporadically or infrequently. Filicales spores are abundant in lower levels but values decline in upper horizons. Aquatic types are mainly represented by Potamogeton which occurs throughout the zone, and Nymphaea which is present sporadically.

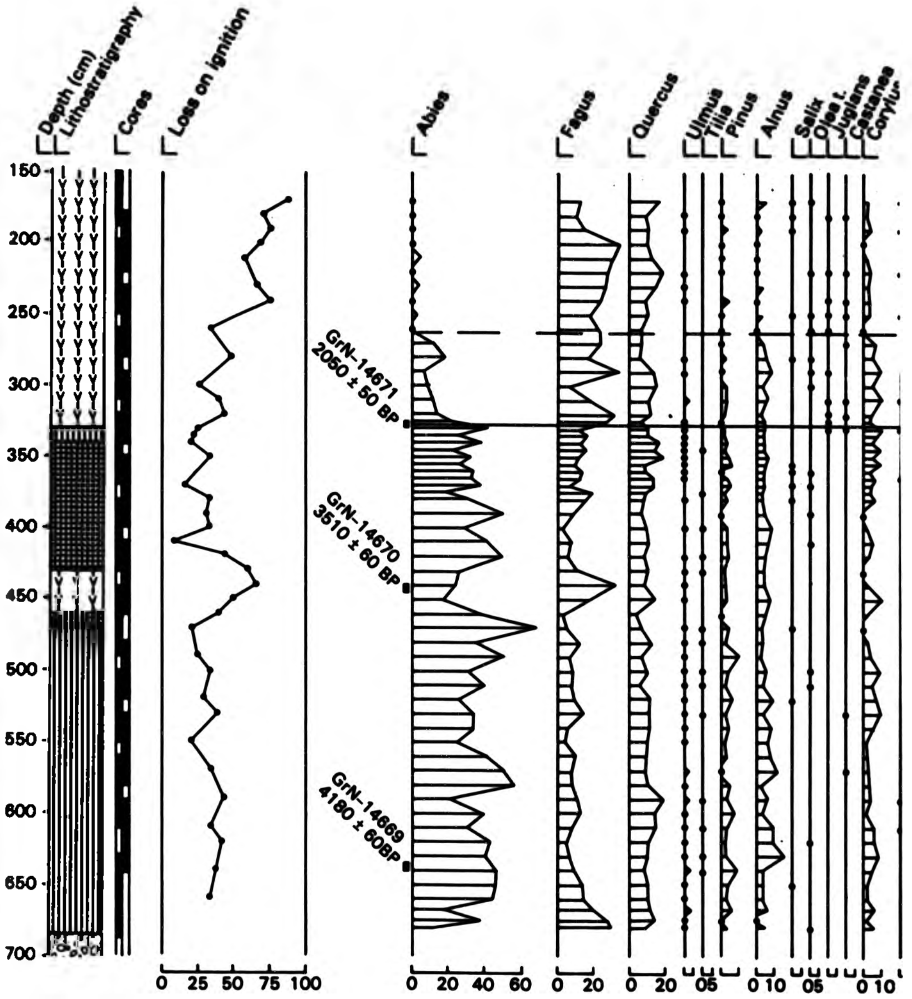
AG2: Fagus-Quercus PAZ (depths 325 to 170 cm, 17 spectra)

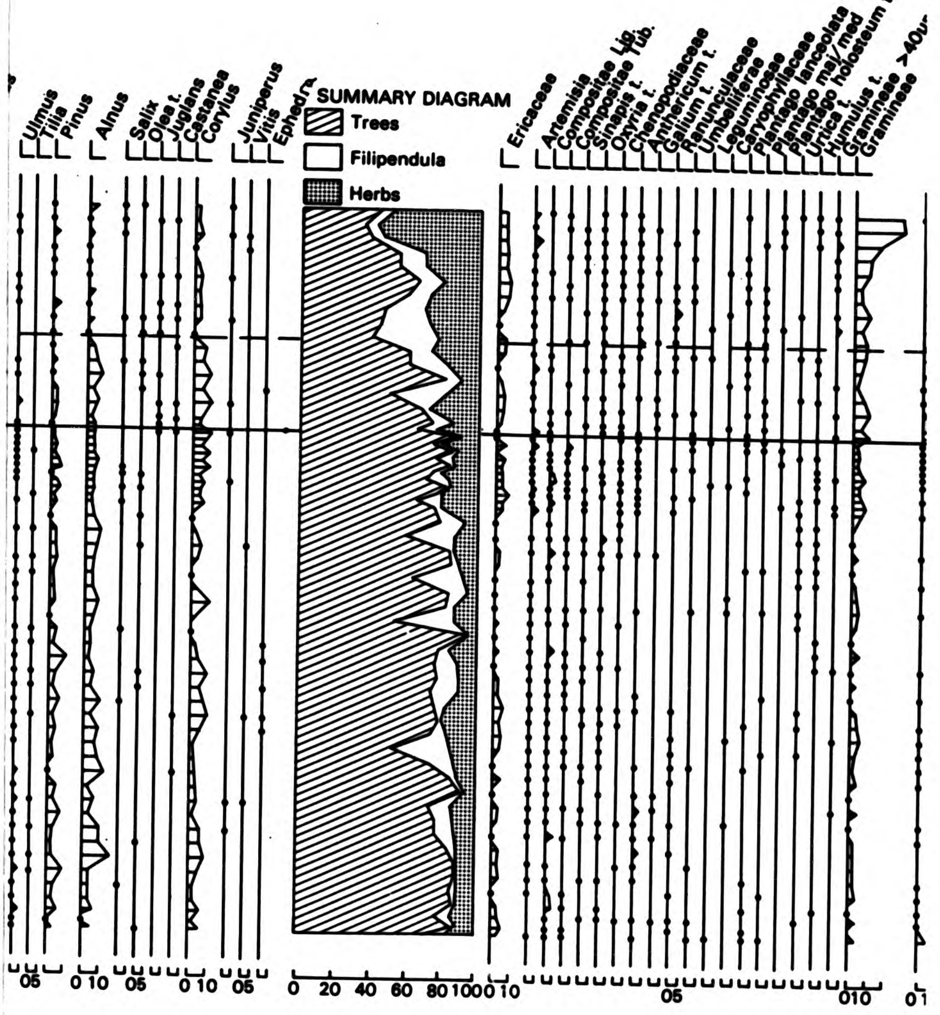
The lower boundary is drawn where Abies values fall to low frequencies and where Fagus percentages rise. Two subzones are identified on the basis of variations in the major taxa.

AG2-a: Fagus-Quercus-Abies PAZ (depths 325 to 270 cm, 7 spectra).

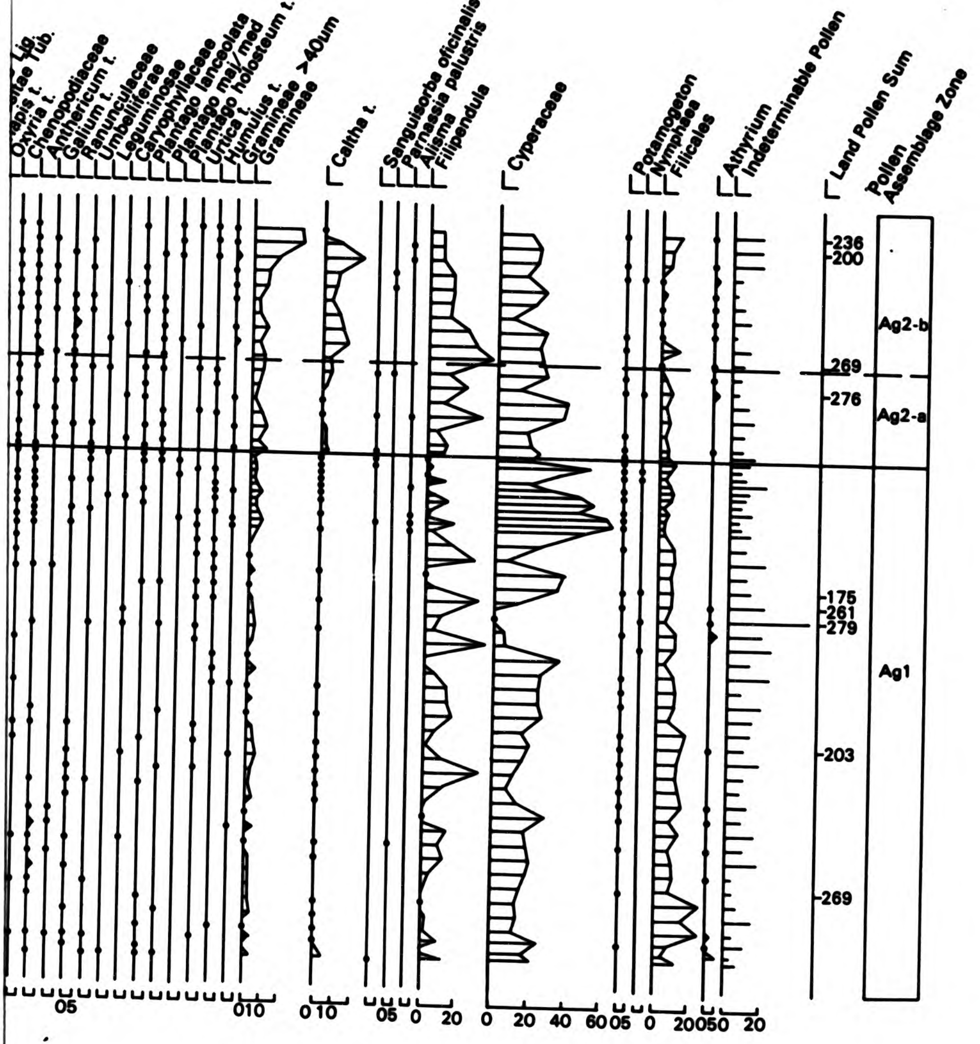
Abies percentages fall to below 18% TLP but with the exception of one sample, Fagus averages 20% TLP. Quercus values are unchanged but Tilia is no longer recorded whereas Juglans and Castanea are both present at low frequencies. Filipendula and Cyperaceae remain abundant and Caltha-type is more frequent. Herbaceous taxa (excluding Filipendula) now account for between 10% to 28% TLP and most of the herb types first recorded in the previous zone are present at more regular intervals.

Fig. 7 Agoraie-pollen percentages.





Ulmus
Tilia
Pinus
Alnus
Salix
Olea t.
Juglans
Castanea
Corylus
Juniperus
Vitis
SUMMARY DIAGRAM
Trees
Filipendula
Herbs
Ericaceae
Artemisia
Compositae Lig.
Compositae Tub.
Sinapis t.
Oxyria t.
Chenopodiaceae
Anthericum t.
Galium t.
Ranunculaceae
Umbelliferae
Leguminosae
Caryophyllaceae
Plantago lanceolata
Plantago maj/med
Urtica t.
Humulus t.
Gramineae
0 20 40 60 80 100



Oxyria t.
Chenopodiaceae
Anthericum t.
Galium t.
Ranunculaceae
Umbelliferae
Leguminosae
Caryophyllaceae
Plantago lanceolata
Plantago mai/med
Plantago holosteum t.
Urtica t.
Humulus t.
Gramineae >40um
Gramineae
Caltha t.
Sanguisorba oficinalis
Parnassia palustris
Alisma
Filipendula
Cyperaceae
Potamogeton
Nymphaea
Filicales
Athyrium
Indeterminable Pollen
Land Pollen Sum
Pollen Assemblage Zone
236
200
269
276
175
261
279
203
269
Ag2-b
Ag2-a
Ag1
05
010
0 10
05 0 20
0 20 40 60
05 0 20
050 20

AG2-b: *Fagus*-*Quercus*-NAP PAZ (depths 260 to 170 cm, 10 spectra).

Herb frequencies rise from 20% to 60% TLP with the major rise occurring in the *Caltha*-type and Gramineae curves. Woody taxa are dominated by *Fagus* which is typically over 20% TLP until the final three samples where values fall to 10%. *Quercus* is still abundant but *Abies*, *Pinus* and *Alnus* are very infrequent. Likewise Filicales values are insignificant until the end of the subzone where they increase again. The *Filipendula* and Cyperaceae curves no longer fluctuate erratically but while Cyperaceae remain common, *Filipendula* values decline.

Pollen Concentrations (Figure 8)

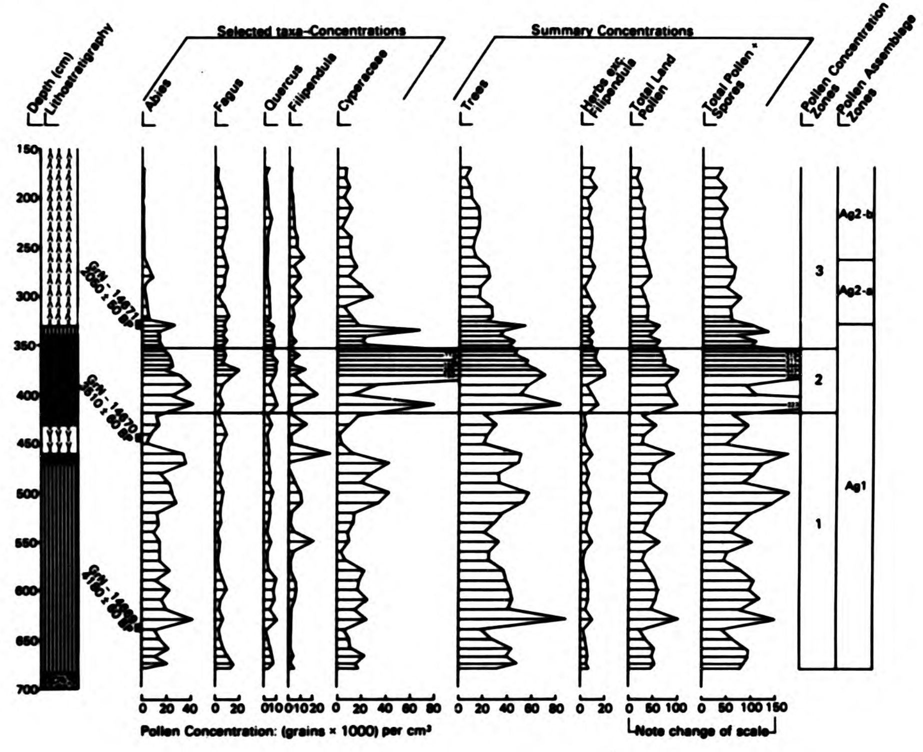
Pollen concentration zone 1: (depths 680 to 420 cm)

Concentrations of total pollen and spores are highly variable with values which fluctuate between 41K grains/cm^3 and 176K grains/cm^3. Land pollen concentrations are dominated by fluctuating *Abies* frequencies varying between 3K grains/cm^3 and over 40K grains/cm^3. Likewise Cyperaceae and *Filipendula* values are highly variable and concentrations of these taxa alternate with each other. Conversely records of *Fagus* and *Quercus* are generally below 10K grains/cm^3 and show none of the major fluctuations of the other major taxa.

Pollen concentration zone 2 (depths 410 cm to 355 cm)

This zone is characterised by a significant increase in pollen and spore concentrations with values of more than 200K

Fig. 8 Agoraie-pollen concentrations.



grains/cm³ in most samples and with maximum frequencies of over 440K grains/cm³. Cyperaceae concentrations are generally notably higher reaching maximum frequencies of 295K grains/cm³ at 375 cm. Land pollen concentrations fall from initially high values of 98K grains/cm³ to 60K grains/cm³ by the upper zone boundary but contrary to the major trends, *Fagus* and *Quercus* concentrations undergo few changes during this zone.

Pollen concentration zone 3 (depths 350 to 170 cm).

Total pollen and spore concentrations fall to below 30K grains/cm³ by the upper zone boundary. *Abies* values are the lowest in the diagram but *Fagus* and herb concentrations remain unchanged.

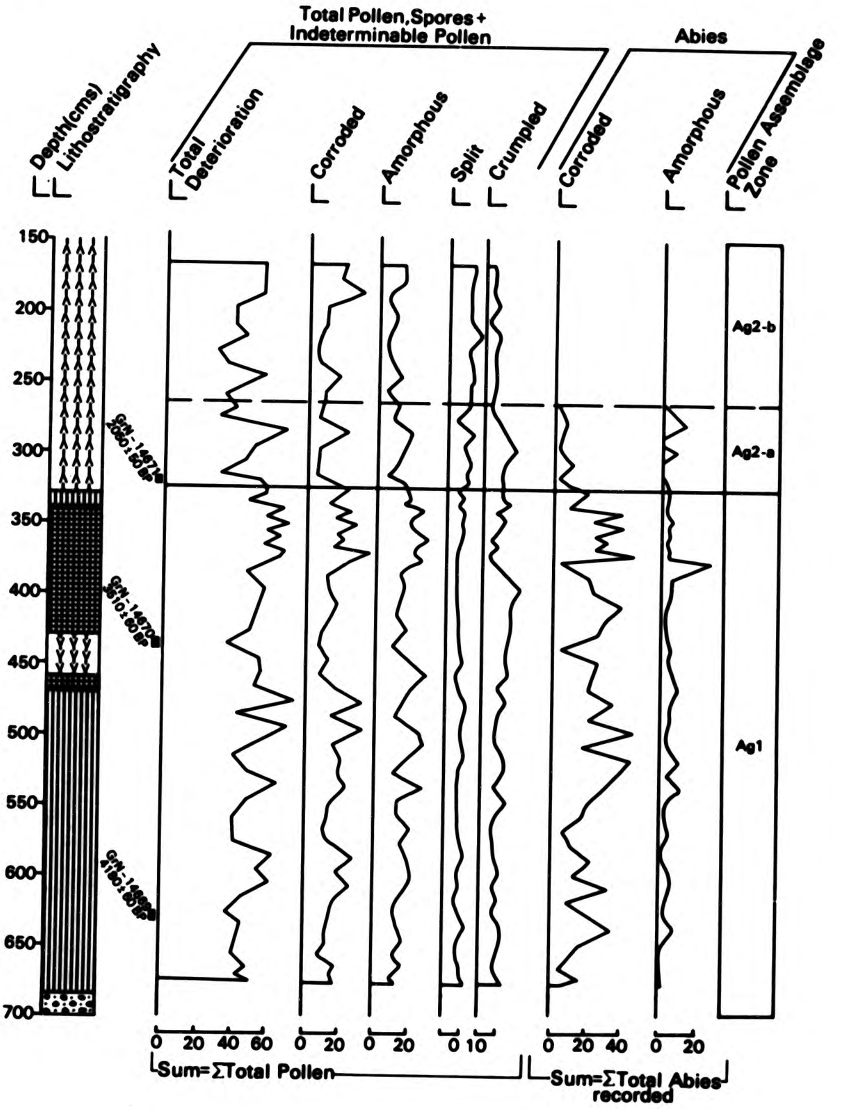
Pollen Preservation (Figure 9)

The pollen preservation data are highly variable and there are few discernible trends in the pollen preservation diagram. Total deterioration is high throughout with deterioration frequencies of at least 30% and more typically, over 40% of all pollen and spores recorded.

Radiocarbon dates

Skeleton pollen counts (Figure 10) were made from seven sediment piston cores from depths between 620 and 244 cm, and these were used for biostratigraphical correlation with the main pollen diagram. Five cm slices were removed for radiocarbon dating from the three cores (cores 1,3 and 5) that displayed the best biostratigraphical and

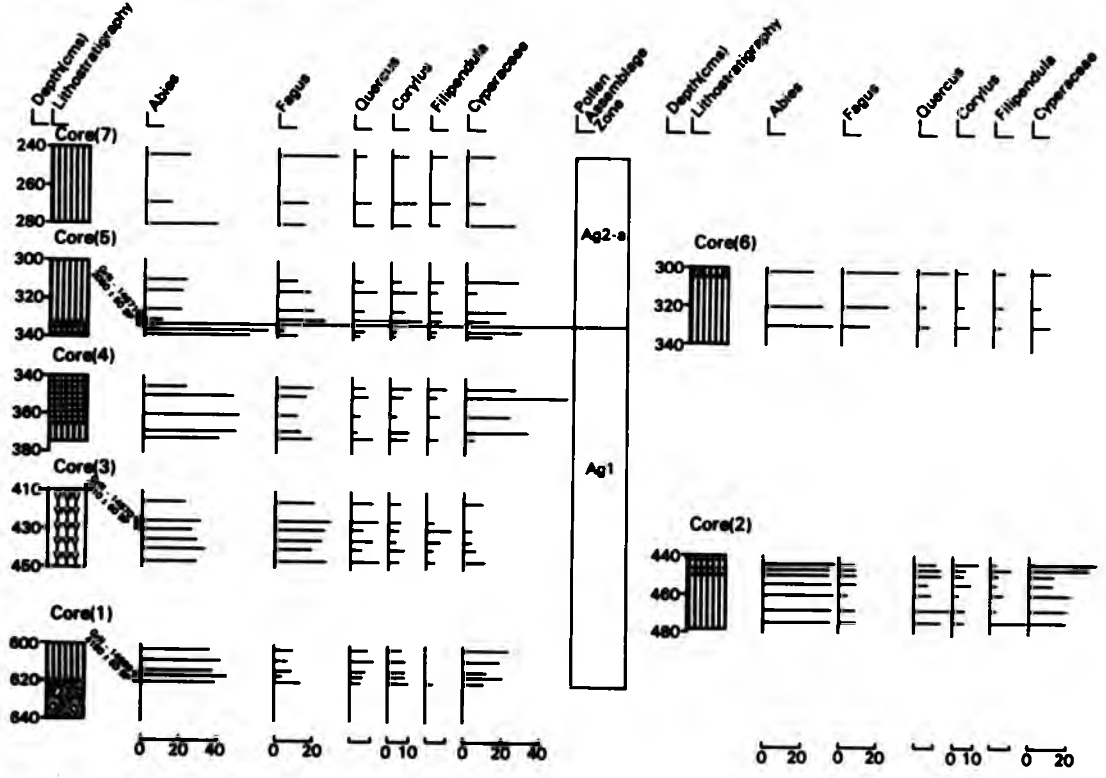
Fig. 9 Agoraie-pollen preservation.



lithostratigraphical correlation with the main diagram.

A 5 cm slice of peat was removed from piston core 1 in order to provide an estimate of the date at which peat formation began, and a result of 4180±60 BP (GrN-14669) was obtained from this sample. Nevertheless, comparison of the basal sequences obtained from the piston core and that observed in the main pollen diagram shows that there are differences in depth and in the Fagus curves, and it is suggested that slightly older sediments existed within the core upon which the main pollen diagram is based. Therefore it is only possible to fix an approximate position on the main diagram for this date. The two remaining radiocarbon dates were derived from sediment slices cut from cores 3 and 5, and correlated with the principal diagram on the basis of lithostratigraphy and variations in the Abies and Fagus curves. A date of 3510±60 BP (GrN-14670) was obtained for a Fagus peak within PAZ AG1 and the major pollen stratigraphical boundary (Ag1/Ag2-a) was dated to 2050±50 BP (GrN-14671).

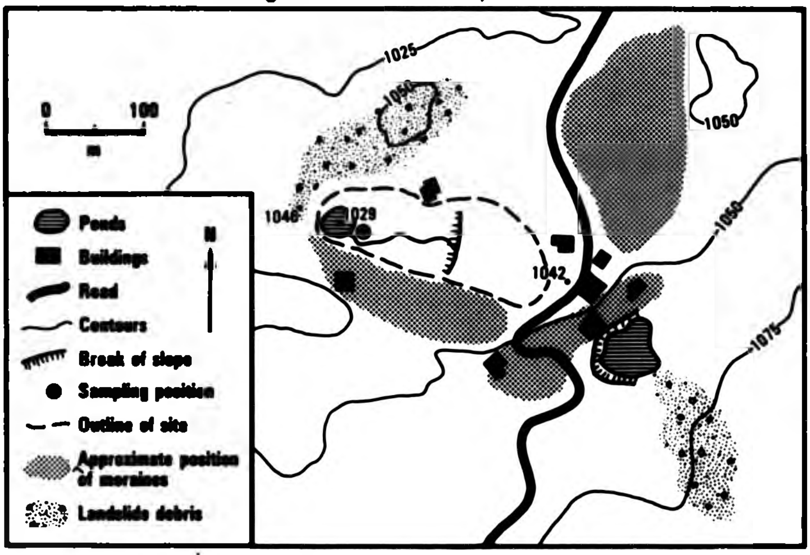
Fig. 10 Agorais-Skeleton pollen counts.



6.2 Lago delle Lame (Lat.44°30'N Lat.9°27'S)

Lago delle Lame is a small circular lake situated at approximately 1050 m on the north-west slope of M.Aiona close to the entrance of the Parco Domaniale delle Lame (Figures 5 and 11). A second basin is situated on a spur approximately 500 m to the north-west of the lake and at an altitude of 1029 m. It is a small, sloping elongated depression approximately 200 m long by 70 m wide, bounded on its southern edge by a drift mound and to the north by a possible landslide debris ridge. A break of slope occurs mid-way across the site at which point a small stream emerges from beneath the surface peat and then flows into a pond in the western corner. There is no stream outlet from the site.

Fig. 11 The peat site at Lago delle Lame and surrounding area (moraines marked according to field observation).



Vegetation

The mire vegetation is dominated by Carex species growing in the lower, wetter surfaces near the pond and Caltha palustris is prolific along the stream edges. Damp pasture grows on the dryer, higher areas of the site consisting of Gramineae spp., Serratula tinctoria, Saponaria officinalis, Colchicum autumnale, Plantago media and Plantago lanceolata. This pasture is cut for hay by the present land-owner. The surrounding rocky surfaces have been planted with Picea abies and Abies alba which together with Fagus sylvatica form a closed canopy reaching to the mire edge. In forest openings Juniperus communis, Vaccinium myrtilis, Erica herbacea and Geranium rotundifolia are frequent.

Lithostratigraphy

A transect of boreholes established that the deepest peat sediments (maximum depth 260 cm) existed towards the central part of the site and that these contained a number of ephemeral clay bands within the peat. However previous sampling of other sites in the field area had already demonstrated that Holocene peats had formed directly above impenetrable green silts and gravels with an absence of basal lake sediments, even in the deepest basin sites. In contrast to other sites, it was found that it was possible to penetrate these basal silts towards the western end of the basin, and that they contained considerable quantities of what was believed to be charcoal (see below). Thus, in order to investigate this matter further, the sediments were sampled at this point.

The following generalised lithostratigraphy is based on observations of sediments recovered from the sampling position.

Depth below surface in cms

0-20	Dark brown. (10YR 4/3) silt and clay.
20-35	Dark greyish brown (2.5Y 3/2) silty peat with wood detritus.
35-36	Dark greyish brown (2.5Y 4/2) silt.
36-41	Dark greyish brown (2.5Y 3/2) amorphous peat.
41-45	Silt and clay.
45-54	Very dark grey (10YR 3/1) silty peat; sharp lower boundary.
54-128	Black (7.5YR 2/0) detrital peat with conifer needles, wood fragments (4 cm) and fine roots; diffuse lower boundary.
128-145	Coarse, black wood peat; sharp lower boundary.
145-177	Very dark, greyish brown (2.5Y) amorphous, organic silt; no macrofossils.
177-210	Olive grey (5Y 4/2) silt.
210-212	Olive grey gravels.
212-250	Olive grey silt with coarse wood detritus becoming sandy towards the base.
Bedrock at	base.

Macrofossils

Details of macrofossil identifications by A.Clapham on materials extracted from the main core, are supplied in Appendix B. Large pieces (3 to 4 cm) of what had appeared to the naked eye as charcoal, were removed from the basal minerogenic sediments but were identified as Abies alba type wood. Although traumatic resin canals were present, suggesting mechanical injury, microscopic examination provided no evidence of burning (A.Clapham, pers. comm.). This conclusion was reached due to an absence of parenchymal cells, the presence of all of the cell structure, and when examined under high intensity light, the material was not entirely opaque. Other macrofossils identified were Abies seeds and needles as well as *Fagus* leaves, mast and wood.

Pollen Assemblage Zones (Figure 12).

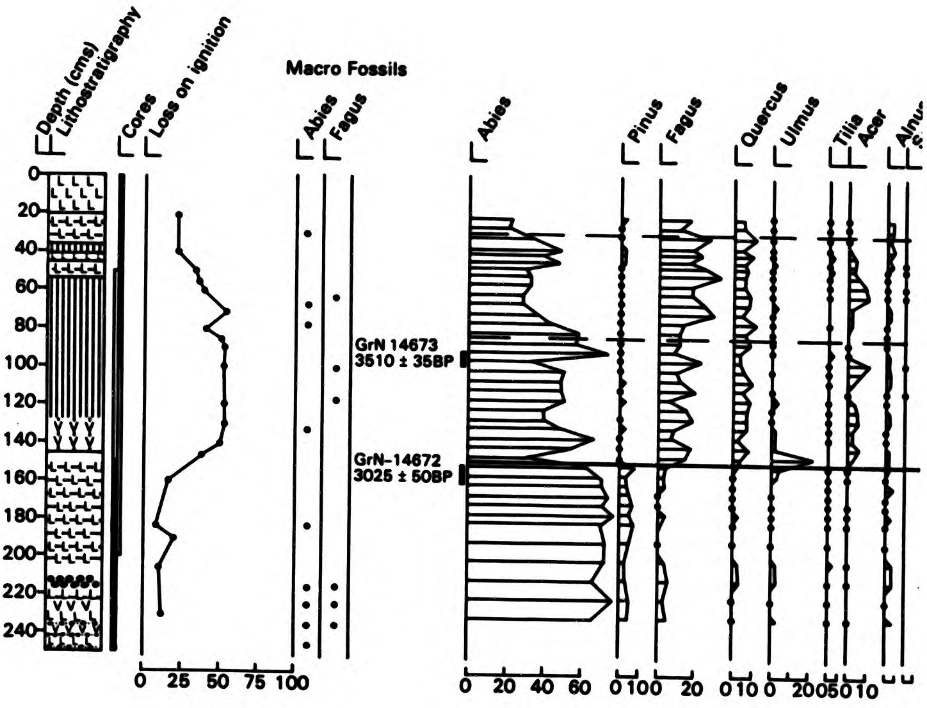
LdL1: Abies PAZ (depth 230 to 150 cm, 12 spectra)

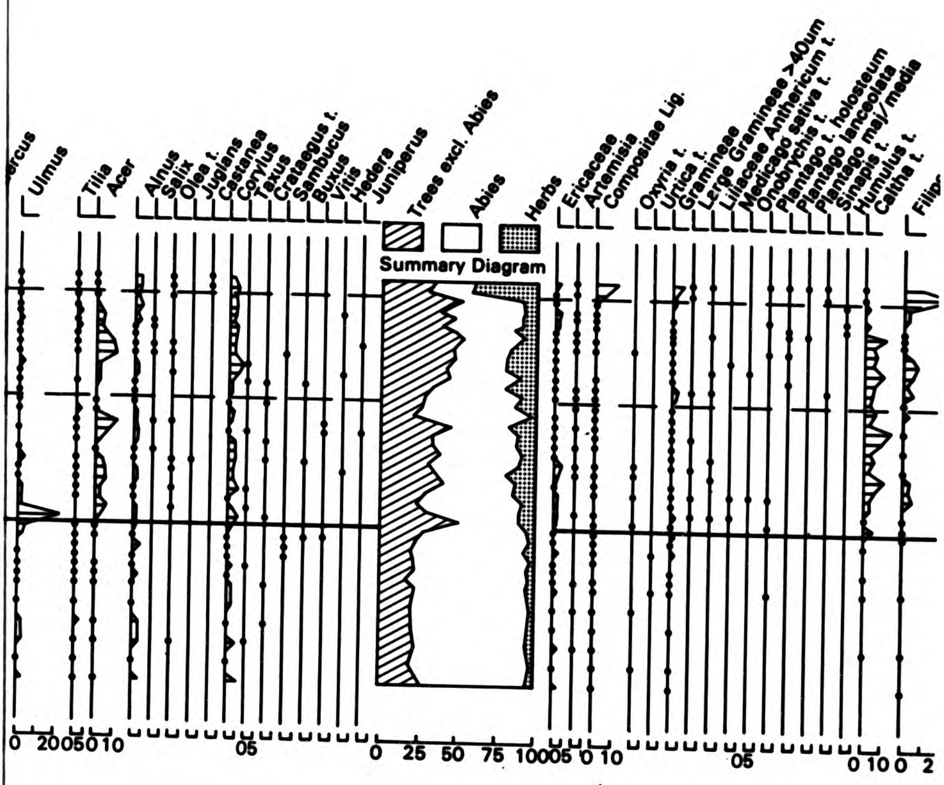
Abies frequencies are typically 70% TLP but all other woody taxa have low values. *Pinus* averages 4% and *Fagus* percentages never rise above 6% of land pollen. *Quercus*, *Ulmus*, *Tilia*, *Acer*, *Corylus* and *Alnus* are present at low frequencies but are never abundant. Herbaceous taxa are generally infrequent although Filicales values are high rising to 50% TLP. Aquatics are represented by *Nuphar* and *Potamogeton* occurring at low frequencies.

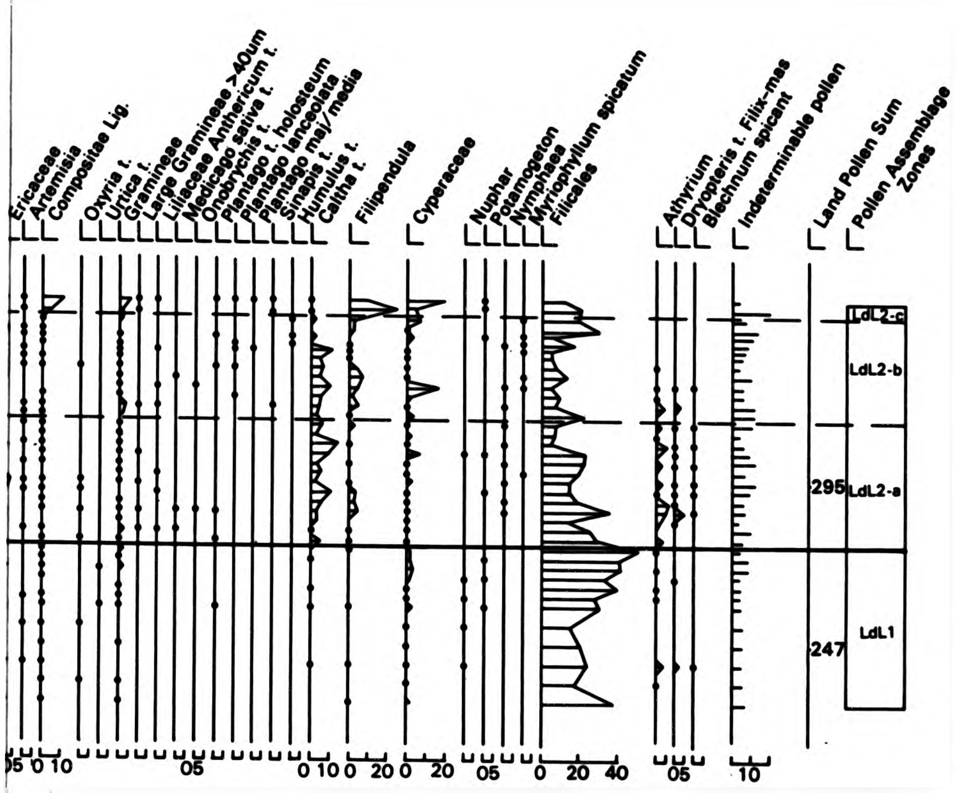
LdL2-a: Abies-Fagus-Acer PAZ (depths 145 to 85 cm, 13 spectra)

Deciduous trees are notably more abundant and *Abies* values, although remaining high, fluctuate markedly between 30% and 72% TLP. *Fagus* percentages are typically over 10% of land pollen. *Ulmus* is more frequent in the lower half of the subzone with one anomalous level reaching over 20% TLP, and *Acer* is notably more abundant although values fluctuate from 10% to below 2% TLP. *Quercus* is also more common but never rises above 10% of land pollen. Herb pollen types average 10% TLP and are dominated by *Caltha*-type. Other herb frequencies are low although *Filipendula* and Ericaceae are more frequent at the base of the subzone where there are also records of Leguminosae, *Oxyria*, *Anthericum* and *Plantago holosteum* pollen types. Filicales values decline although *Athyrium* spores are common. *Nymphaea* is recorded in several samples.

Fig. 12 Lago delle Lame-pollen percentages.




Ulmus
Tilia
Acer
Alnus
Salix
Olea t.
Juglans
Castanea
Corylus
Taxus
Crataegus t.
Sambucus
Buxus
Vitis
Hedera
Juniperus
Trees excl. Abies
Abies
Herbs
Summary Diagram
Ericaceae
Artemisia
Compositae Lig.
Oxyria t.
Urtica t.
Gramineae
Large Gramineae >40um
Liliaceae Anthericum t.
Medicago sativa t.
Onobrychis t.
Plantago t. holosteum
Plantago lanceolata
Plantago maj/ media
Sinapis t.
Humulus t.
Caltha t.


Ericaceae
Artemisia
Compositae Lig.
Oxyria t.
Urtica t.
Gramineae
Large Gramineae >40um
Liliaceae Anthericum t.
Medicago sativa t.
Onobrychis t.
Plantago t. holosteum
Plantago lanceolata
Plantago maj/media
Sinapis t.
Humulus t.
Caltha t.
Filipendula
Cyperaceae
Nuphar
Potamogeton
Nymphaea
Myriophyllum spicatum
Filicales
Athyrium
Dryopteris t. Filix-mas
Blechnum spicant
Indeterminable pollen
Land Pollen Sum
Pollen Assemblage Zones
LdL2-c
LdL2-b
295
LdL2-a
247
LdL1

LdL2-b: Fagus-Abies-Acer PAZ (depths 80 to 30 cm, 12 spectra)

Fagus frequencies rise to above 20% in most samples whereas the Abies curve follows a broadly downward trend although percentages continue to fluctuate between 22% and 46% TLP. Acer percentages also vary markedly. Caltha type and Filipendula are more abundant in lower samples but values decline towards the upper limit of the subzone. Plantago lanceolata and Humulus type are recorded for the first time. Cyperaceae values fluctuate. Filicales spores are more abundant in uppermost spectra where Athyrium is absent.

LdL2-c: Abies-Fagus-NAP PAZ (depths 25 to 20 cm, 2 spectra)

Herbs rise to over 30% TLP, the major increases occurring in the Filipendula and Compositae Liguliflorae curves. Abies averages 20% TLP and Fagus frequencies are below 20% TLP but Acer values are insignificant and Castanea is recorded for the first time. Cyperaceae values are higher but with the exception of Potamogeton, aquatics are no longer recorded.

Pollen Concentrations (Figure 13)

Pollen concentration zone 1: (depths 230 to 150 cm).

Concentrations of total pollen and spores climb from low values at the beginning of the subzone (averaging 20K grains/cm^3) to higher frequencies in the uppermost samples (59K grains/cm^3). Filicales spores become more abundant reaching over 30K grains/cm^3 but in contrast, Abies concentrations show little variation with values typically below 15K grains/cm^3.

Pollen concentration zone 2: (depths 145 to 85 cm).

Pollen and spore concentrations fall to below 20K grains/cm^3 near the lower boundary and rise again to average 45K grains/cm^3. *Abies* concentrations remain at low frequencies, typically below 20K grains/cm^3, whereas *Fagus* and herb concentrations are more abundant although never exceeding 10K grains/cm^3. Conversely there is a decline in concentration of Filicales spores.

Pollen concentration zone 3: (depths 80 to 20 cm).

With the exception of two samples, concentrations of total pollen and spores are notably higher reaching above 140K grains/cm^3 by the upper zone limit. Herbaceous taxa and Filicales spores attain maximum frequencies of above 40K grains/cm^3 in uppermost levels whereas *Abies* concentrations increase only slightly, averaging about 20K grains/cm^3. *Fagus* values reach a maximum of 20K grains/cm^3 in the middle of the subzone but decline thereafter.

Pollen Preservation (Figure 14)

Pollen preservation is poor with deterioration frequencies of over 40% of all pollen and spores being typical of most levels. Three pollen preservation zones have been identified on the basis of variations in the preservation characteristics of *Abies* grains.

Pollen preservation zone 1: (depths 230 to 150 cm)

At least 50% of all pollen and spores recorded are deteriorated with high frequencies of both amorphous and corroded grains. At least 30% of *Abies* grains are amorphous

Fig. 13 Lago delle Lame-pollen concentrations.

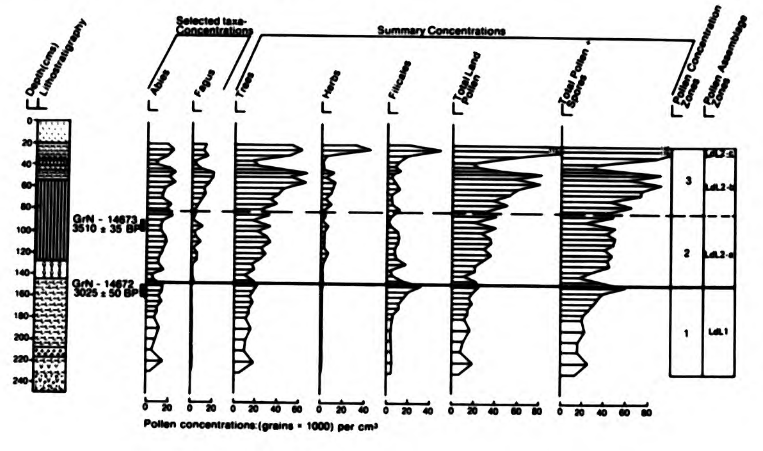
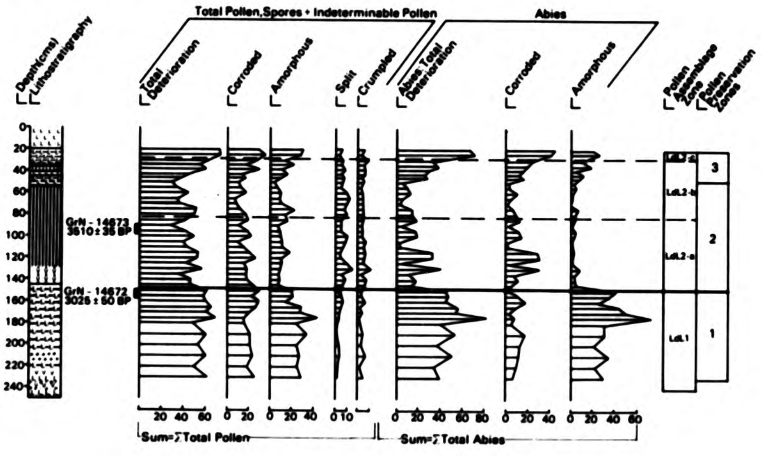


Fig. 14 Lago delle Lame-pollen preservation.



(rising to above 70% in the middle of the zone) but corroded frequencies average 9% of *Abies* recorded.

Pollen preservation zone 2: (depths 145 to 50 cm)

Amorphous *Abies* grains are insignificant although corroded frequencies fluctuate between 30% and 2% in contiguous samples.

Pollen preservation zone 3: (depths 46 to 20 cm)

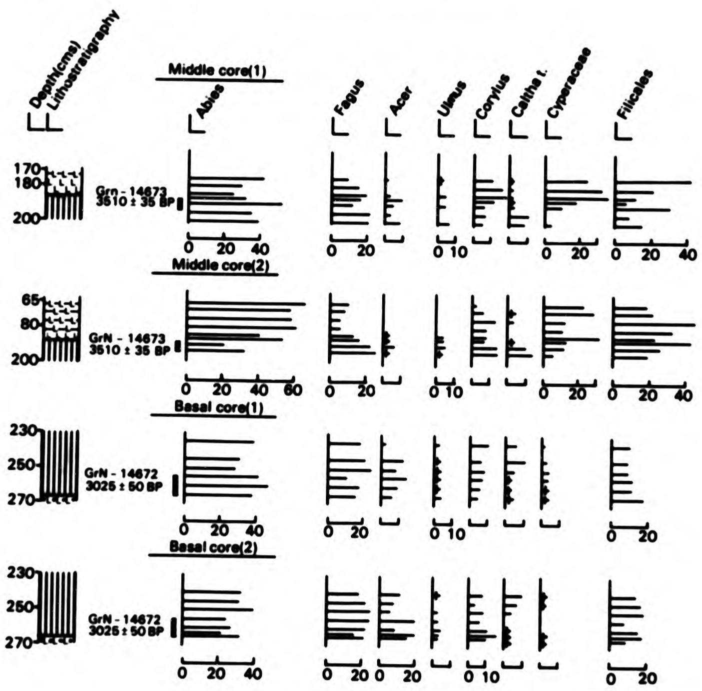
Deteriorated *Abies* grains rise from 27% to 68% of all *Abies* recorded with increased frequencies in both the corroded and amorphous categories.

Radiocarbon dates

Four sediment cores were removed from the deepest organic deposits on the site in order to provide sufficient material for radiocarbon dating. These samples consisted of two basal peat cores and two cores through a major clay band which occurred within the peat sediments of the higher, more peripheral parts of the site (see Figure 15). Two 10 cm slices of sediment from the basal peat in the bottom cores were combined to provide a bulk sample for an estimate of the date of peat initiation, *viz*. 3025 ± 50 BP (GrN-14672). Two 5 cm slices of sediment were removed from depths approximately 90 cm higher than the previous samples, but immediately underlying the clay band. This material was dated to 3510 ± 35 BP (GrN-14673).

It was not possible to cross-correlate between these cores and the main pollen core with a high degree of precision due to a number of variations in lithostratigraphy and in the pollen counts. Firstly, the basal sediment piston cores contain significant percentages of Fagus and Acer which unlike the main core, do not increase in higher samples; there is no basal Ulmus peak in the skeleton counts and the rise in Caltha type frequencies occurs some way into the peat and not at the base. Therefore it has been assumed that this deeper peat is slightly older than that of the pollen diagram, that some differential pollen preservation has occurred in the minerogenic sediments and it is only possible to establish an approximate position for this date within the pollen stratigraphy. Secondly, lithostratigraphical variations in the piston cores are absent in the original sediment core so cross-correlation has been based on biostratigraphical variations, and the second radiocarbon date has been positioned at a depth of approximately 90 cm where Acer frequencies decline and Abies values increase.

Fig. 15 Lago delle Lame-Skeleton pollen counts.

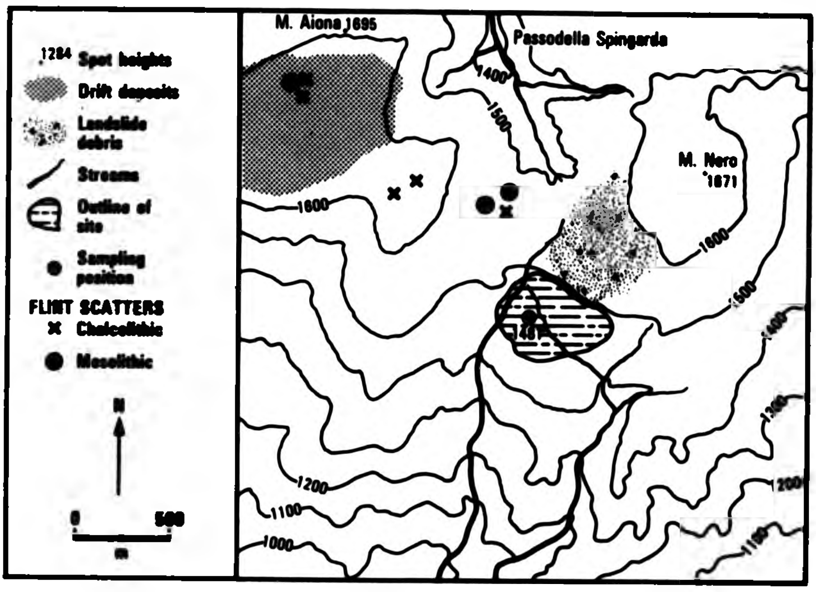


CHAPTER 7: THE SITES PRATO MOLLO AND LAGO NERO

7.1 Prato Mollo (Lat.44°28'N Long.9°31'E)

This site is situated on a broad, south-facing shelf at an altitude of 1481 m beneath a col between M.Aiona and M.Nero (Figures 5 and 16). It is a shallow depression of approximately 500 m diameter which is bounded on its southern edge by a rock ridge. Upslope from the site, slopes rise gently to above 1600 m and these are mantled by landslide debris to the north-east whereas drift deposits lie on the highest slopes of M.Aiona to the north-west. In addition, flint scatters of Mesolithic and Chalcolithic ages lie NNW and NW of the site respectively. Two small seasonal streams enter the site from the northern end and exit from the south-western and south-eastern corners.

Fig. 16 The peat site at Prato Mollo and surrounding area.



Vegetation

A mosaic of plant communities grow on the mire surface according to variations in local site topography. Carex spp. and Parnassia palustris are the commonest vegetation types in the lower, wetter parts, and these are interspersed with Sphagnum and grass hummocks supporting Nardus stricta, Calluna vulgaris, Vaccinium myrtilis, Gentianella campestris and Potentilla erecta. The vegetation of the slopes immediately surrounding the site is typically ageing Fagus sylvatica coppice and scrub growing with an understorey of Vaccinium myrtilis and Anemone nemorosa. However beech woods in this area are limited to the highest slopes above approximately 1300 m and grassland is the more typical vegetation type. Locally Hypericum perforatum, Juniperus nana, Centaurea spp., Globularia spp., Succisa pratensis, Euphorbia spp. and Helianthemum spp. are frequent but lower altitude pastures below approximately 1000 m are characterised by Helichrysum stoechas, Calluna vulgaris, Pteridium aquilinum and with scattered Corylus avellana, Rubus and Crataegus monogyna bushes.

Lithostratigraphy

The sediments on the site were systematically probed and it was found that a shallow peat varying from 20 cm to 90 cm depth overlay either an undulating surface of in situ weathered bedrock or, at the edges of the site, podzolic soils. The presence of rocks at various levels within the peat was characteristic of the site. The deepest peat levels contained charcoal-rich basal layers and these were found at irregular intervals across the site. A peat monolith was extracted from the deepest point of the site.

Depth below surface (cm)

0-12	Very dark, greyish brown (10YR 3/3) fibrous, silty peat.
12-13	Olive brown (2.5YR 4/4) silt.
13-79	Very dark, greyish brown (2.5YR 3/2) silty amorphous peat changing to dark, olive grey (5Y 3/2) at 32 cm; many fine roots, Abies wood (30 cm) at 65 cm; sharp lower boundary.
79-82	Black (5Y 2.5/1) silty peat with small stones (2 mm); sharp lower boundary.
82-85	Mottled olive (5Y 5/4) and black (5Y 2.5/1) silt and peat with root fragments and fine stones.
85-91	Black (5Y 5/4) amorphous, silty peat with fine roots; very sharp lower boundary.
91-100	Olive grey (5Y 4/2) silt with some olive mottling and root fragments.
below 100	Impenetrable.

Pollen Assemblage Zones (Figure 17)

PM1: Abies-Corylus PAZ (depths 90 to 79 cm, 6 spectra)

The basal PAZ is dominated by high *Abies* percentages which decline from over 60% to below 30% TLP. *Pinus* frequencies average 10% TLP with the exception of one level and *Corylus* averages 12% TLP. Maximum *Tilia* values (3% TLP) are recorded in the two basal horizons but are insignificant thereafter. Other arboreal taxa are poorly represented although *Alnus*, *Fagus* and *Quercus* are more frequent near the upper zone boundary. Non-arboreal taxa are dominated by Gramineae (averaging 10% TLP) and Cyperaceae rising to 30% TLP. *Pteridium* values average 3% TLP and Filicales spores are frequent.

PM2: Abies-Fagus-Alnus-Corylus PAZ (depths 77 to 33 cm. 10 spectra).

The lower zone boundary is placed where Abies frequencies fall to below 30% TLP with a complementary rise in the curves of other woody taxa. Two subzones are identified on the basis of variations in the Alnus and Ulmus curves.

PM2-a: Abies-Ulmus-Alnus-Corylus PAZ (depths 77 to 63 cm. 4 spectra)

Ulmus and Alnus are more abundant reaching values of 4% TLP and 16% TLP respectively, while Fagus percentages are below 10% TLP and Corylus remains unchanged. A wider range of herbs are present most notably Compositae Liguliflorae. Filicales spores attain maximum frequencies (16% TLP) but Pteridium is insignificant.

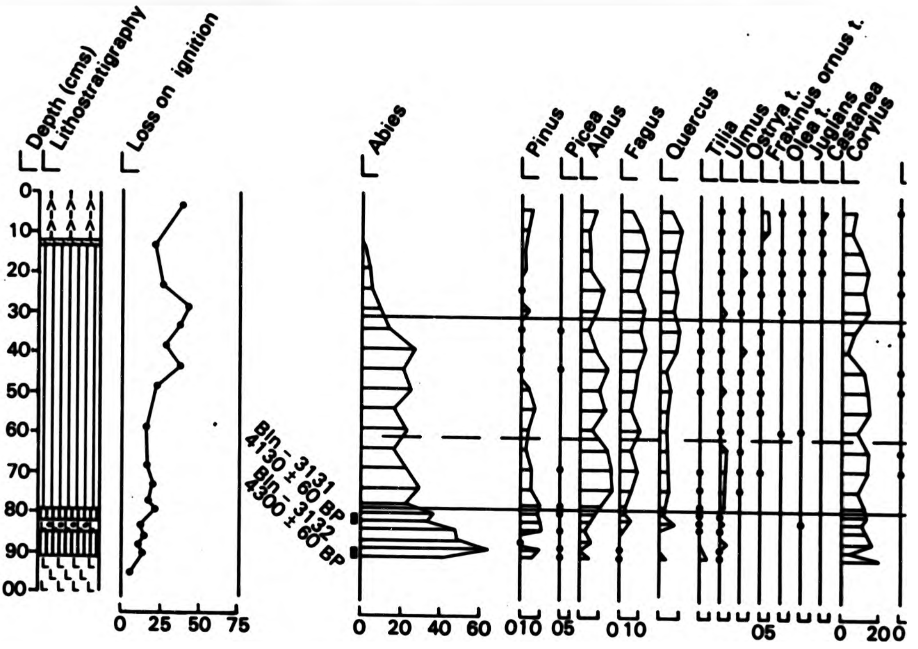
PM2-b: Abies-Fagus-Corylus PAZ (depths 58 to 33 cm. 6 spectra)

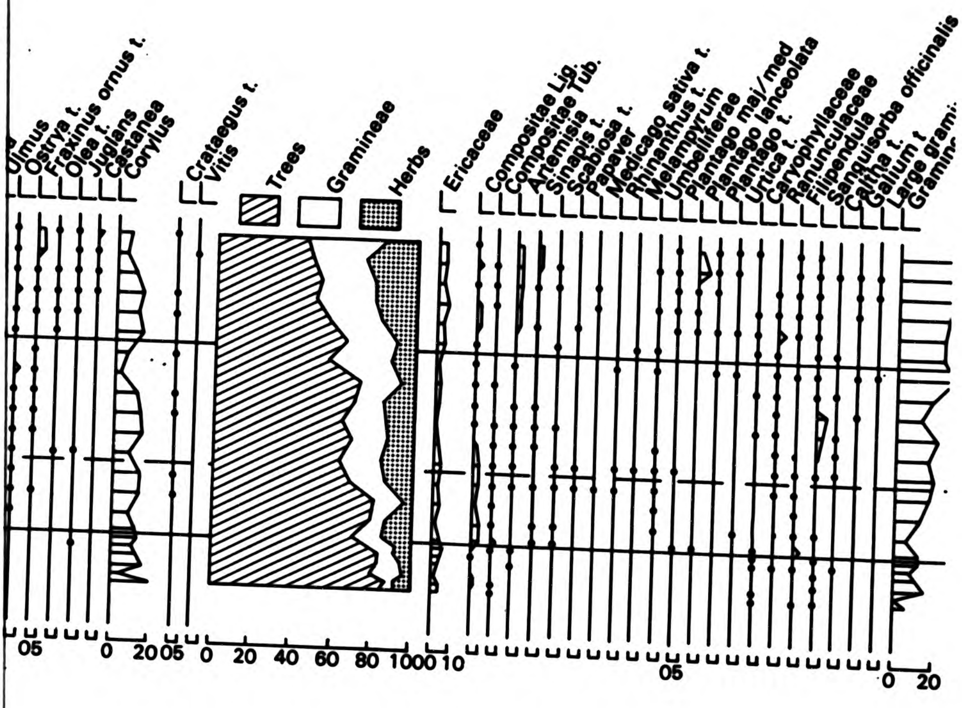
Abies averages 20% TLP although values fall in the uppermost horizon while the Fagus curve rises gradually to above 10% TLP. Likewise Quercus values increase upwards although they never rise above 10% TLP. Cyperaceae and Sanguisorba officinalis are frequent in the lower half of the subzone but Compositae and Filicales values diminish.

PM3: Fagus-Quercus-Corylus-NAP PAZ (depths 28 to 3 cm. 6 spectra).

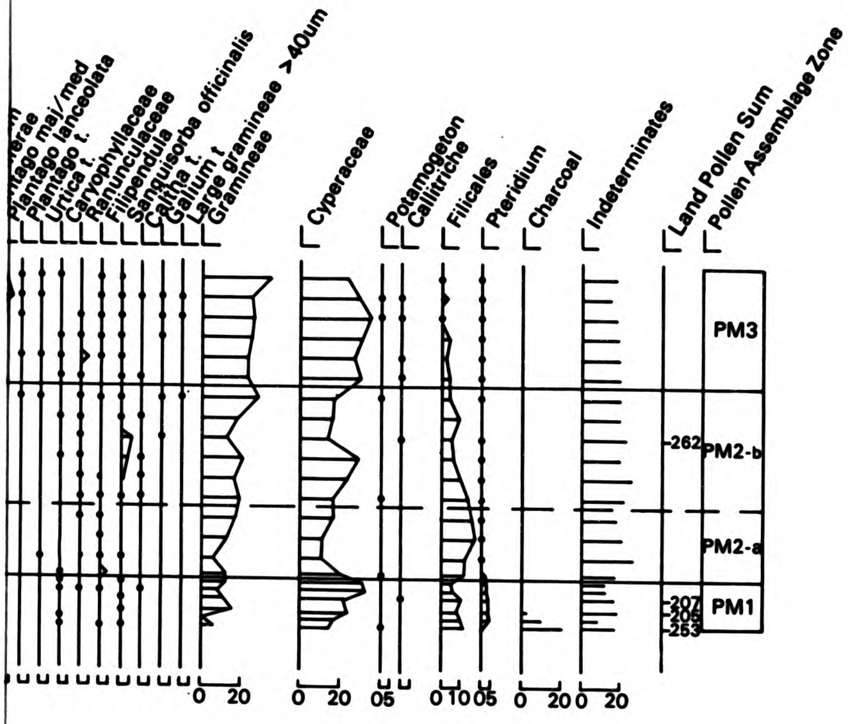
The uppermost PAZ is characterised by a major increase in herbaceous pollen percentages, particuarly in Gramineae which averages 27% TLP. Abies frequencies fall dramatically

Fig. 17 Prato Mollo-pollen percentages.





Ulmus
Ostrya t.
Fraxinus ornus t.
Olea t.
Juglans
Castanea
Corylus
Crataegus t.
Vitis
Trees
Gramineae
Herbs
Ericaceae
Compositae Lig.
Compositae Tub.
Artemisia
Sinapis t.
Scabiosa t.
Papaver
Medicago sativa t.
Rhinanthus t.
Melampyrum
Umbelliferae
Plantago maj./med
Plantago lanceolata
Plantago t.
Urtica t.
Caryophyllaceae
Ranunculaceae
Filipendula
Sanguisorba officinalis
Caltha t.
Galium t.
05
0 20
05
0 20 40 60 80 100
0 10
05
0 20


Plantago maj/med
Plantago lanceolata
Plantago t.
Urtica t.
Caryophyllaceae
Ranunculaceae
Filipendula
Sanguisorba officinalis
Caltha t.
Galium t.
Large gramineae >40um
Gramineae
Cyperaceae
Potamogeton
Callitriche
Filicales
Pteridium
Charcoal
Indeterminates
Land Pollen Sum
Pollen Assemblage Zone
PM3
PM2-b
PM2-a
PM1
262
207
205
253

to below 2% TLP in the uppermost level although Fagus and Quercus values remain unchanged. Tilia is no longer recorded although Fraxinus ornus pollen type is more frequent in the two final levels while Olea type, Juglans and Castanea are recorded in successive samples. Artemisia, Sinapis type and Plantago lanceolata are better represented and Cyperaceae are very abundant reaching 20% to 30% TLP but Filicales are infrequent.

Pollen Concentrations (Figure 18)

Three pollen concentration zones have been drawn on the basis of variations in concentrations of total pollen and spores recorded.

Pollen concentration zone 1: (depths 90 to 77 cm).

Total concentrations are highly variable with values fluctuating between 15K grains/cm³ to over 100K grains/cm³ near the upper zone boundary. The major contributors to the pollen spectra are Abies and Cyperaceae with low concentrations at the beginning although they rise to 18K grains/cm³ and 35K grains/cm³ respectively in uppermost horizons.

Pollen concentration zone 2: (depths 73 to 38 cm).

Pollen and spore concentrations are notably higher than in zone 1 with values of above 150K grains/cm³ being typical of most levels and with maximum frequencies of over 200K grains/cm³. All of the major taxa follow the same general trend with the exception of Filicales spores which attain maximum values (28K grains/cm³) in the lower half of the zone

Fig. 18 Prato Mollo-pollen concentrations.

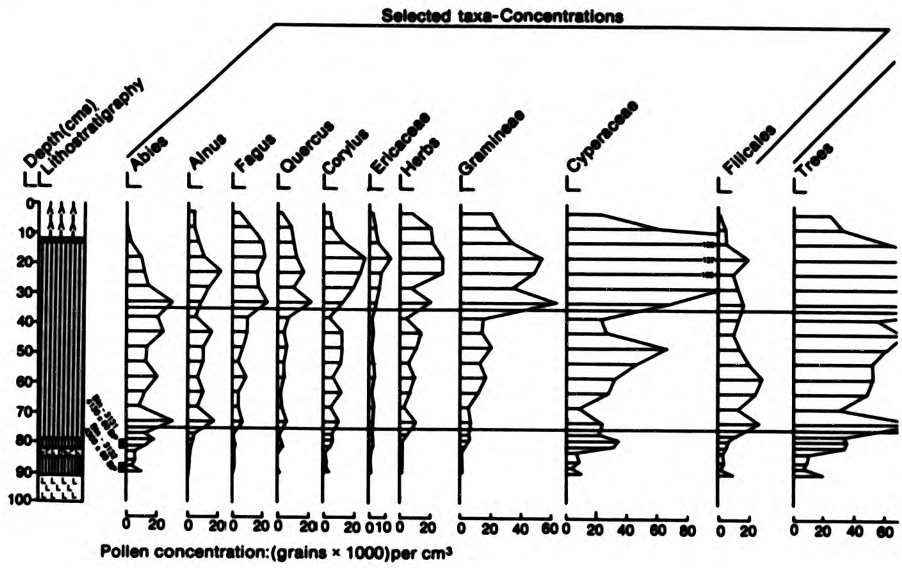
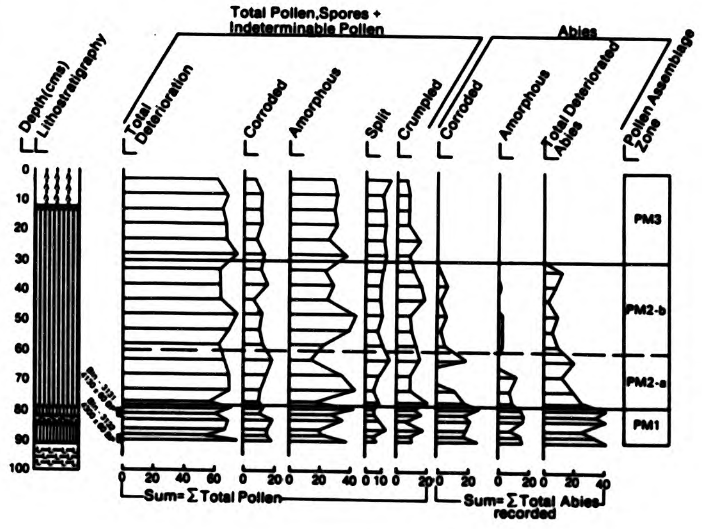
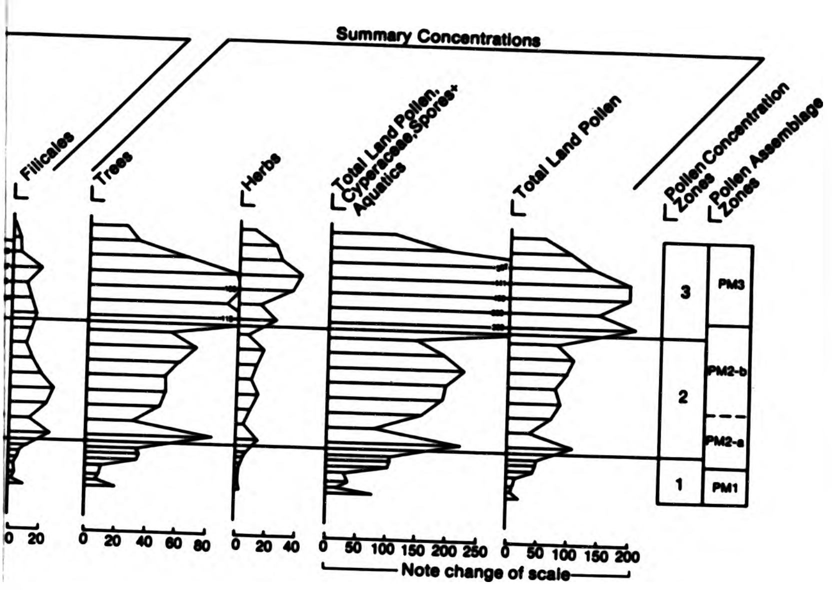


Fig. 19 Prato Mollo-pollen preservation.





Summary Concentrations
Filicales
Trees
Herbs
Total Land Pollen, Cyperaceae,Spores+ Aquatics
Total Land Pollen
Pollen Concentration Zones
Pollen Assemblage Zones
3
2
1
PM3
PM2-b
PM2-a
PM1
0 20
0 20 40 60 80
0 20 40
0 50 100 150 200 250
0 50 100 150 200
Note change of scale

and fall thereafter.

Pollen concentration zone 3: (depths 33 to 3 cm).

Maximum pollen and spore concentrations occur in the uppermost zone with frequencies rising to over 400K grains/cm³ although values fall again to below 100k grains/cm³ by the upper zone limit. However *Abies* concentrations fail to follow the main trend and fall to insignificant levels.

Pollen preservation (Figure 19)

Pollen preservation is poor throughout the sedimentary sequence and deterioration frequencies of at least 60% are characteristic of most levels with high percentages of amorphous grains being typical. No discernible major variations occur in the general preservation characteristics but in contrast to the general pattern, *Abies* deterioration frequencies decline from over 30% of all *Abies* grains recorded in PAZ PM1, to below 10% in PM2-b.

Charcoal Analyses

i) Microscopic charcoal. Maximum charcoal frequencies (20% TLP) occur in the basal sample and decline in subsequent levels. Fragments were recorded for all samples up to depth 68 cm but none above that level.

ii) Macroscopic charcoal. Macroscopic charcoal was removed from the sediments at depths 79-82 cm and 85-91 cm and identified by R.Nisbet (1989, in press). As many of the charcoal pieces were poorly preserved only 15 fragments were recognisable and these were identified as Alnus spp. In addition, included charcoal in thin sections were identified as being of coniferous type (A.Clapham, pers.comm.).

Micromorphology

In order to provide information on events leading up to the onset of peat formation at this site a large slice of the basal 6 cm of peat and underlying mineral sediments were removed from the peat monolith. This was subsequently investigated micromorphologically by R.I.Macphail (Institute of Archaeology, University of London) who showed that peat formation had been preceded by the inwash of a complex of silts, clays and coarse serpentinite soil fragments. The basal peat had been burned *in situ* and also contained inclusions of burned coniferous type wood. Details of the results of this study are supplied in Appendix C together with the results of a further investigation of a soil profile located close to the peat site.

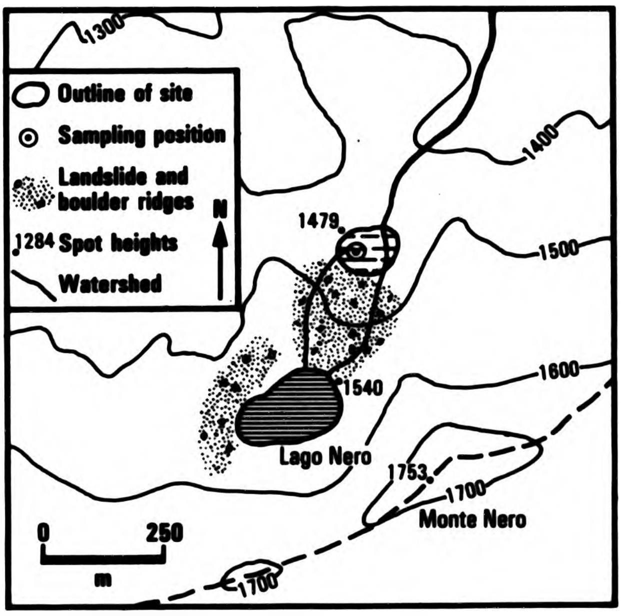
Radiocarbon dates

Materials for radiocarbon dating were removed concurrently with sediment sampling for pollen and were extracted from an adjacent exposed peat face. The basal charcoal-rich sediments were of particular interest and were sampled at depths 80-82 cm and 88-90 cm. The charcoal was not assayed separately. Bulk dates of 4300 ± 60 BP (Bln-3132) and 4130 ± 60 BP (Bln-3131) provide an estimate of the date at which peat formation began at this site.

7.2 Lago Nero (Lat.44°30'N Long.9°27'E)

This site is situated on a broad bench on the northern flanks of M.Nero (1788 m) at an altitude of 1479 m approximately 60 m to the north-east of a small lake, named Lago Nero (Figure 20). The lake is formed within a cirque-like depression in the NE-SW trending watershed but there is no appreciable marginal sediment accumulation in the basin. Lo Sacco (1949) identified moraine ridges bordering the northern edges of the lake and the peat site but these do not have the appearance of drift ridges and hummocks, and instead may be rock ridges with a mantling cover of landslide debris.

Fig. 20 The peat site at Lago Nero and surrounding area.



The mire surface is a roughly circular in form, approximately 100 m in diameter, and is crossed by a small ephemeral stream which enters from the south-east, flows 1 m below the level of the peat along the bedrock surface and exits towards the north-east.

Vegetation

The vegetation of the highest, north-facing slopes of M.Nero includes stands of Abies alba and Pinus mugo both of which are rare in the field area as a whole. However, more typical of the vegetation surrounding the site is dense, ageing Fagus sylvatica coppice woodland interspersed with rapidly growing young beech trees and occasional Sorbus aria. Vaccinium myrtilis and Geranium rotundifolia are typical constituents of the understorey vegetation while in clearings and on woodland edges the vegetation is dominated by low shrub and heath communities most notably Juniperus nana, Arctostaphylos uva-ursi and Calluna vulgaris. The mire surface vegetation is dominated by Carex species in lower, damper situations separated by hummock vegetation carrying Sanguisorba officinalis, Calluna vulgaris, Filipendula ulmaria and Potentilla erecta.

Lithostratigraphy

A shallow peat had formed within the site and this was systematically probed to find the deepest sediments.

Depth below surface in cm

0-23	Very dark, greyish brown (10YR 3/2) coarse, surface peat.

23-81	Very dark, greyish brown peat with some fine roots but becoming amorphous from 36 cm; lower boundary diffuse.
81-101	Black (2.5Y 2/0) organic, amorphous silt; fine charcoal fragments; lower boundary diffuse over 1 cm.
101-106	Olive grey (5Y 4/2) silt with light olive brown (5Y 5/4) mottles; rotting stones and root fragments.

Pollen Assemblage Zones (Figure 21).

LN1: Abies-Pinus PAZ (depth 100 to 98 cm, 2 spectra).

The basal PAZ is dominated by *Abies* (43% TLP) and *Pinus* (varying from 18% to 43% TLP) with low frequencies of all other woody taxa. The basal horizon contains high herb pollen frequencies (28% TLP) and these are dominated by Gramineae and a further pollen type which has has not been identified with certainty but may be *Polygonum bistorta* type.

LN2: Abies PAZ (depth 95 to 82 cm, 4 spectra).

The pollen spectra in this zone are dominated by very high *Abies* frequencies (over 70% TLP). *Corylus* is more common but the curve never rises above 10% TLP and *Pinus* is below 10% TLP in all samples. Filicales spores are abundant reaching over 10% TLP by the upper zone boundary where *Pteridium* attains its maximum frequencies of 2% TLP.

LN3: Corylus-Alnus-Abies PAZ (depth 77 to 52 cm, 6 spectra).

In this zone *Corylus* and *Alnus* frequencies increase dramatically (to 30% and 20% TLP respectively) with a complementary decline in *Abies* percentages. They then decline towards the upper zone boundary while the *Abies* curve falls to average 25% TLP. *Ulmus*, *Quercus*, and *Fagus* are more abundant in this zone with *Fagus* in particular reaching 20% TLP in the uppermost spectra. Ericaceae values average 3% TLP

Fig. 21 Lago Nero-pollen percentages.

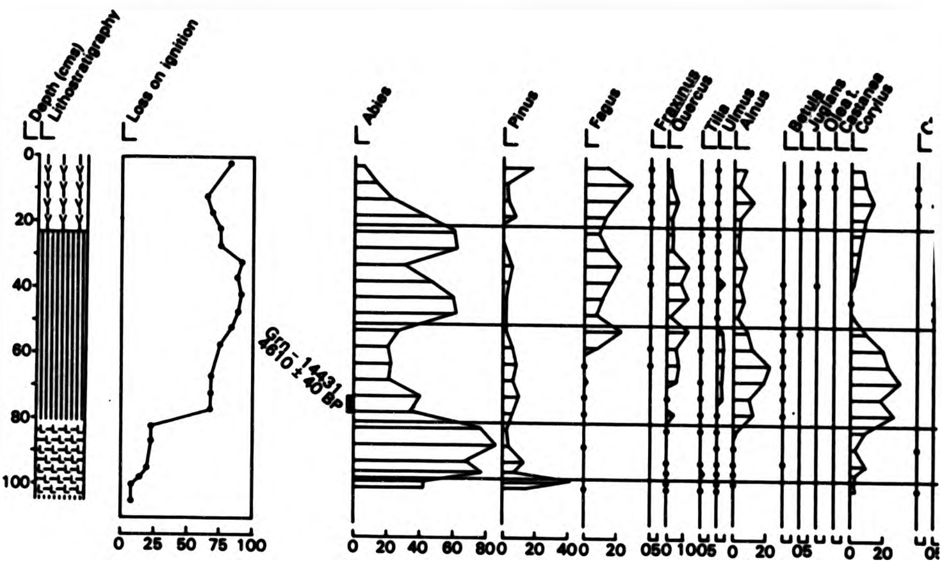
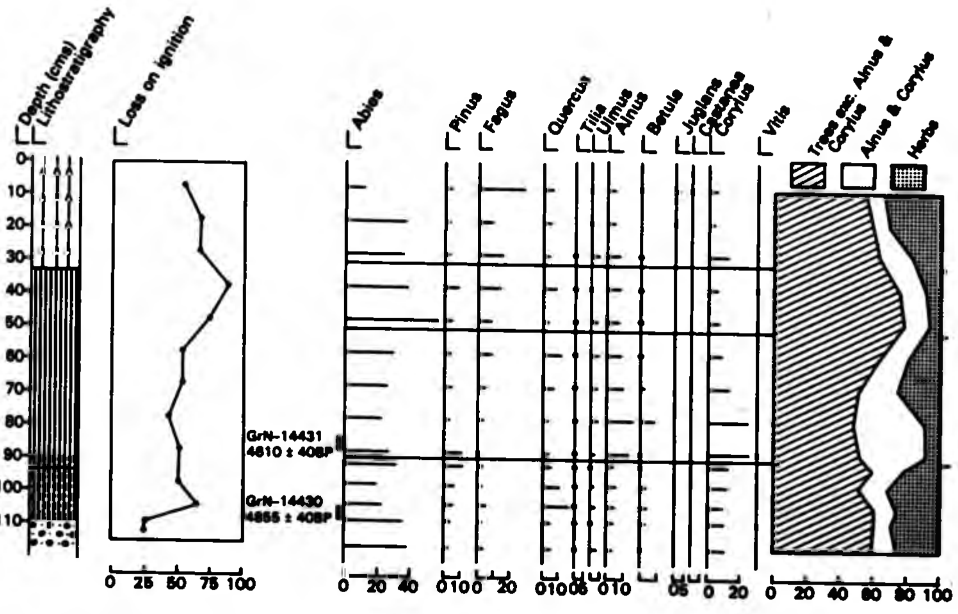
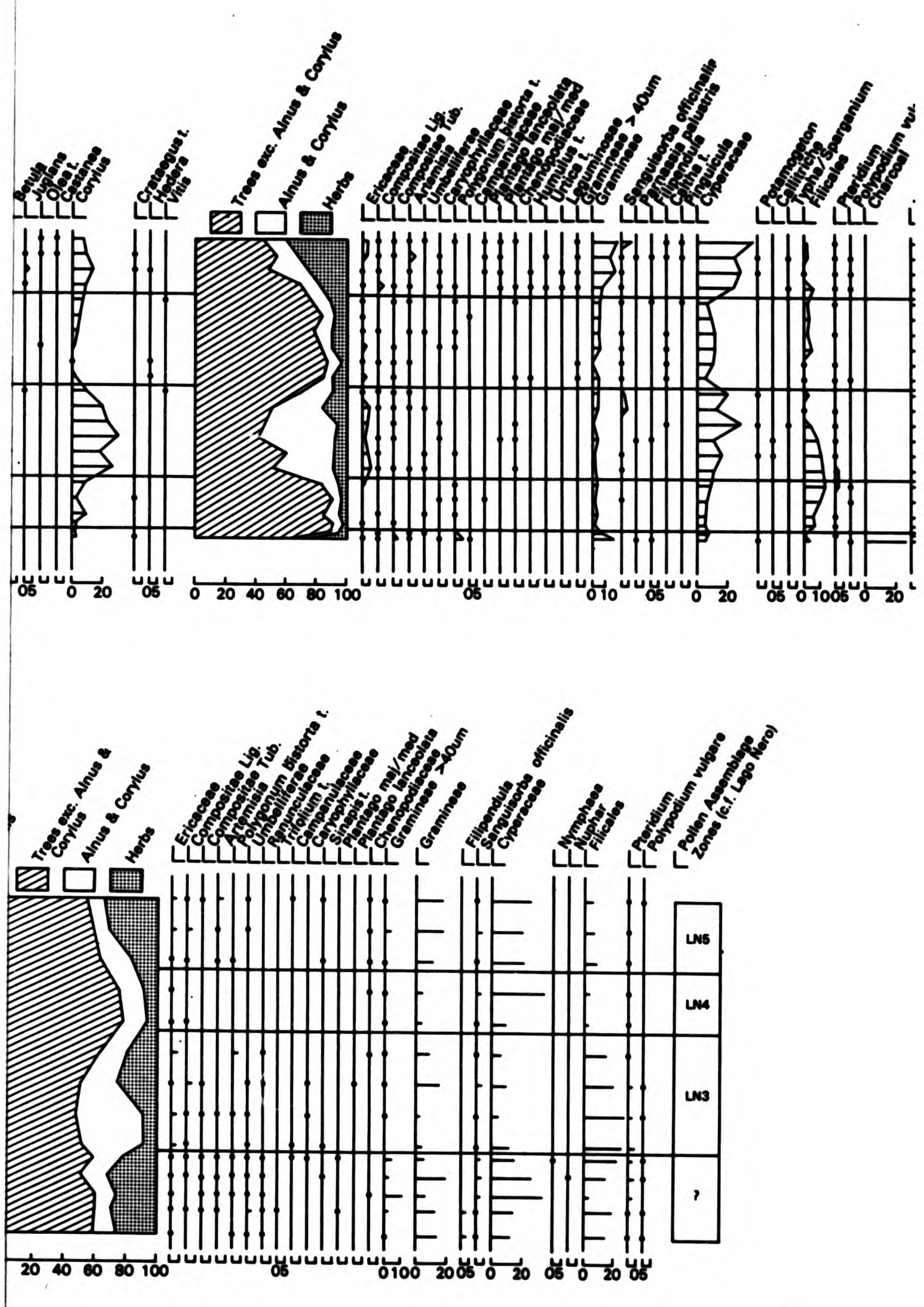
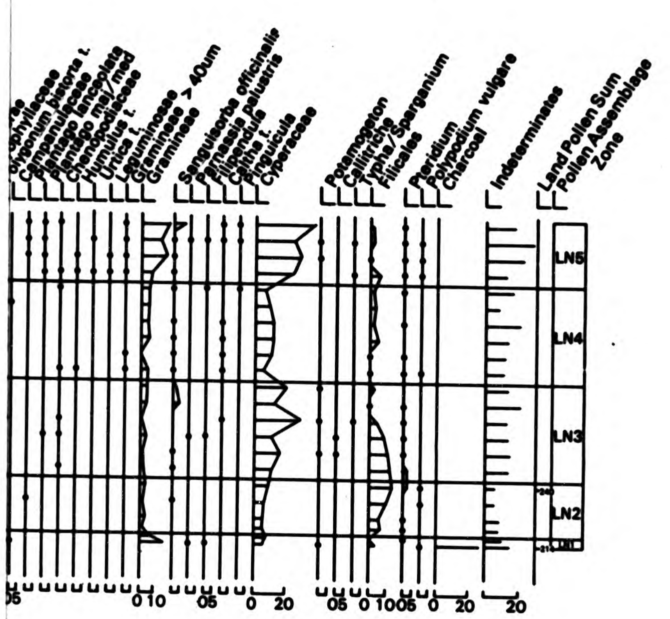
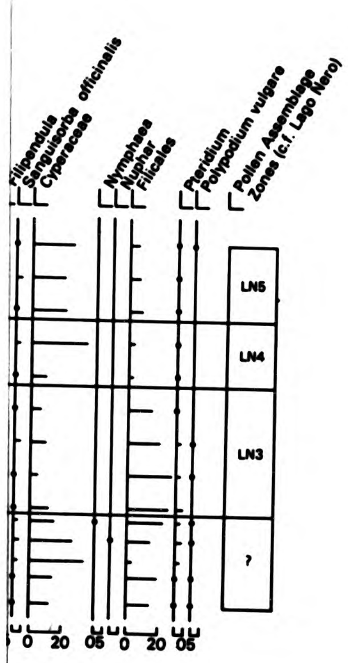


Fig. 22 Lago Nero A-pollen percentages.




Betula
Juglans
Olea t.
Castanea
Corylus
Crataegus t.
Hedera
Vitis
Trees exc. Alnus & Corylus
Alnus & Corylus
Herbs
Ericaceae
Compositae Lig.
Compositae Tub.
Artemisia
Umbelliferae
Caryophyllaceae
Polygonum bistorta t.
Campanulaceae
Plantago lanceolata
Plantago maj/med
Chenopodiaceae
Humulus t.
Urtica t.
Leguminosae
Gramineae > 40um
Gramineae
Sanguisorba officinalis
Parnassia palustris
Filipendula
Caltha t.
Pinguicula
Cyperaceae
Potamogeton
Callitriche
Typha/Sparganium
Filicales
Pteridium
Polypodium vulgare
Charcoal
Trees exc. Alnus & Corylus
Alnus & Corylus
Herbs
Ericaceae
Compositae Lig.
Compositae Tub.
Artemisia
Polygonum bistorta t.
Umbelliferae
Ranunculaceae
Trifolium t.
Campanulaceae
Caryophyllaceae
Sinapis t.
Plantago maj/med
Plantago lanceolata
Chenopodiaceae
Gramineae >40um
Gramineae
Filipendula
Sanguisorba officinalis
Cyperaceae
Nymphaea
Nuphar
Filicales
Pteridium
Polypodium vulgare
Pollen Assemblage Zones (c.f. Lago Nero)
LN5
LN4
LN3
?
0 20 40 60 80 100
20 40 60 80 100


Graminae > 40um
Gramineae
Sanguisorba officinalis
Parnassia palustris
Cyperaceae
Potamogeton
Callitriche
Typha/Sparganium
Filicales
Pteridium
Polypodium vulgare
Charcoal
Indeterminates
Land Pollen Sum
Pollen Assemblage Zone
LN5
LN4
LN3
LN2
LN1

Filipendula
Sanguisorba officinalis
Cyperaceae
Nymphaea
Nuphar
Filicales
Pteridium
Polypodium vulgare
Pollen Assemblage Zones (c.f. Lago Nero)
LN5
LN4
LN3
?

and Cyperaceae average 20% TLP in the uppermost horizon. Low frequencies of aquatic taxa also occur in this zone. Filicales spores decline to insignificant values by the upper zone boundary and Pteridium is also insignificant.

LN4: Abies-Fagus-Quercus PAZ (depth 47 to 22 cm, 6 spectra).

The lower zone boundary is drawn where the Abies curve rises. It then fluctuates between 30% and 60% TLP. Fagus percentages are typically over 13% TLP and Quercus averages 10% TLP in the first half of the zone but frequencies decline towards the upper zone boundary. Ulmus, Alnus and Corylus values are insignificant and Cyperaceae fall to average 10% TLP.

LN5: Fagus-Gramineae PAZ (depth 17 to 2 cm, 4 spectra).

The major characteristic of this zone is a steady rise in NAP frequencies from 14% TLP to 40% TLP and a decline in Abies values to 5% TLP by the uppermost level. Gramineae is the best represented of the herbaceous taxa rising to 18% TLP and low frequencies of Plantago species appear in contiguous samples. Fagus averages 18% TLP and Pinus frequencies rise to 18% TLP in the uppermost sample although Quercus is infrequent. Juglans, Olea and Castanea are present together in this zone. Cyperaceae are more abundant reaching over 20% TLP in most spectra.

Pollen Concentrations (Figure 23)

Pollen concentration zone 1: (depths 100 to 82 cm).

Concentrations of all pollen and spores recorded rise from low values in the basal sample (23K grains/cm³) to high frequencies of at least 140K grains/cm² and maximum concentrations of above 250K grains/cm² in two levels. The major contributor to the pollen influx is Abies with at least 60K grains/cm² being characteristic of all but the two basal spectra. Corylus and Cyperaceae are well represented but never exceed 10K and 20K grains/cm² respectively.

Pollen concentration zone 2: (depths 77 to 37 cm).

Total concentrations fall dramatically to 13K grains/cm² and thereafter average 63K grains/cm². Abies concentrations fall to below 10k grains/cm² although values rise towards the upper zone boundary. Corylus frequencies remain unchanged and Alnus concentrations increase slightly but are never above 6K grains/cm². The Cyperaceae curve fluctuates with slightly increased concentrations in the middle of the zone.

Pollen concentration zone 3: (depths 32 to 12 cm).

This zone is characterised by a general rise in concentrations reaching a maximum value of over 700K grains/cm² at depth 12 cm. Abies concentrations rise to over 170K grains/cm² in samples from 27 cm and 22 cm but thereafter decline to below 40K grains/cm² by the upper zone boundary.

Pollen concentration zone 4: (depths 7 to 2 cm).

Concentrations of all pollen and spores fall to below 100K grains/cm² in the uppermost sample. All of the major taxa follow the major trend.

Pollen preservation (Figure 24).

Overall pollen preservation is poor throughout the

Fig. 23 Lago Nero-pollen concentrations.

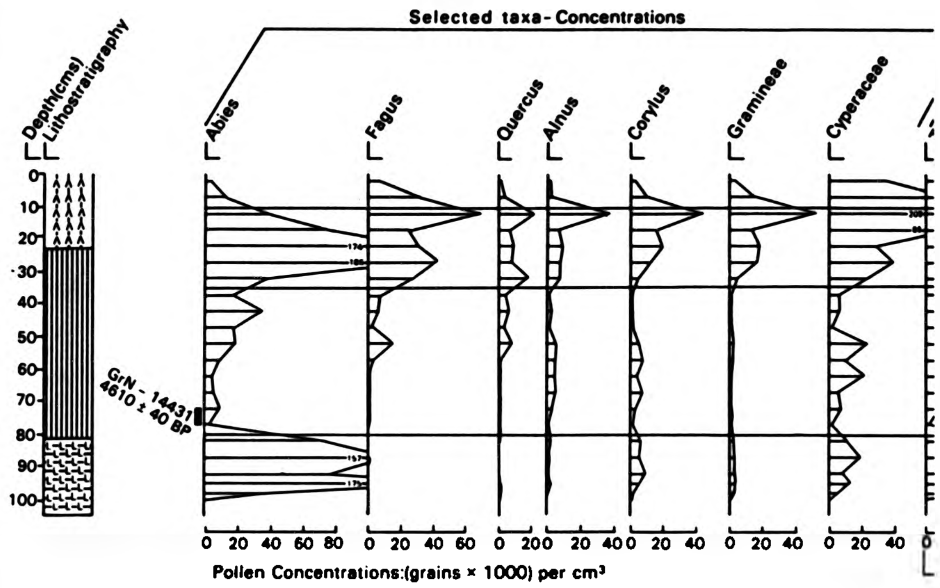
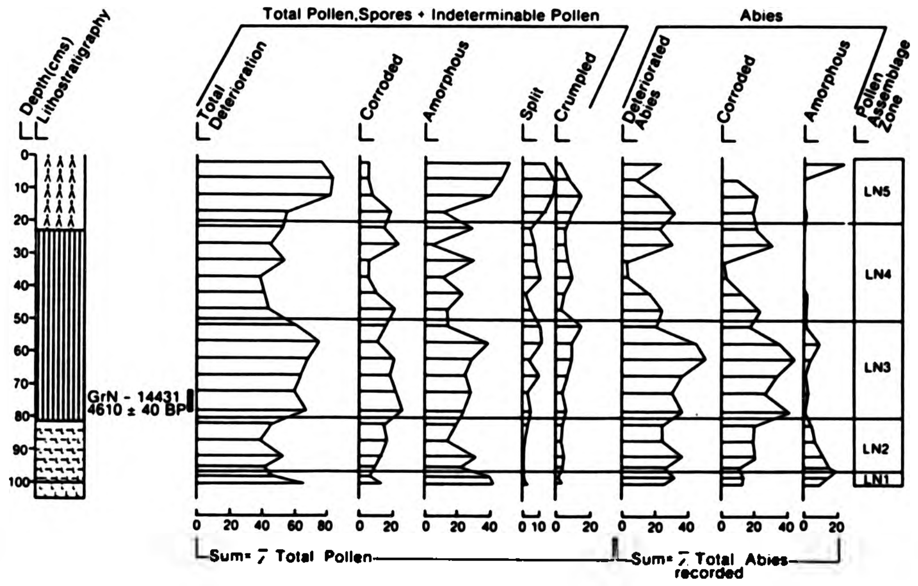
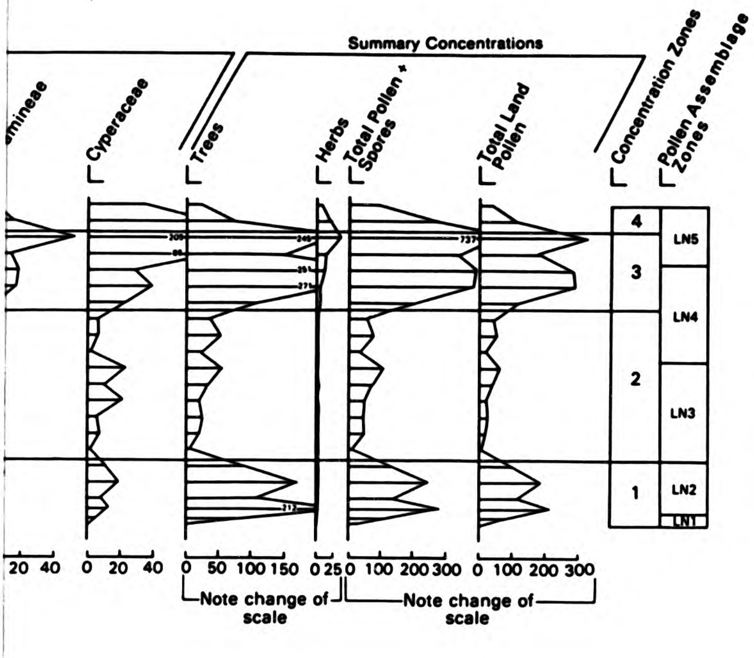
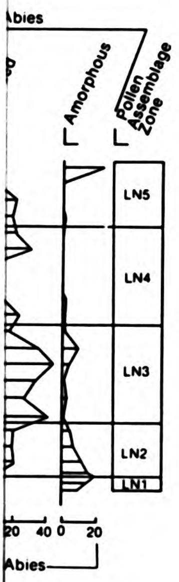


Fig. 24 Lago Nero-pollen preservation.




Summary Concentrations
amineae
Cyperaceae
Trees
Herbs
Total Pollen + Spores
Total Land Pollen
Concentration Zones
Pollen Assemblage Zones
4
3
2
1
LN5
LN4
LN3
LN2
LN1
20 40
0 20 40
0 50 100 150
0 25
0 100 200 300
0 100 200 300
Note change of scale
Note change of scale


Abies
Amorphous
Pollen Assemblage Zone
LN5
LN4
LN3
LN2
LN1
20 40
0 20
Abies

stratigraphical sequence and there are few consistant trends in the preservation data. Total deterioration frequencies are at least 40% of all pollen and spores recorded. Likewise Abies grains were in a highly deteriorated condition but with the exception of PAZ LN4 where preservation of this taxon generally improves during the first half of the zone.

Charcoal Analysis

Low frequencies of charcoal were observed in the pollen preparations from several levels but charcoal was abundant only in the basal sample where a count of 27% TLP was recorded.

Micromorphology

Micromorphological analysis of the basal peat at depth 100 cm and the underlying mineral sediments were undertaken by R.I.Macphail (Appendix C). It is shown that peat initiation at this site had been preceded by the inwashing of silt, soil fragments and charcoal onto an underlying freely-draining serpentinite substrate.

Radiocarbon dates

A pit was excavated approximately 2 m to the north-east of the original sampling position, and a large peat monolith was removed in order to provide sufficient material for radiocarbon dating. Skeleton pollen counts showed that the pollen spectra of the basal sediments differed significantly from the original pollen diagram. In order to resolve these differences skeleton pollen counts were increased to 300 TLP and additional samples from the remainder of the stratigraphical sequence were also counted. These results (named Lago Nero A) are shown in Figure 22 with a correlation where possible with the Lago Nero diagram. Upwards from depth 90 cm the sequence corresponds to PAZ's LN3, LN4 and LN5 but the basal spectra cannot be correlated due to significant variations in the curves of the principal taxa. *Quercus*, *Fagus*, *Alnus*, *Betula*, Gramineae and Cyperaceae frequencies are notably higher in the basal sediments of Lago Nero A whereas *Abies* and *Pinus* values are significantly lower.

In order to obtain an estimate of the date of peat inception at this site a 5 cm slice of peat was removed from the basal peat of Lago Nero A. A second sample with which to date the beginning of the rise in the *Corylus* and *Alnus* curves was also extracted. These produced results of 4855 ± 40 BP (GrN-14430) and 4610 ± 40 BP (GrN-14431) respectively.

CHAPTER 8: THE SITES CASANOVA AND BARGONE

8.1 Casanova (Lat.44°33'N Long.9°24'E)

This site occupies an infilled, nearly circular basin located on a spur on the west-north-west slope of Rocca Bruna (1448 m), approximately 2 km east of Fontanigorda at an altitude of 1056 m (Figure 25). The Carta Geologica d'Italia (Sheet No.83) indicates a widespread presence of glacial drift but more typical of the area are steep, eroded rocky surfaces with little soil cover, and any drift deposits are probably very localised (see below).

Flint scatters ranging in age from Middle Palaeolithic to early Neolithic occur in the area at Pian Brogione and Passo di Esola. At Pian Brogione the concentration of Middle Palaeolithic, Mesolithic and Neolithic flints within the present-day surface soil is probably a result of a combination of soil erosion and biological activity (R.I.Macphail,pers.comm).

The mire surface is approximately 75 m diameter (Figure 26) with a steep, vegetated debris-mantled slope to the east, probably derived from landslide activity. The north-western edge of the site is bounded by a low ridge which appears to be an arcuate moraine. A small spring emerges from beneath the landslide debris in the north-east corner and flows across the mire surface in a diffuse fashion while a stream exits towards the west.

Fig. 25 Location of Casanova peat site.

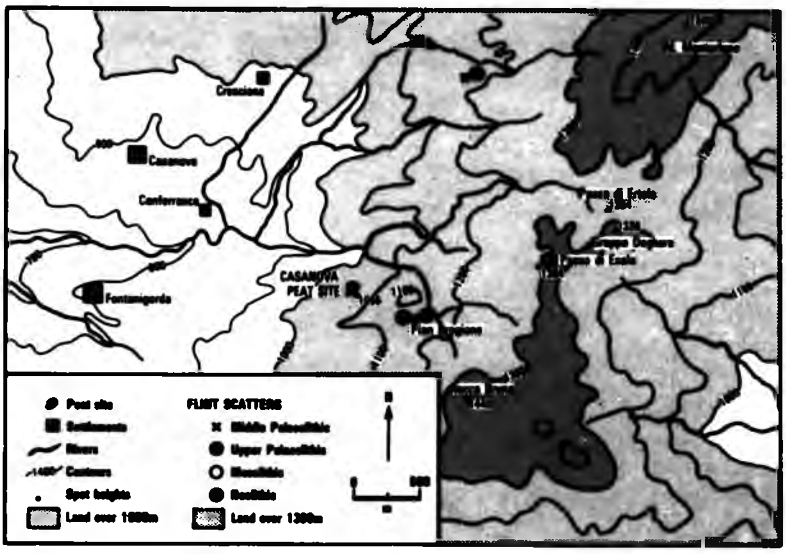
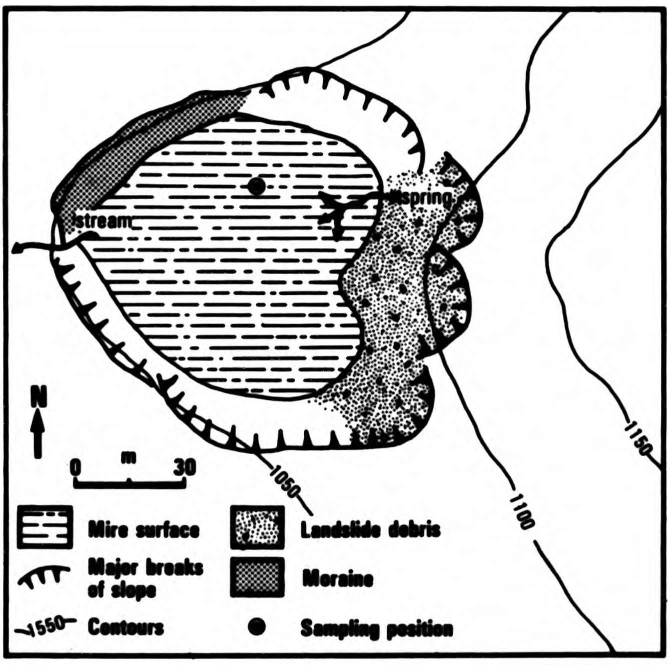


Fig. 26 Casanova peat site.



Vegetation

The vegetation of the bog can be divided into two well-demarcated zones: (1) an outer fringe of Carex spp., Eriophorum spp., and Menyanthes trifoliata. and (2) a central zone of Phragmites communis. Occasional Alnus viridis and A.incana bushes are currently colonizing the mire surface. The steep rocky slopes immediately surrounding the site are covered by heath and grassland communities of Nardus stricta, Calluna vulgaris, Vaccinium myrtilis and V.vitis-idaea with scattered Populus tremula trees and Castanea sativa bushes. Alnus viridis and A.incana commonly grow along stream edges and are also colonizing some of the heathland communities. Patches of Fagus sylvatica woodland occur in the vicinity but woodland is no more than 10% of the land surface and a closed Fagus canopy only occurs in this area from an altitude of at least 1200 m. The vegetation is regularly burned by local farmers and burned bushes of Juniperus communis are common with dry heath and grassland of which Erica herbacea, Thymus spp., Helichrysum stoechas and Ornithogalum spp. are major constituents. Below an altitude of about 900 m much of the land is cultivated with orchards and pastures interspersed with Castanea sativa woodland with occasional Quercus pubescens and Fagus sylvatica.

Lithostratigraphy

A transect of boreholes across the site revealed that the thickest sequence of deposits was located towards the northern part of the basin and the sediments were sampled at this point (Figure 26).

Depth in cm

0 - 18	Poorly compacted root layer near surface; not sampled.
18 - 83	Dark greyish-brown (2.5YR4/2) changing to very dark greyish-brown (2.5YR3/2) at 49 cm, coarse monocotyledonous peat.
83 - 228	Black (10YR2/1) wood peat; wood fragments of 2 cm to 10 cm becoming coarser with depth; unable to sample for pollen between 212 cm and 229 cm; some coarse monocotyledonous peat 100 cm to 165 cm.
228 - 330	Black, monocotyledonous peat.
330 - 341	Black, wood peat (wood fragments 3 cm).
341 - 409	Black, highly humified, wet peat; no macrofossils.
409 - 445	Black, woody detrital peat; twigs (2 cm).
445 - 473	Black, well-humified amorphous peat.
473 - 485	Dark greyish-brown (2.5YR4/2) organic silt.
485 - 504	Very dark greyish-brown (2.5YR3/2) silty, well-humified amorphous peat.

Bedrock at base.

In addition, fungal acospores (Type 77A or 77B in van Geel, 1978) were observed in the pollen preparations from depths 150 to 180 cm, 212 cm, 240 cm and from 410 to 465 cm.

Pollen Assemblage Zones (Figure 27)

CN-1: Pinus-Abies PAZ (depths 500 to 495 cm, 2 spectra)

Tree pollen percentages are high in the basal PAZ (85%), consisting mainly of *Pinus* (59%) and *Abies* (18%). *Quercus*, *Ulmus*, *Tilia*, *Betula* and *Corylus* are present at low frequencies and *Ephedra fragilis* type is recorded in this zone. Herbs and grasses are poorly represented while Cyperaceae are abundant (18%), but there are no records of any aquatic taxa.

CN-2: Pinus-Abies-NAP PAZ (depths 490 to 475 cm, 4 spectra)

Herbs and grasses account for 50-60% TLP with major increases in *Artemisia* (10%) and *Sanguisorba officinalis* (8%)

frequencies as well as regular occurrences of Helianthemum and Compositae Tubuliflorae. The fall in tree pollen percentages corresponds to a decline in Pinus values to 22% but in contrast, Abies percentages remain stable. Thermophilous tree taxa are still represented at low frequencies and include the first recorded occurrences of Fagus and Acer. Ephedra distachya type and Juniperus appear together in this zone, and Salix is recorded for the first time. Cyperaceae are abundant and Filicales are more frequent by the end of the zone.

CN-3: Pinus-Abies-Alnus PAZ (depths 470 to 440 cm. 6 spectra).

The lower zone boundary is marked by a sharp increase in tree pollen frequencies to above 75% TLP. Pinus percentages increase from 7% to 40% in contiguous levels and drop thereafter, and Alnus averages 10% after an initial peak at the base of the zone. Abies percentages fluctuate at around 20% TLP. Betula and Salix are present at low values and there is a greater diversity of deciduous tree types as well as unbroken curves for Quercus, Fagus and Corylus. Herb pollen values are considerably lower than the previous zone being 10% of land pollen but include a wider range of herbaceous taxa of which the most commonly occurring are Compositae Liguliflorae and Filipendula. Negligeable values of Cyperaceae are recorded but aquatic species appear at low frequencies and Filicales are abundant.

PAZ CN-4: Abies-Alnus-Fagus (depths 430 to 180 cm. 28 spectra).

In this zone Pinus, Betula and Salix fall to insignificant levels, and Abies percentages are generally notably higher. The zone is divided into three subzones on the basis of the variations in the Abies, Alnus, Fagus and Corylus curves.

CN-4-a: Abies-Alnus-Fagus PAZ (depths 430 to 320 cm, 11 spectra).

Tree pollen is dominated by Abies which rises to 40% TLP, falls to 16% in contiguous horizons, then rises again to 50% by the end of the subzone. Alnus and Fagus values fluctuate inversely with those of Abies. Compositae Liguliflorae and Filipendula values fall at the beginning of the subzone although Compositae soon recover and rise to 8% TLP in the uppermost spectra. Initially Cyperaceae are insignificant but become more frequent in later horizons.

CN-4-b: Corylus-Abies-NAP PAZ (depths 320 to 280 cm, 5 spectra).

The principal characteristics of this subzone are a fall in Abies percentages to 11% TLP and a rise in Corylus values to 26% TLP although these subsequently decline. Alnus and Fagus frequencies are low but herbs and grasses are more abundant with notable peaks in the Compositae Liguliflorae and Gramineae curves as well as in Cyperaceae values. Filicales are less frequent although Pteridium reaches 4% TLP for the first time.

CN-4-c: Abies-Alnus-Fagus PAZ (depths 270 to 180 cm, 11 spectra).

Alnus values recover and never fall to below 20% TLP while Abies frequencies fluctuate between 11% and 44% and decline towards the end of the subzone. Fagus averages about 6% TLP but declines in the upper levels. Corylus is insignificant and herb values fall to below 10% TLP although they rise in later spectra. Filipendula is once more abundant and a wide range of herbaceous taxa are present at low frequencies. Cyperaceae are no longer common but Filicales become very abundant although less frequent in the middle of the subzone.

PAZ CN-5: Fagus-Alnus-NAP PAZ (depths 170 to 20 cm. 15 spectra).

The lower zone boundary is drawn where Abies percentages fall to below 10% TLP. The zone is subdivided into three subzones on the basis of variations in the Alnus, Fagus and herb pollen frequencies.

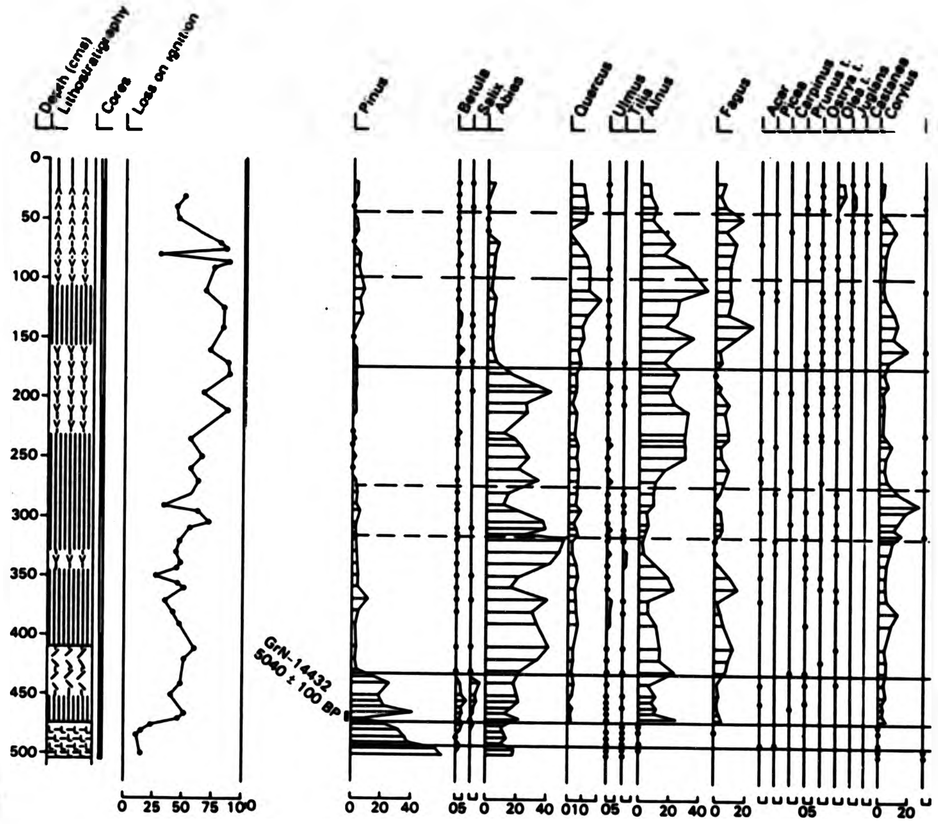
CN-5-a: Fagus-Alnus PAZ (depths 170 to 110 cm. 7 spectra).

Abies percentages are insignificant but Alnus remains at high levels reaching 44% TLP by the end of the subzone. Fagus frequencies rise to a peak of 24% and thereafter average 10% TLP. Quercus and Pinus values rise slightly and the first record of Juglans occurs in this subzone. Corylus, herbs and Gramineae generally fall from initially high levels. The Cyperaceae and Filicales curves fluctuate erratically but inversely with each other.

CN5-b: Fagus-NAP PAZ (depths 90 to 50 cm. 5 spectra).

In this subzone tree pollen falls from 80% to 42% of land pollen, much of the decline occurring in the Alnus curve which falls to 8% TLP. Conversely Fagus values remain unchanged and the first records of Castanea occur at the end of the subzone. Herb values climb to 30% TLP represented initially by a jump in the Compositae Liguliflorae curve followed by rises in Ericaceae and Gramineae frequencies. Cyperaceae and Filicales curves continue to fluctuate and Typha latifolia is present for the first time.

Fig. 27 Casanova-pollen percentages.



Ostrya t.
Olea t.
Juglans
Castanea
Corylus
Ephedra t. fragilis
Ephedra t. distachya
Juniperus
Crataegus t.
Vitis
Herbs
Trees
Alnus
Gramineae
Ericaceae
Artemisia
Compositae Tub.
Compositae Lig.
Chenopodiaceae
Caryophyllaceae
Helianthemum
Primula t.
Galium t. vulgaris
Stachys t.
Umbelliferae
Liliaceae Anthericum t.
Medicago t. sativa
Sinapis t.
Melampyrum
Rhinanthus t.
Humulus t.
Rumex t. acetosella
Plantago t. holosteum
Plantago lanceolata
Plantago maj/med
Sanguisorba officinalis
Filipendula
Parnassia palustris
Caltha t.
Potentilla t.
Gramineae >40um
Gramineae
Cyperaceae
0 20
05
0 25 50 75 100
0 10
0 5
0 10
05
0 10
05
0 10
0 10

Melampyrum
Rhinanthus t.
Humulus t.
Rumex t. acetosella
Plantago t. holosteum
Plantago lanceolata
Plantago maj/med
Sanguisorba officinalis
Filipendula
Parnassia palustris
Caltha t.
Potentilla t.
Gramineae >40um
Gramineae
Cyperaceae
Potamogeton
Nuphar
Nymphaea
Menyanthes
Typha latifolia
Filicales
Pteridium
Charcoal
Indeterminable pollen
Pollen Assemblage Zone
CN5-c
CN5-b
CN5-a
CN4-c
CN4-b
CN4-a
CN3
CN2
CN1

CN-5-c: NAP PAZ (depths 40 to 20 cm, 3 spectra).

There is a notable rise in frequencies of *Olea* type, *Juniperus* and certain herbaceous taxa, notably *Plantago holosteum* type, *Plantago lanceolata* and Gramineae. *Alnus* and *Fagus* are infrequent. Cyperaceae are very abundant but Filicales are uncommon.

Pollen concentrations (Figure 28).

Pollen concentration zone 1: (depths 500 to 475 cm)

Concentrations of all pollen and spores are typically above 140K grains/cm³ with the exception of one level at 480 cm. However arboreal pollen concentrations fall from above 84K grains/cm³ to 40K grains/cm³ by the upper zone boundary whereas herbaceous pollen types rise to over 40K grains/cm³. Cyperaceae values follow the main trend in herb concentrations and the Filicales curve rises towards the end of the zone.

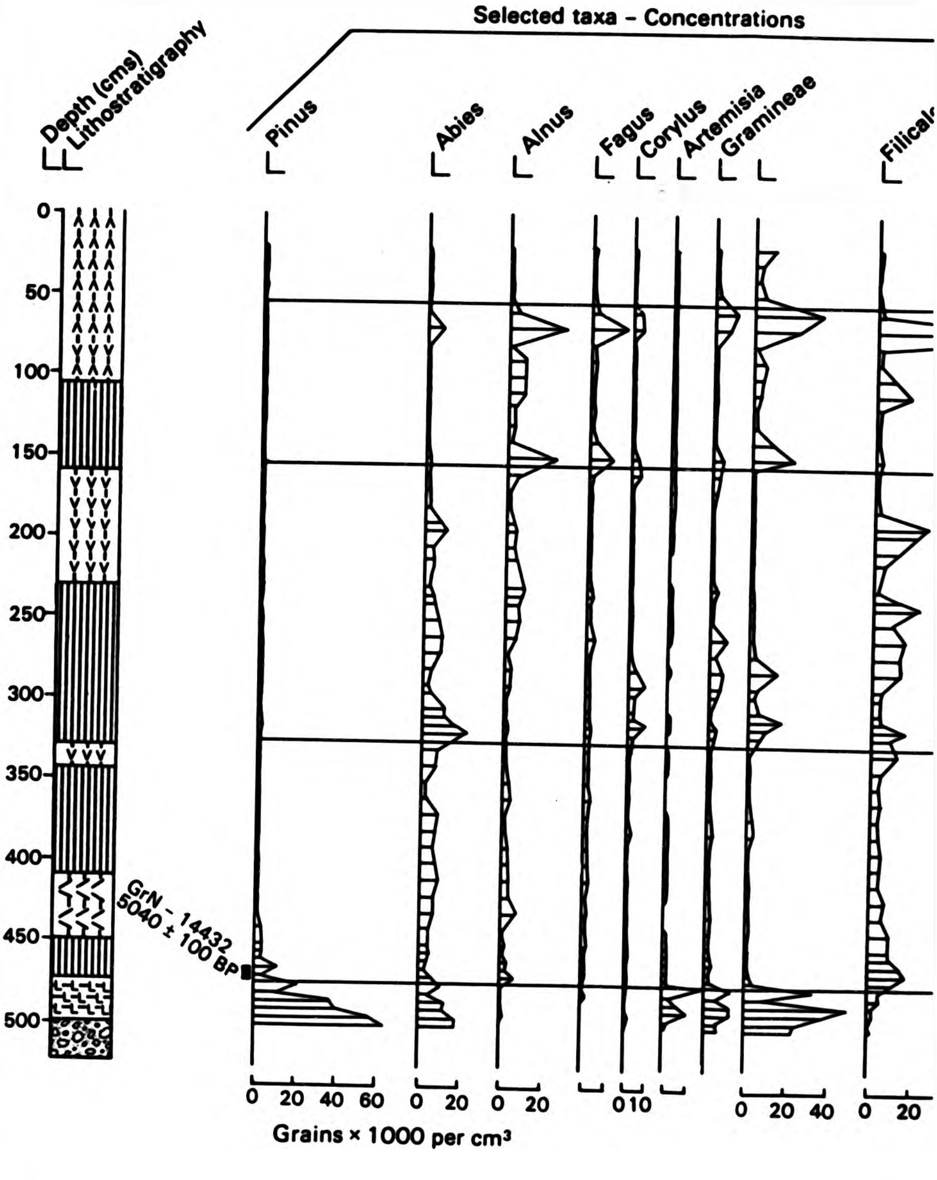
Pollen concentration zone 2: (depths 470 to 330 cm)

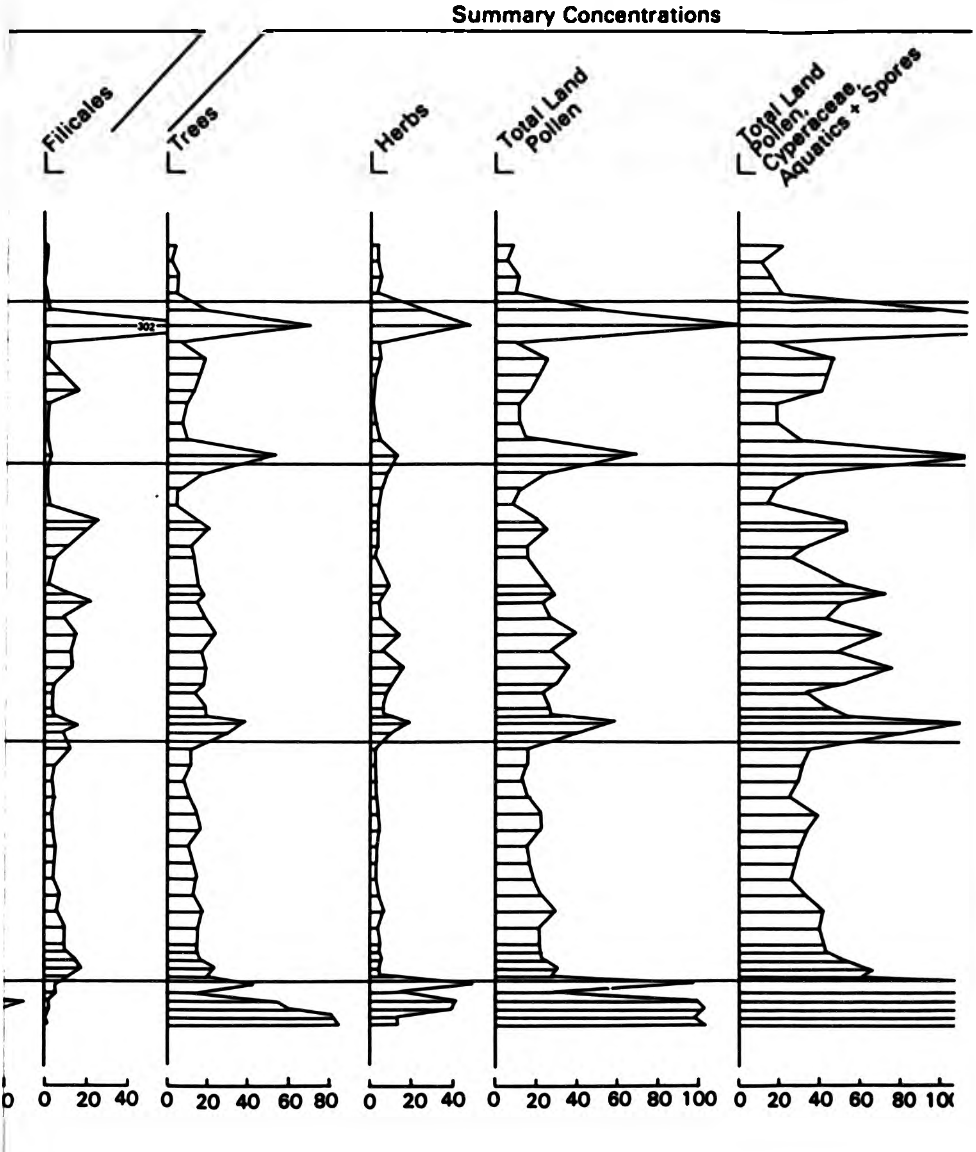
Concentrations are considerably lower than the previous zone with total pollen and spores falling from 68K grains/cm³ to below 30K grains/cm³.

Pollen concentration zone 3: (depth 320 to 160 cm)

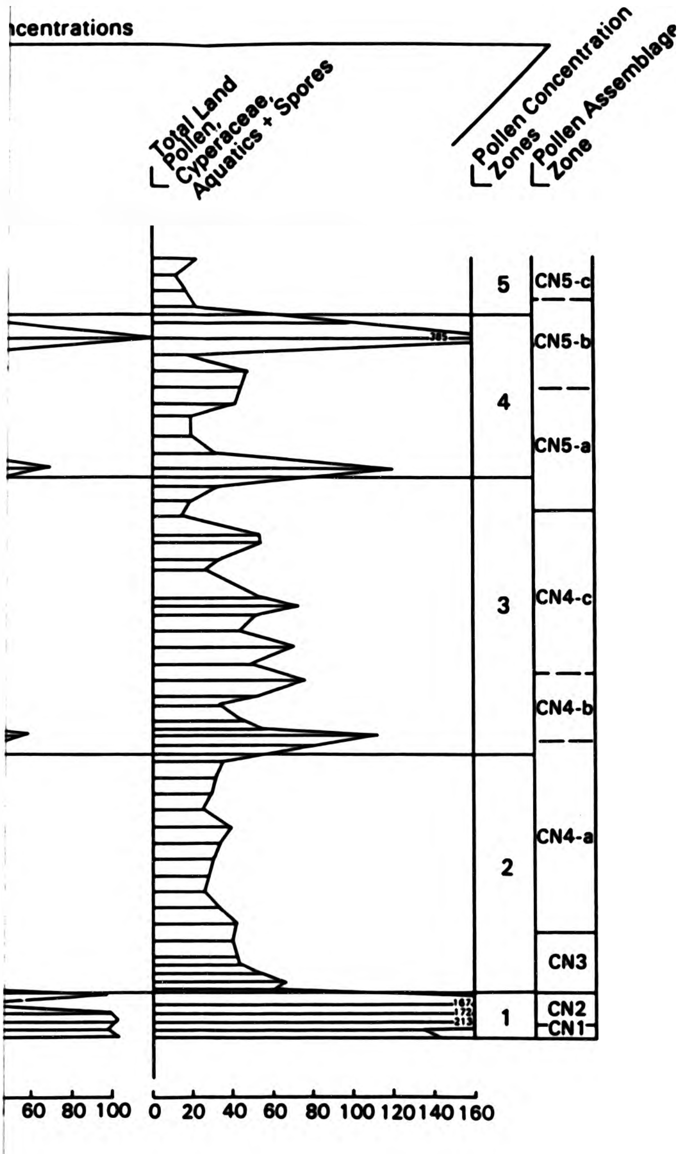
Concentrations of all pollen and spores are variable but there is an overall decline from initially high values of 78K grains/cm³ to below 20K grains/cm³ in uppermost spectra. *Alnus* and Filicales spores are the only major taxa to increase their concentrations in higher levels.

Fig. 28 Casanova-pollen concentrations.





Summary Concentrations
Filicales
Trees
Herbs
Total Land Pollen
Total Land Pollen, Cyperaceae, Aquatics + Spores
302
0 20 40
0 20 40 60 80
0 20 40
0 20 40 60 80 100
0 20 40 60 80 100


ncentrations
Total Land Pollen, Cyperaceae, Aquatics + Spores
Pollen Concentration Zones
Pollen Assemblage Zone
5
4
3
2
1
CN5-c
CN5-b
CN5-a
CN4-c
CN4-b
CN4-a
CN3
CN2
CN1
60 80 100
0 20 40 60 80 100 120 140 160

Pollen concentration zone 4: (depths 150 to 60 cm)

This zone is characterised by highly variable concentrations with total pollen and spores fluctuating between 385K grains/cm^3 and 16K grains/cm^3 in contiguous spectra. *Abies* frequencies are insignificant and is the only major taxa which fails to follow the overall fluctuations.

Pollen concentration zone 5: (depths 50 to 20 cm)

Concentrations are low with average values of 16K grains/cm^3 for all pollen and spores recorded.

Pollen preservation (Figure 29).

Pollen preservation is generally poor throughout the sediments with 60% deterioration of all pollen, spores and indeterminable pollen recorded being typical of most counts. Four pollen preservation zones are identified on the basis of variations in the amorphous curve.

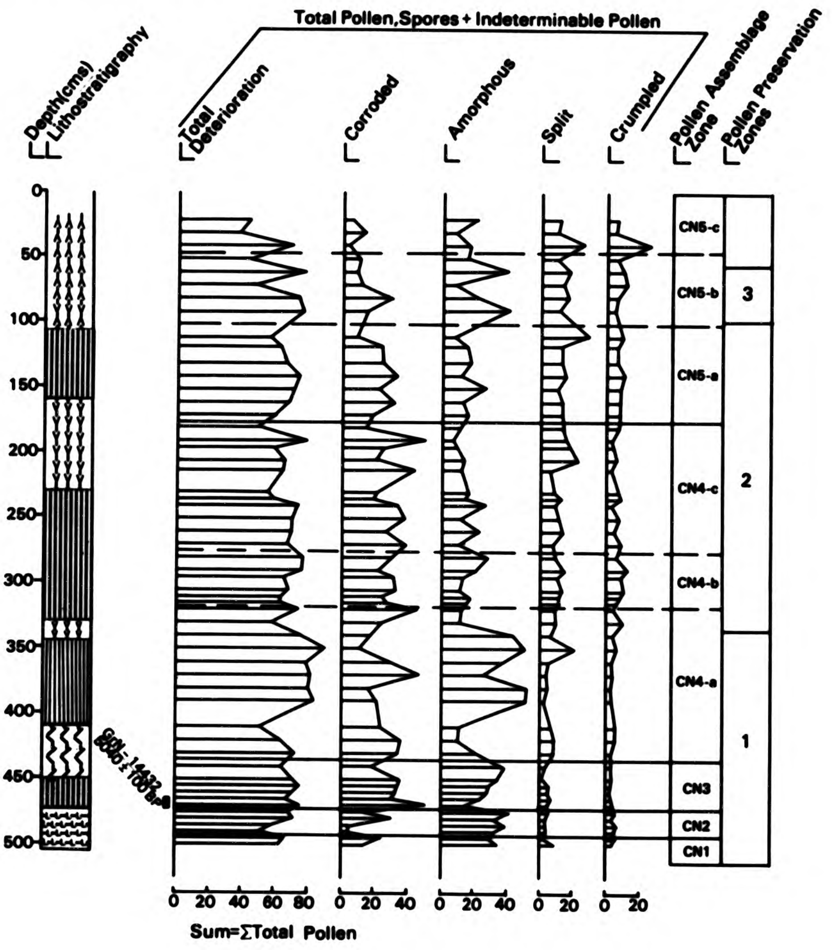
Pollen preservation zone 1: (depths 500 to 340 cm)

Amorphous frequencies are typically over 30% of all pollen and spores recorded with the exception of samples at depths 470 cm and 430 to 410 cm. Corroded values fluctuate but frequencies of above 20% are characteristic of most levels.

Pollen preservation zone 2: (depths 330 to 110 cm)

Corroded frequencies remain unchanged in this zone but amorphous grains are less abundant with values of below 20% being typical of most samples. Split grains become more frequent in the later half of the zone.

Fig. 29 Casanova-pollen preservation.



Pollen preservation zone 3: (depths 90 to 60 cm)

Amorphous grains are more frequent with maximum values of 40% while corroded grains fall to 10% in most levels.

Pollen preservation zone 4: (depths 50 to 20 cm)

Amorphous frequencies are below 22% of all pollen and spores recorded and corroded grains are below 14%.

Wood Identification

Wood samples were identified where possible by A.Clapham (see Appendix B). Wood from depths 331-338 cm and 216-229 cm were identified as Abies alba type but other samples were badly preserved and it was only possible to establish that they were of coniferous type.

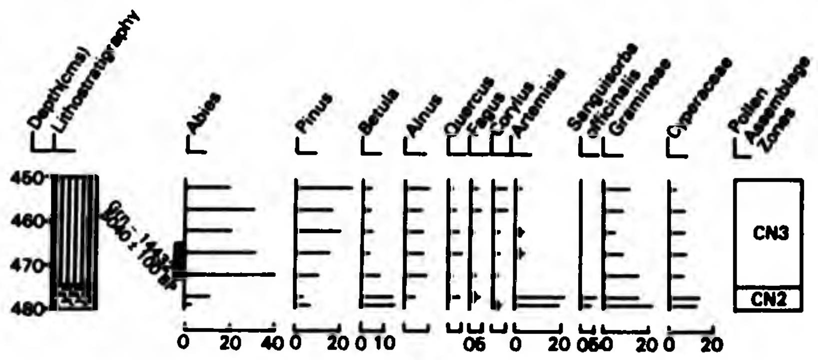
Charcoal Analysis

Low frequencies of charcoal were recorded throughout the sediments but only frequencies of at least 2% TLP are indicated on the pollen diagram (Figure 27). Charcoal is most abundant in PAZ's CN2, CN3 and CN4-a (lithostratigraphic unit 5); charcoal was also recorded in the lowermost horizon of CN4-b, one level in CN4-c and also in CN5-b and CN5-c. Most of the carbonised material recorded consisted of black opaque microspherules with the greatest number in the size range 20-35 microns.

Radiocarbon dating

A single piston core from the basal sediments at the site was collected in order provide an estimate of the date of peat initiation. Skeleton pollen counts are presented in Figure 30 and were correlated with the principal pollen diagram on the basis of lithostratigraphy and variations in the Abies, Corylus, Artemisia and Sanguisorba officinalis curves.

Fig. 30 Casanova-Skeleton pollen counts.

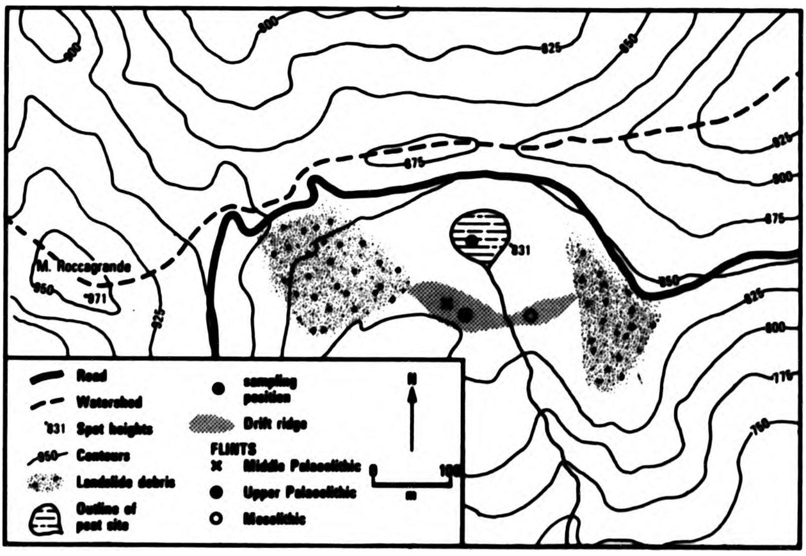


The biostratigraphical correlation suggests that PAZ CN1 and the first half of CN2 are absent from this core. Therefore, an 8 cm slice of sediment was removed from depths 473 cm to 465 cm and a date of 5040 ± 100 BP (GrN-14432) was obtained for the beginning of PAZ CN3.

8.2 Bargone (Lat.44°18'N Long.9°31'E)

This site occupies a south-facing basin (Figure 31) immediately below a ridge between M.Roccagrande (971 m) and M.Alpe (1094 m), located at an altitude of 831 m and approximately 9 km NE of Sestri Levante. The site is a small (75 m diameter) circular basin set against an eroded cliff to the north and enclosed to the south by a low ridge either of weathered bedrock or possibly of drift. Landslide debris mantles the slopes to the west and east of the basin. A pond occurs in the centre of the basin but no stream enters the site and in summer months the water level falls by at least 1 metre. The only outflow is a small ephemeral stream which is dry for much of the year.

Fig. 31 The peat site at Bargone and surrounding area.



Flint scatters of Middle Palaeolithic, Late Palaeolithic and Mesolithic ages have been found on the ridge to the south of the site (R.Maggi, pers.comm.). A large Chalcolithic mine has recently been discovered approximately 4 km to the north-west (R.Maggi, pers.comm.) while Chalcolithic and Bronze Age burials are located approximately 4 km to the south-west of the site (Maggi and Formicola, 1978).

Vegetation

Carex species are dominant in the lowest, wettest situations on the mire surface and these are separated by tall, grassy hummocks carrying Gramineae, *Juncus effusus*, *Calluna vulgaris* and *Sanguisorba officinalis*. *Buxus sempervirens* is frequent on the slopes immediately surrounding the site growing with *Juniperus communis*, *Erica arborea* and *Pteridium aquilinum*. More typically the vegetation of the area is dry grass and heathland communities with *Calluna vulgaris*, *Erica herbacea* and *Bromus erectus* as dominants with a rich diversity of herbs including *Thymus vulgaris*, *Helychrysum stoechas* and *Dianthus* spp. Bare soil and exposed rock surfaces are characteristic of the area. Woodland is only found below an altitude of 700 m where *Castanea sativa*, *Quercus pubescens* and *Quercus ilex* are widespread.

Lithostratigraphy

A transect of boreholes across the site demonstrated that the deepest sediments were located in the central portion of the site where up to 380 cm of peat had accumulated.

Depth in cm

0-45	Undecomposed surface root layer; not sampled.
45-381	Black (5YR 2.5/1) changing to very dark, greyish brown (10YR 3/2) at 238 cm; well-humified monocotyledonous peat with fine roots and bark fragments (1 cm); occasional small stones between 136 cm and 255 cm.
below 381	Bedrock

The sediments were sampled initially with a 1 m long "Dutch" gouge and subsequently the basal succession between 300 cm and 380 cm was sampled with a piston corer. The pollen-stratigraphical sequence described here is a composite figure based upon pollen spectra derived from both sets of data.

Pollen Assemblage Zones (Figure 32)

Bg1: Abies-Gramineae PAZ (depths 380 to 308 cm. 20 spectra).

The basal pollen assemblage zone is dominated by high percentages of Gramineae which are typically over 40% TLP. *Abies* frequencies average 26% TLP although the curve fluctuates erratically between 53% and 17% TLP. The *Pinus* curve declines from initially modest values to below 10% TLP by the upper zone boundary while combined *Quercus* frequencies only attain maximum values of 15% TLP and are more typically below 10% TLP. *Quercus robur* pollen type is the most commonly occuring of the oaks although both *Q. cerris* and *Q.ilex* types (Appendix A) are present throughout the zone. Herbs are generally not abundant, Cyperaceae values average 16% TLP and spores are infrequent. The upper zone boundary is placed where Abies frequencies fall and there is a corresponding rise in the curves of other woody taxa.

Bg2: Quercus-Fagus PAZ (depths 304 to 70 cm, 28 spectra).

Abies frequencies decline dramatically being typically below 10% TLP whereas combined Quercus values now average 28% TLP, and Fagus and Alnus are more abundant. This zone has been subdivided into three subzones on the basis of variations in the Quercus curves.

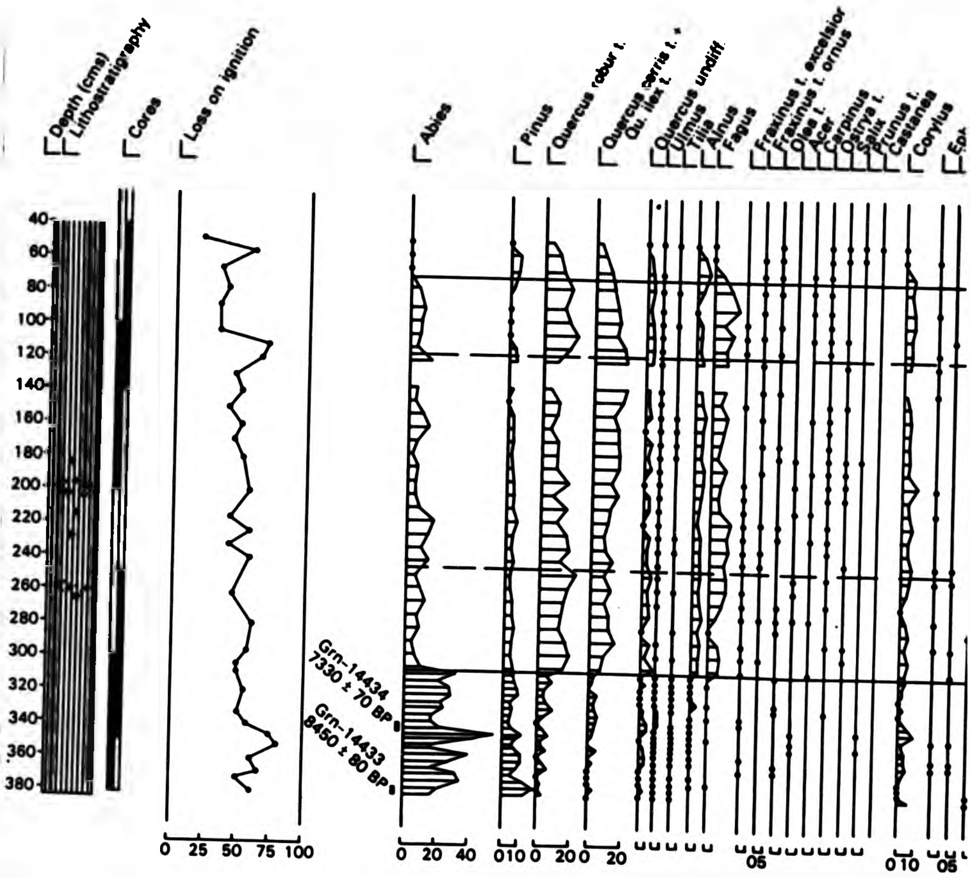
Bg2-a: Quercus(types robur, cerris/ilex)-Fagus PAZ (depths 304 to 248 cm, 8 spectra)

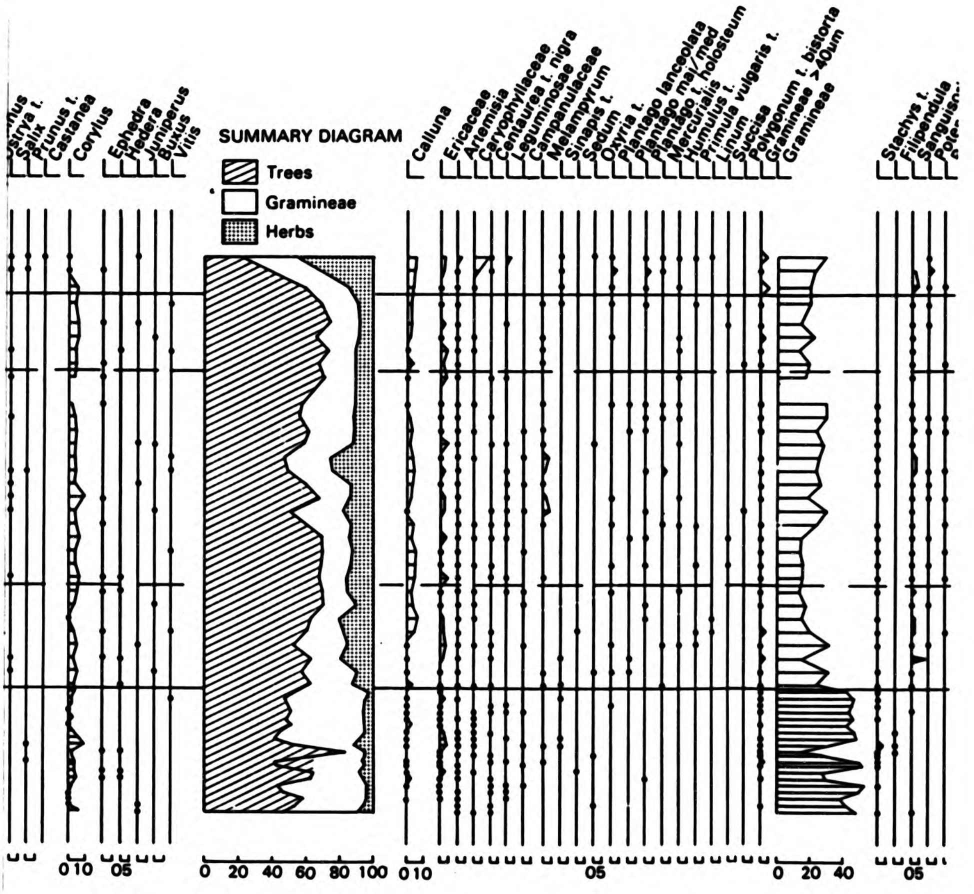
Quercus robur type is the best represented of the oaks, with average values of 15% TLP as compared to average frequencies of 8% TLP for the other differentiated Quercus pollen types. Fagus values are typically 8% TLP with the exception of one anomalous level. Gramineae frequencies are noticeably lower falling from 30% to 14% TLP by the upper zone boundary whereas Cyperaceae are typically over 35% TLP. Herbs (excluding grasses) and Ericaceae values rise to 20% TLP and Calluna in particular, reach significant levels in the latter half of the subzone.

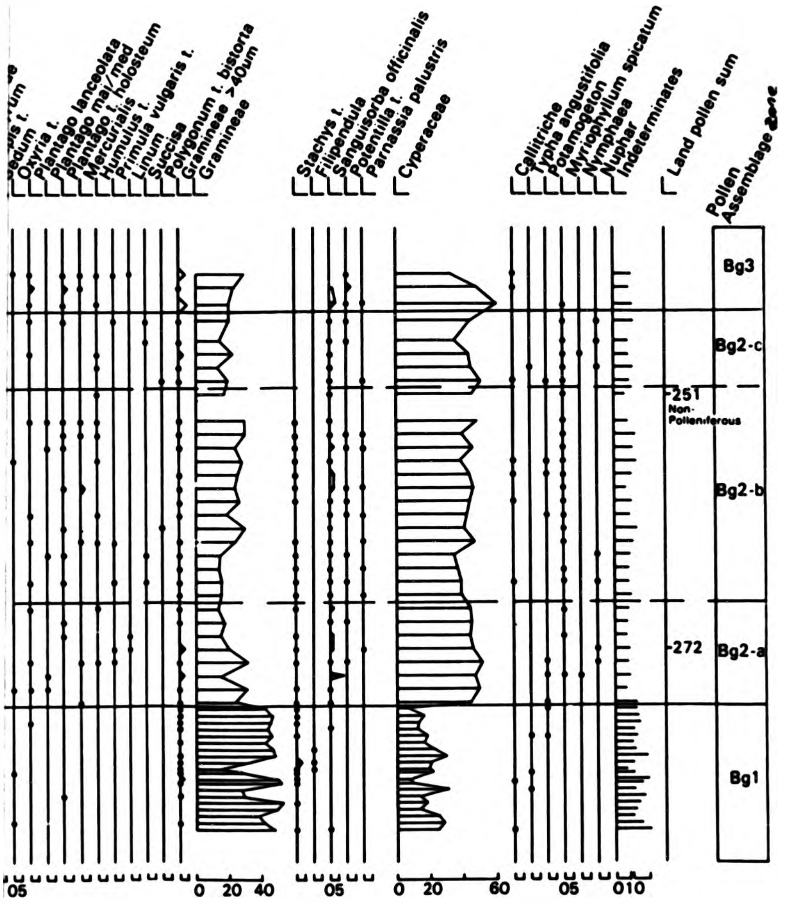
Bg2-b: Quercus(types cerris/ilex, robur)-Fagus PAZ (depths 240 to 120 cm, 15 spectra)

The Quercus robur t. curve declines to below 10% TLP in upper spectra, a trend which is followed by Fagus. Conversely Quercus cerris/ilex pollen types rise to attain combined maximum values of 20% TLP by the upper subzone boundary. Corylus and Alnus frequencies remain at levels comparable to the previous subzone but Gramineae values rise to above 20%

Fig. 32 Bargone-pollen percentages.




Salix
Prunus t.
Castanea
Corylus
Ephedra
Hedera
Juniperus
Buxus
Vitis
SUMMARY DIAGRAM
Trees
Gramineae
Herbs
Calluna
Ericaceae
Artemisia
Caryophyllaceae
Centaurea t. nigra
Leguminosae
Campanulaceae
Melampyrum
Sinapis t.
Sedum
Oxyria t.
Plantago lanceolata
Plantago maj/med
Plantago t. holosteum
Mercurialis
Humulus t.
Primula vulgaris t.
Linum
Succisa
Polygonum t. bistorta
Gramineae >40um
Gramineae
Stachys t.
Filipendula
0 10
05
0 20 40 60 80 100
0 10
05
0 20 40
05



Sedum
Oxyria t.
Plantago lanceolata
Plantago maj/med
Plantago t. holosteum
Mercurialis
Humulus t.
Primula vulgaris t.
Linum
Succisa
Polygonum t. bistorta
Gramineae >40um
Gramineae
Stachys t.
Filipendula
Sanguisorba officinalis
Potentilla t.
Parnassia palustris
Cyperaceae
Callitriche
Typha angustifolia
Potamogeton
Myriophyllum spicatum
Nymphaea
Nuphar
Indeterminates
Land pollen sum
Pollen Assemblage Zone
Bg3
Bg2-c
Bg2-b
Bg2-a
Bg1
-251
Non-Polleniferous
-272
05
0 20 40
05
0 20 60
05
010

TLP whereas Cyperaceae are unchanged. Herb pollen values rise to a maximum of 26% TLP in the middle of the subzone where Melampyrum is abundant, but herb frequencies decline to 10% TLP in upper spectra.

Bg2-c: Quercus(types robur, cerris/ilex)-Fagus PAZ (depths 112 to 76 cm. 5 spectra)

Combined Quercus cerris t. and Quercus ilex t. frequencies decline to 10% TLP by the upper zone boundary whereas the Quercus robur t. curve rises to vary between 10% and 20% TLP, a trend which is paralleled by Fagus. Gramineae and herb values average 20% TLP and 10% TLP respectively.

Bg3: NAP PAZ (depths 68 to 48 cm. 3 spectra).

Gramineae, herb and Ericaceae frequencies together reach 80% TLP in the uppermost level and the curves of woody taxa correspondingly decline.

Pollen Concentrations (Figure 33)

Three pollen concentration zones have been recognised on the basis of variations in the concentrations of total identified pollen, Cyperaceae, spores and aquatics.

Pollen concentration zone 1: (depths 380 to 308 cm)

Total concentrations fluctuate between 26K grains/cm^3 and 125K grains/cm^3 although frequencies of over 70K grains/cm^3 are characteristic of most levels. The major contributor to the pollen spectra is Gramineae with variable concentrations but which generally exceed 20K grains/cm^3. Abies values vary between 6K grains/cm^3 and 27K grains/cm^3 but Quercus concentrations are low and combined Quercus frequencies never exceed 8k grains/cm³.

Pollen concentration zone 2: (depths 304 to 216 cm)

Concentrations are considerably lower than the preceding zone with below 50K grains/cm³ in most samples. Abies and Gramineae values are insignificant but Quercus concentrations are unchanged from the previous zone and Cyperaceae frequencies average 20k grains/cm³.

Pollen concentration zone 3: (depths 208 to 48 cm)

Pollen concentrations fluctuate between 46K grains/cm³ and 200K grains/cm³ although frequencies of over 75K grains/cm³ are characteristic of most levels with the exception of the sample from depth 128 cm which is non-polliniferous. All of the curves for the major taxa show slightly increased concentrations and Cyperaceae concentrations exceed 40K grains/cm³ in most samples.

Pollen Preservation (Figure 34)

Deterioration frequencies are high throughout the stratigraphical sequence with records of over 50% deteriorated grains being typical of most levels. Two pollen preservation zones have been recognised on the basis of significant changes in the amorphous component.

Pollen preservation zone 1: (depths 380 to 308 cm)

Amorphous frequencies are the highest in the diagram with average values of 38% of all pollen and spores recorded as compared to average corroded frequencies of 21%.

Fig. 33 Bargone-pollen concentrations.

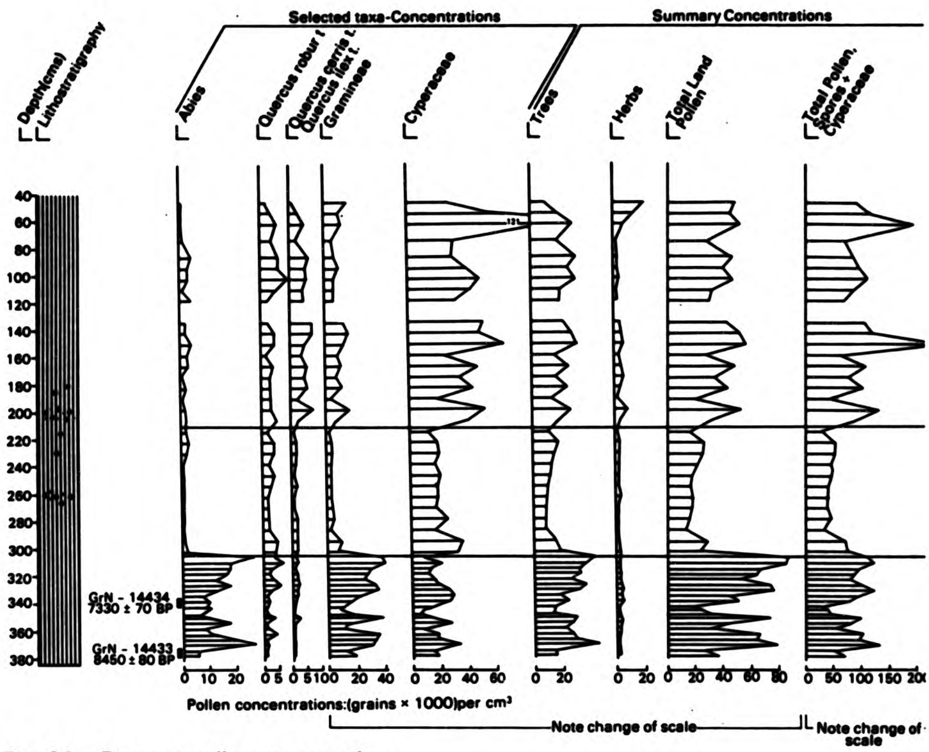
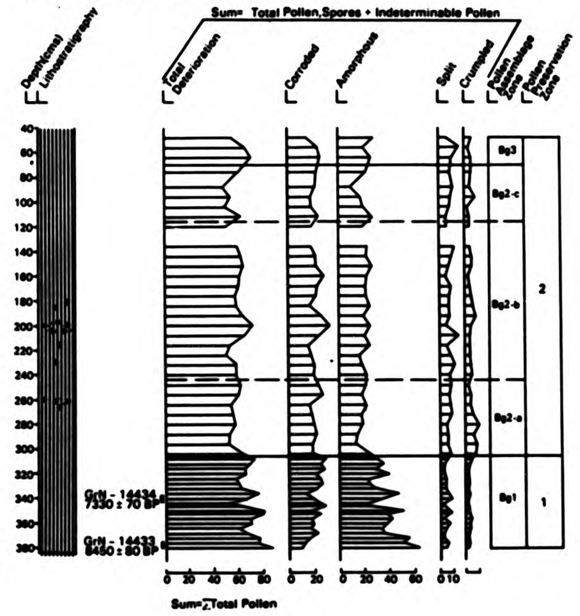
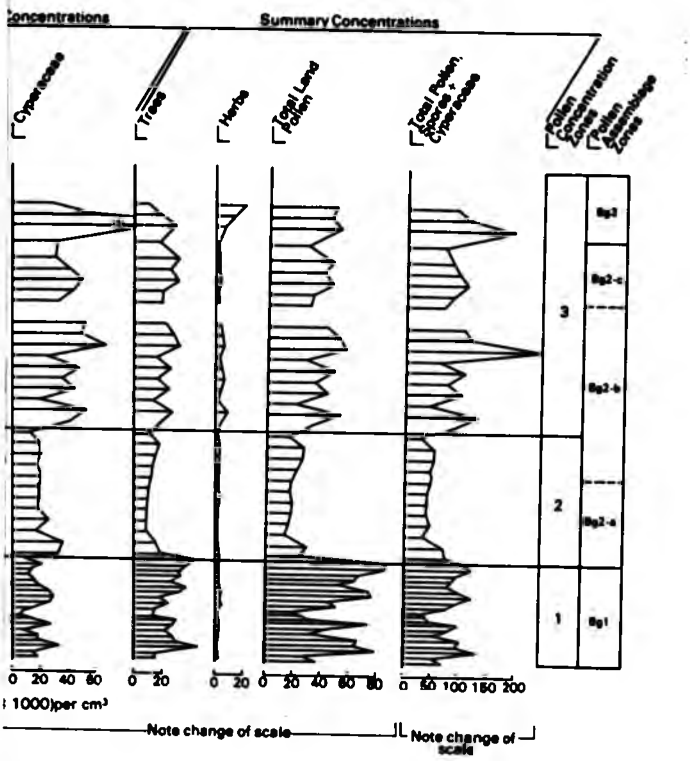
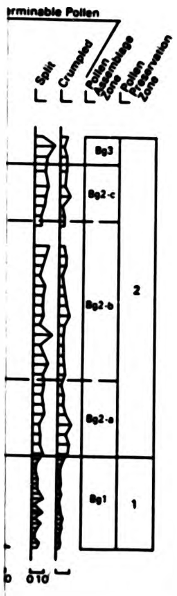


Fig. 34 Bargone-pollen preservation.



B.


Concentrations
Summary Concentrations
Cyperaceae
Trees
Herbs
Total Land Pollen
Total Pollen, Spores + Cyperaceae
Pollen Concentration Zones
Pollen Assemblage Zones
Bg3
Bg2-c
Bg2-b
Bg2-a
Bg1
3
2
1
0 20 40 60
0 20
0 20
0 20 40 60 80
0 50 100 150 200
1000)per cm³
Note change of scale
Note change of scale


rminable Pollen
Split
Crumpled
Pollen Assemblage Zone
Pollen Preservation Zone
Bg3
Bg2-c
Bg2-b
Bg2-a
Bg1
2
1
010

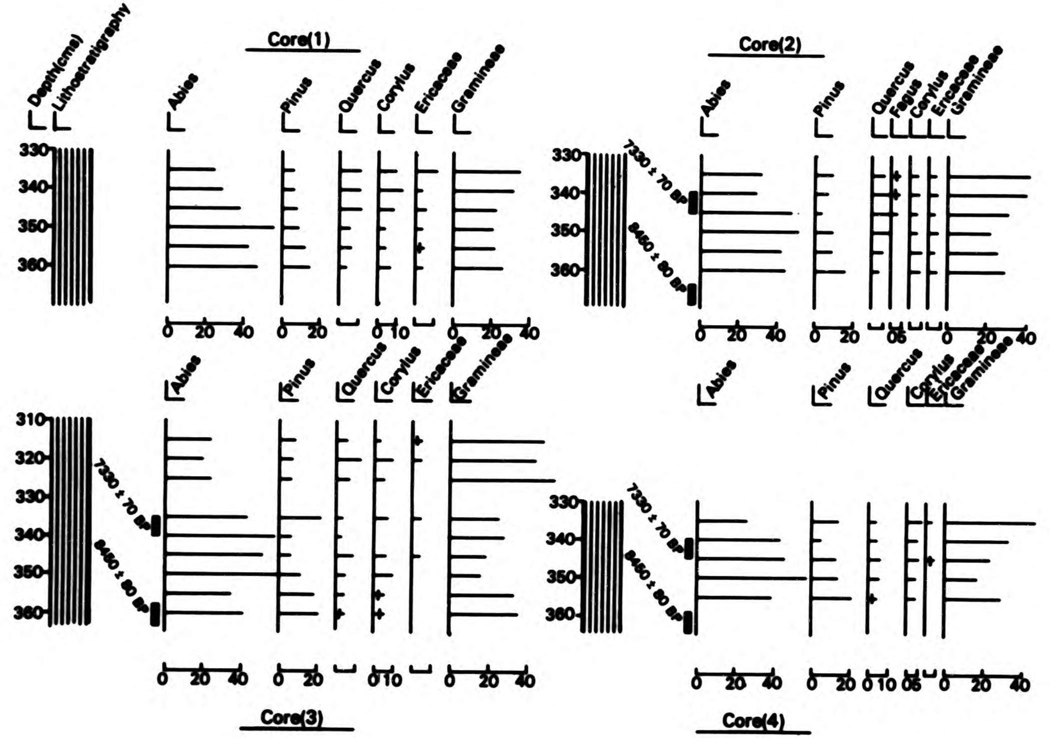
Pollen preservation zone 2: (depths 304 to 48 cm)

Amorphous frequencies average 20% and corroded values are unchanged.

Radiocarbon dating.

Four basal cores were obtained from the basal succession to provide sufficient material for radiocarbon dating. Skeleton pollen counts used for biostratigraphical correlation are illustrated in Figure 35. Core 1 was reserved for detailed pollen counting and the basal 5 cm of peat from cores 2, 3 and 4 were extracted and combined to provide a bulk date for the onset of peat formation at the site. This produced a result of 8450 ± 80 BP (GrN-14433). A further date of 7330 ± 70 BP (GrN-14434) was obtained using the same method for a decline in *Abies* percentages and a rise in Gramineae values apparent in the cores at depths of between 350 and 340 cm.

Fig. 35 Bargone-Skeleton pollen counts.



PART FOUR: INTERPRETATION OF RESULTS

CHAPTER 9: AGORAIE AND LAGO DELLE LAME

9.1 Agoraie

The basal radiocarbon assay provides an age estimate for peat inception of shortly before 4180 ± 60 BP (GrN-14669) at which time peat sediments accumulated directly above weathered bedrock and gravels. The available evidence indicates that there are no early Holocene sediments within this basin and an examination of the basal pollen spectra in Figure 7 provides no insight into the causal nature of peat inception. In the absence of any data on conditions prior to peat formation it must be assumed that a rise in the local water table had occurred for unknown reasons, thereby leading to a cessation of the breakdown of organic matter. However, the remaining radiocarbon dates of 3510 ± 60 BP (GrN-14670) and 2050 ± 50 BP (GrN-14671) suggest that once this process had begun, sedimentation was extremely rapid with approximately 3 m of peat growth in 2000 years.

Investigations of pollen recruitment processes in lakes supplied by streams (Peck, 1973; Bonny, 1978; Pennington, 1979)) have demonstrated that a large proportion (up to 90%) of the pollen entering the sediments at such sites is water transported and derives from extra-local sources. The Agoraie site is fed by a major stream and it can be inferred that as a result of streamborne pollen recruitment, the sediments at Agoraie may contain pollen from both higher in the catchment area as well as locally derived pollen. The presence of a large proportion of stream derived pollen may in part be responsible for the high levels of pollen deterioration recorded.

Throughout the period recorded by the pollen diagram the mire surface vegetation was dominated by sedges and occasional Potamogeton and Nymphaea growing in pools of deeper water. On the dryer margins of the site or along stream edges Filipendula was very common. The erratic fluctuations in the Filipendula and Cyperaceae curves are interpreted as variations in stream movement across the site or variations in stream activity which resulted in major fluctuations in the representation of flush and mire-edge communities and concomitant changes in the curves of woody taxa.

During PAZ Ag1 the dominant forest type in the catchment area was Abies with Fagus and possibly Quercus in sheltered localities. Other deciduous trees such as Ulmus, Tilia, Acer and Carpinus may have been present locally but were always rare while Corylus and Alnus were infrequent. The pollen data in PAZ Ag1 are indicative of a tall forest community with local canopy openings concentrated along stream and mire edges from which Filipendula, Gramineae and Ericaceae were able to periodically colonise the mire surface. A peak in the Fagus curve at depth 440 cm coincides with an increase in loss on ignition values and is probably indicative of a temporary reduction in stream activity and corresponding change in pollen recruitment rather than a significant change in the relative frequencies of Abies and Fagus within the local forest. The relative pollen diagram therefore suggests that the site was surrounded by a stable forest community with no discernible changes occurring within the time period covered by PAZ Ag1.

However major changes in forest composition are indicated at the pollen-stratigraphical boundary Ag1/Ag2-a. Changes in pollen concentrations (Figure 8, pollen concentration zone 3) confirm that Abies declined locally at that time but Fagus, Quercus and herbs became more important in the local vegetation. A lack of records for Tilia in PAZ's Ag2-a and Ag2-b suggest that it had previously been a minor constituent of the Abies forest. The pollen-stratigraphical boundary is coincident with a change in sediment type from diatomite to peat which is suggestive of a diminution of stream activity with a notable increase in pollen influx from mire edge vegetation dominated by Filipendula. Gramineae, Galium t. and Ranunculaceae may have been able to exploit mire edge habitats. Cruciferae and Oxyria acetosella are common constituents of present-day beech and fir woods in southern Europe (Oberdorfer and Hofmann, 1967; Barbero, 1970; Barbero and Bono, 1970; Gentile, 1974) and collectively with Plantago species, Leguminosae, Urtica and Humulus t. suggest the existence of woodland edge communities and forest clearings. However, most of these taxa were present in the previous zone and together with Corylus and Alnus, which do not appear to have taken advantage of any openings in the forest canopy, the pollen spectra are indicative of the continuation of woodland conditions in which Abies played a diminishing role.

The similarity between the decline in the Abies and Alnus curves at the Ag2-a/Ag2-b boundary and the corresponding rise in Caltha t. frequencies again signifies a change in stream and mire edge communites with a reduction in the fringing woody vegetation.

The Ag1/Ag2-a stratigraphical boundary is preceded by marked changes in lithostratigraphy and pollen concentrations, and an appreciation of those changes may be critical to the understanding of later events in the pollen record. The presence of diatomite within the peat sediments together with very high sedge pollen concentrations (Figure 8, pollen concentration zone 2) indicate a rise in the local water table and this may have occurred for a number of reasons:

1) One possibility is that during the early stages of peat growth the basin was freely-draining but during later stages, a reduction in seepage would temporarily have resulted in deeper water conditions. In those changed hydrological conditions a reduction in sedimentation rates may have occurred resulting in higher pollen concentrations. If the radiocarbon dates are reliable they would indicate an average sedimentation rate of 29 cm/100yrs during the first 440 cm of sediment followed by an average rate of 7 cm/100yrs between depths 440 cm and 330 cm.

2) A second possibility is that increased stream activity and increased surface run-off from within the catchment area

would have resulted in deeper water conditions. Silt and sand was retained in the fine sieves during pollen preparations of samples from depths 320 cm to 335 cm which could relate to soil and sediment erosion, suggesting that older carbon may have been included in younger sediments. If this is the case then the radiocarbon date of 2050 ± 50 BP would be too old and the estimated average sedimentation rates above would therefore be less divergent. However, as discussed above there is little evidence of disruption of the forest canopy that may have been associated with such soil disturbance and given the presently available data, it is not possible to specify whether the changes in sediment type were caused by purely local hydrological conditions within the basin or by events of wider regional significance.

In order to resolve this problem it would be neccessary to (1) investigate the diatom flora to ascertain the nature of hydrological changes within the basin; (2) examine the relationship (if any) between changes in the pollen stratigraphy and ephemeral silt bands known to exist within the sediments elsewhere in the basin, and (3) investigate the sediments and pollen stratigraphy of neighbouring basins to establish the pattern of events over a wider geographical area.

9.2 Lago delle Lame

The onset of peat formation at this site was preceded by the deposition of predominantly clastic sediments shown to contain high frequencies of amorphous *Abies* pollen grains (PAZ LdL1, Figure 12; pollen preservation zone 1, Figure 14). Elsewhere it has been observed that amorphous (degraded) conifer grains were concentrated into silty sediments and these were interpreted as being a result of secondary redeposition from surrounding drift deposits (Cushing, 1964, 1967; Birks, 1970). The nature of the sediments and the poor pollen preservation charcateristics of PAZ LdL1 indicate that a large proportion of the pollen spectra consists of redeposited pollen derived from the erosion of soils and sediments surrounding the site. The macrofossil evidence (Appendix B) suggests that both *Abies* and *Fagus* were growing locally during this period and it is likely that *Fagus* is underrepresented probably as result of differential preservation. Conspicuously high percentages of Filicales spores are difficult to interpret as they can also be an artefact of differential preservation (Hall, 1981).

The radiocarbon dates of 3025 ± 50 BP (GrN-14672) and 3510 ± 35 BP (GrN-14673) are in reverse order the reason for which is not clear, but may have been caused by one of three processes: (1) water could have percolated through the basal peat thereby introducing younger carbon into older sediments; (2) transient clay bands within the peat at various locations on the site may represent episodic soil erosion from slopes surrounding the site, thus leading to the incorporation of older carbon into younger sediments, or (3) sampling error. As the cause of error is unknown the date of peat initiation can only be approximated to 3250 yrs BP (an average of the two radiocarbon dates).

The site is a small basin with a very limited stream catchment and the major proportion of the pollen entering the sediments are likely to have originated from a distance of between 20 m and a few hundred metres of the site (Jacobsen and Bradshaw, 1981). In PAZ LdL2-a deciduous trees are well represented in the organic rich deposits. Acer is an entomophilous taxon which is poorly dispersed (Markgraf, 1980) but is very abundant here and would have been a major element in the surrounding forest. Likewise Ulmus is a poor pollen producer (Andersen, 1970) and appears to have been present locally, probably temporarily growing on or close to the mire surface. The site was a small damp hollow surrounded by a mixed coniferous-deciduous forest of Abies, Fagus, Acer, Ulmus and possibly some Quercus. Low frequencies of Alnus and Corylus and low herb values are indicative of a generally closed forest canopy with the relatively shade tolerant Caltha palustris growing in flush zones or along stream edges. Intermittent records of Ericaceae, Filipendula, Leguminosae and Plantago holosteum t. at the beginning of the subzone may represent a temporary expansion of woodland edge habitats at that time.

During PAZ LdL2-b and pollen concentration zone 3 (Figure 13) changes occur in the frequencies of Abies and Fagus, with Fagus becoming more abundant relative to Abies. A general decline in loss on ignition values is interpreted as reflecting soil erosion from slopes surrounding the site. Heliophilous herbs such as Leguminosae and Plantago species were able to flower possibly in gaps occurring in the Abies canopy. Nevertheless both Fagus and Acer were unaffected by this event and closed woodland conditions were maintained. A rise in Abies percentages from depth 45 cm coincides with an increase in pollen deterioration in pollen preservation zone 3 and concomitant changes in lithostratigraphy, indicating considerable local soil disturbance. It is probable that Abies is overrepresented in these samples as a result of increased pollen influx from pollen bearing soils.

In the generally lighter conditions of PAZ LdL2-c Compositae colonised disturbed ground, Filipendula occupied flush zones and Cyperaceae occurred in the dampest areas of the mire surface. However grasses were infrequent and Corylus percentages remained unchanged suggesting that these disturbances were very localised and that substantial tracts of woodland survived in the area.

CHAPTER 10: PRATO MOLLO AND LAGO NERO

10.1 Prato Mollo

A detailed micromorphological investigation of the basal sediments (Appendix C) provided important information on the causal nature of peat inception at Prato Mollo, and this has major implications for the interpretation of the basal pollen sequence and the associated radiocarbon dates.

Initially the site was a shallow permeable bedrock depression that was sealed by the deposition of silt, clay and fragments of serpentinite soils which provided a rooting bed for peat forming plants in conditions of intermittent wetting and drying. This was followed by a phase of increasing mineral deposition and then by a renewal of peat growth. Counts of charcoal from pollen preparations demonstrated the existence of charcoal in these basal layers but the micromorphology provided additional information which indicated that the charcoal was derived from both in situ burning of the peat as well as from extraneous sources. Finally, organic silt and clay from higher levels had been able to penetrate lower samples along fossil root channels, a process that would not have been evident from visual examination of the sediments alone (R.I.Macphail, pers. comm.).

Therefore a number of factors have affected the basal sediments of the Prato Mollo profile which will in turn have affected both the record of radiocarbon activity and the pollen spectra.

The radiocarbon assays of 4300 ± 60 BP (Bln-3132) and

4130 ± 60 BP (Bln-3131) almost certainly include extraneous carbon and charcoal that were introduced into the sediments as a result of erosion of soils from the catchment area. This may have had an ageing effect on the radiocarbon dates. On the other hand the penetration of organic silts and clays along fossil root channels presumably with water carrying humic acids, could have introduced younger organic material into older sediments. It is not possible at present to determine the relative proportions of the different types of possible error that may occur in the "bulk" radiocarbon dates although on balance, any contamination by significantly younger carbon would have introduced a greater error than that incurred through contamination by older carbon.

The interpretation of the basal pollen assemblages (PAZ PM1, Figure 17) is also problematic. During the earliest stages of peat formation pollen-bearing soils rich in Abies were washed into the site. The presence of Pteridium in PM1 was probably a response to soil disturbance possibly associated with burning. However the status of deciduous trees is more difficult to determine as high frequencies of deteriorated Abies pollen (Figure 19) and low pollen concentrations (pollen concentration zone 1, Figure 18) indicate the probability of differential preservation and alteration of the pollen assemblages. At least Alnus would have been growing locally as shown by charcoal analyses from the site (Nisbet, 1989 in press), and Tilia frequencies are highest (3% TLP) in the two basal spectra possibly indicating a local presence.

A decline in the Abies curve and a rise in Alnus, Fagus, Quercus and herb values in PAZ PM2-a could be interpreted as a change in forest composition at that time but it is more likely that as soil erosion diminished and peat growth progressed, pollen transport mechanisms would have changed markedly. The site is a broad exposed shelf and up to 40% of the pollen entering the sediments may have been regionally derived from rainfall and above the canopy (Jacobsen and Bradshaw, 1981) as well as from up valley winds or regional gravity winds (Markgraf, 1980). At the same time, however, a large part of the pollen entering the sediments would have originated from local sources (Jacobsen and Bradshaw, 1981) of which mire and mire edge communities would have been well represented. In addition high frequencies of deteriorated pollen recorded throughout the sediments combined with generally low loss on ignition values probably indicate some continuation of stream and surface wash from the catchment area as well as periodic drying out of the site. Of the major taxa Quercus and Pinus are easily dispersed, prolific pollen producers (Andersen, 1974; de Beaulieu, 197?; Markgraf, 1980;) and are frequently overrepresented in mountain areas whereas Abies, Fagus, Ulmus and many herbs are poorly dispersed or are poor pollen producers (Andersen, 1974; de Beaulieu, 1977; Markgraf, 1980; Janssen, 1981;) and these are likely to have originated from local sources. In addition the Corylus curve is unchanged from the previous zone inspite of local changes in sedimentation suggesting that much of the Corylus could have originated from non-local sources.

In PAZ PM2-a the dominant vegetation of the area was an Abies forest with Fagus on freely draining slopes, Ulmus on damper soils and Alnus on stream and mire edges. A notable improvement in the preservation of Abies grains without any change in overall deterioration frequencies may indicate that stream and soil inwash no longer included this pollen type. Throughout the period covered by the pollen diagram the mire vegetation was dominated by sedges and grasses. However a depression of Cyperaceae values in PM2-a and a corresponding increase in Compositae Liguliflorae pollen and Filicales spores may indicate a slight drying out of the mire surface and an extension of mire edge habitats. Locally, clearings and woodland edges may have been occupied by heliophilous herbs such as Scabiosa t., Papaver t., Medicago sativa t. and Glaucium.

During PAZ PM2-b there were changes in the composition of mire and stream edge communities as indicated by the decline in Alnus, Ulmus, Compositae and Filicales percentages and the corresponding rise in Sanguisorba officinalis and Cyperaceae frequencies. A diminution of Abies values at the upper zone boundary may have occurred as a consequence of a rise in the Gramineae curve at the same level but during PAZ PM3 and pollen concentration zone 3 Abies underwent a real decline relative to other taxa suggesting that it ceased to be a major constituent of the local vegetation communities. Slight rises in the Fagus and Quercus curves in PAZ PM3 are too weak to suggest that these taxa behaved as agressive colonisers of the Abies forest and it is more likely that the rise in values is a consequence of the percentage method. Nevertheless, shrinkage of the Abies forest was apparently not paralleled by similar developments in the Fagus population so that local forest communities were transformed into beech-dominated woodland. Increases in Gramineae, Artemisia, Plantago lanceolata t. and Sinapis t. as well as minor frequencies of a range of herb types indicate an expansion of open grassland and herb communities within an increasingly open woodland canopy. One effect of a reduction in woodland cover would have been an increased representation of regionally derived pollen most notably Fraxinus ornus t. which, although widespread in the present-day vegetation below 1000m, is infrequent at higher altitudes (Oberdorfer and Hofman, 1967).

10.2 Lago Nero

Major differences have been noted between the pollen assemblages derived from the basal sediments of two closely-located boreholes at this site. High Abies and Pinus frequencies were recorded in the Lago Nero diagram (Figure 21) whereas significantly higher counts for Quercus, Fagus, Alnus, Gramineae and Cyperaceae were noted at the base of Lago Nero A (Figure 22). In view of these discrepancies some consideration of the various factors that might have contributed to such contrasts is required.

(1) The pollen sequence of Lago Nero A may be younger than that of Lago Nero thereby accounting for lower Abies and

Pinus percentages. If so, then the oldest sediments on the site have not been dated. However the trends of the Alnus and Corylus curves in PAZ LN3 of both diagrams are strikingly similar and (assuming there is no hiatus in the Lago Nero diagram) it would appear that the basal sediments are contemporaneous but that other factors have influenced the pollen spectra.

(2) One possibility is that groundwater seepage through the peat and basal sandy, gravelly layers contaminated lower levels of Lago Nero A thus altering the basal pollen assemblages. If this is the case then younger organic material would have been introduced into the lowermost sediments and the radiocarbon date of 4855 ± 40 BP (GrN-14430) is too young.

(3) A further factor to be considered is the complex nature of the mode of peat inception at this site. Micromorphological details (Appendix C) indicate that the basal peat of Lago Nero include the inwash of silt, detrital organic material and colluvial fragments of burned peat and soils. This type of information is lacking for Lago Nero A but substantial amounts of sand and gravel in the lowermost samples may likewise represent considerable soil and stream bankside erosion and deposition. Spatial variations in sedimentation within the site can result from stream migration across the site and to local differences in the effects of soil erosion within the catchment area. If this is the case, then two different vegetation communities may be depicted in basal pollen assemblages of the two successions.

Firstly, PAZ's LN1 and LN2 may consist of inwashed soil and humus derived from a source rich in Abies and Pinus while on the other hand, the Lago Nero A basal assemblages may correspond to a mixed forest association of Abies, Quercus, Fagus, Alnus, Corylus with herbs, grasses and sedges. By inference therefore, the sediments could have been contaminated by older carbon and the radiocarbon date of 4855 ± 40 BP may be slightly old.

In view of the problematic nature of the basal pollen sequences, interpretation of higher stratigraphical levels is also open to question. The rise in the Alnus and Corylus curves was dated as 4610 ± 40 BP (GrN-14431) at which time pollen concentrations fell (pollen concentration zone 2, Figure 23) and in the Lago Nero core, the sediments became markedly more organic. The sharpness of the pollen stratigraphical boundary LN2/LN3 is likely, therefore, to be indicative of a major change in the nature of sedimentation and of pollen recruitment to the site. It is suggested that a reduction in soil and stream erosion and deposition was followed by slope stabilisation and resumption of peat growth. During LN3 the local forest was dominated by Abies with some Ulmus on damper soils although Corylus and Alnus were locally very abundant possibly growing on previously disturbed soils and stream edges. There may have been a minor expansion of heath communities growing either under a lighter woodland canopy or on the mire surface itself but given the lack of herbaceous taxa, there is no evidence of major forest reduction. A rise in the Cyperaceae curve and occurrences of aquatics in this zone have no equivalents in the Lago Nero A diagram and probably reflect variations in mire topography rather than a rise in the local water-table at this time. The high frequencies of deteriorated grains that were recorded in LN3 (Figure 24) point to regular drying out of the mire surface, a process that appears to have been less frequent in LN4.

A forest succession is apparent in the Quercus, Fagus and Abies curves with a corresponding reduction of heliophilous trees and shrubs in PAZ's LN3 and LN4. However it is difficult to determine whether there was a real change in forest composition at that time with the development of Fagus and Quercus within an Abies forest, or simply the regeneration of a pre-existing mixed coniferous-deciduous forest association. In LN5 however, the Abies forest quite clearly declined and Fagus became the dominant tree within the local area.

The LN4-LN5 pollen stratigraphical boundary is preceded by a dramatic rise in pollen concentrations (pollen concentration zone 3). A reduction in sedimentation rates associated with the natural process of basin infilling is probable. In addition however, a broad correlation between the rise in pollen concentrations, reduction in loss on ignition values and an increase in the frequency of deteriorated Abies grains may also indicate an increased pollen influx due to renewed soil/stream bank erosion and deposition of pollen-bearing soils. If this is the case, high Abies percentages between depths 27 cm and 17 cm may largely consist of redeposited pollen and the Abies decline was probably more gradual than the relative diagram alone would suggest.

In LN5 the site was surrounded by Fagus woodland but with only scattered Abies trees and less Quercus than previously. Some evidence of canopy openings occurs in LN5 with a rise in the Gramineae curve and low frequencies of herbaceous pollen types in addition to Cyperaceae which may have become more extensive on the mire surface at that time. However any clearings were not extensive and well wooded conditions appear to have continued throughout the time period represented by the sedimentary record.

CHAPTER 11: CASANOVA AND BARGONE

11.1 Casanova

The pollen stratigraphy of the lowermost sediments (PAZ CN1, Figure 27) indicates a phase of mixed *Pinus*-*Abies* coniferous forest. Deciduous tree types were recorded at very low frequencies and are likely to represent long-distant wind-blown pollen transportation. Cyperaceae dominated the mire vegetation and a lack of obligate aquatics suggests a low water-table. Following this initial phase there was an expansion of open communities (PAZ CN2) dominated by Cyperaceae and Gramineae but which also included taxa typical of bare ground and skeletal soils. These included species of *Artemisia*, Compositae Tubuliflorae and *Helianthemum* with *Sanguisorba officinalis* on flush zones adjacent to the mire surface. Conversely the local *Pinus* population diminished although *Abies* was apparently unaffected by this event. High charcoal frequencies recorded at the base of CN2 indicate that this could have been a response to fires within the vicinity.

High frequencies of both *Pinus* and *Artemisia* were not recorded at any other site in the field area and the pollen assemblages of CN1 and CN2 show no affinities with the pollen stratigraphy of other sites in eastern Liguria. However radiocarbon-dated pollen diagrams from north-western Italy (Schneider, 1978), the Maritime Alps (de Beaulieu, 1977) and the lower Rhone valley (Triat-Laval, 1978) have shown that maximum *Pinus* and *Artemisia* frequencies occurred during the Lateglacial of the north-western Mediterranean and fell rapidly at the beginning of the Holocene. Recent unpublished work on sites in the northern Apennines (J.J.Lowe, pers.comm.) has also demonstrated that *Pinus* and *Artemisia* percentages decline at horizons believed to represent the Lateglacial-Holocene boundary, although in that area, *Abies* was also very abundant during the same period. Therefore it is inferred that PAZ's CN1 and CN2 represent a time period of no later than the earliest Holocene.

However the radiocarbon date of 5040 ± 100 BP (GrN-14432) for the base of PAZ CN3 cannot be reconciled with a Lateglacial/early Holocene age for the preceding pollen zone and the date must be either too young or there is a major hiatus in the sedimentary record. Contamination by younger carbon as a result of sampling error is also a possibility but similar pollen counts were obtained from cores using both the Russian and piston corers and this type of error is considered to be unlikely.

The presence of *Fagus* in PAZ CN3 may supply a general indication of age. *Fagus* was not recorded in the Maritime Alps before about 5000 yr BP (de Beaulieu, 1977) and although recorded at low frequencies (below 1%) in the early Holocene of north-western Italy, *Fagus* percentages failed to increase until after 5270 yr BP (Schneider, 1978). Likewise it appears to have been infrequent in the northern Apennines until the mid-Holocene (Bertoldi, 1980; J.J.Lowe, pers.comm.) and so, it is likely that the sediments of CN3 are of mid-Holocene age which is commensurate with the radiocarbon date. This being the case there was a cessation of peat growth and a hiatus in the sedimentary record of the site amounting to several thousand years.

Pollen concentrations are high in PAZ's CN1 and CN2 (pollen concentration zone 1, Figure 28) but are low in CN3 (pollen concentration zone 2). If the concentration data is a reflection of rates of sediment accumulation in the basin it would appear that during the Lateglacial sedimentation was very slow and was followed by a discontinuation of peat formation. There is no indication in the lithostratigraphy of disruption of the sediments so cessation of peat formation presumably occurred, in common with some sites in central Europe (Succow and Lange, 1984), as a result of dry site conditions brought about by a combination of a lack of rainfall and surface run-off from a thickly forested catchment area. Reduced concentrations in pollen concentration zone 2 indicate rapid sedimentation rates during the middle Holocene, a phenomenon that was also characteristic of the sediments at Agoraie.

However high Pinus percentages recorded in PAZ CN3 together with Betula and Salix is more typical of early Holocene pollen assemblages in the north-west Mediterranean (de Beaulieu, 1977; Schneider, 1978) which is difficult to reconcile with a mid-Holocene age for the sediments. Therefore it is suggested that renewal of peat growth during the mid-Holocene could have been accompanied by slumping and redeposition of older littoral sediments. If this is the case then the pollen assemblages of PAZ CN3 represent a mixing of sediments of differing ages and by inference, resumption of peat growth may have occurred at a date even later than that indicated by the radiocarbon assay.

During PAZ CN4-a the site would have been surrounded by a fringe of Alnus while the dominant vegetation of the area was Abies forest with Fagus on freely draining slopes and occasional Ulmus and Tilia. Ferns were common in the understorey and were probably abundant on the mire surface with Filipendula at the beginning of the zone. Throughout the stratigraphical record the Cyperaceae and Filicales curves are in contraposition suggesting fluctuations in the plant communities occupying the mire surface. Compositae Liguliflorae include a large group of herbs, some of which are components of fen and stream-side vegetation whereas others are species of meadows or disturbed soils, so the exact status of this group is difficult to determine. However a broad association between charcoal, minor variations in loss on ignition values and high frequencies of amorphous grains (pollen preservation zone 1, Figure 29) suggests a plant response to fire and soil disturbance within the local area.

Most of the charcoal recorded at this site consisted of opaque microspherules the origin and dispersal of which is still incompletely understood (Patterson et al..1987) although they appear to originate from the burning of a wide range of materials. Most commonly they have been recorded in recent sediments where their occurrence relates to the burning of fossil fuels but similar particles in New England lake sediments may relate to wildland fires (Patterson et al., 1987) and at Etton, Cambridgeshire they have been found in large numbers in a firing pit apparently used for the manufacture of pottery during the Beaker period (R.Scaife, pers. comm.). Charcoal in sediments may relate to natural combustion, lightning strike, forest canopy or understorey fires or cooking fires and is subject to dispersal and depositional processes similar to those affecting pollen recruitment and transport (Patterson et al., 1987). The site is a small basin with negligeable stream input and at times of mature forest stands, up to 90% of the pollen in the sediments can have originated from local and extralocal sources (Jacobson and Bradshaw, 1981). By comparison then, if wind was the dominant means of transporting charcoal microspherules to the site they may have derived from very local fires. However the small size of recorded particles (20 to 35 um) at this site, would suggest that the charcoal was not of local origin. An alternative and possibly more likely source was slope and surface wash and redeposition from soils and deposits near the basin edges. If this was the case then, combined with a relatively wide sampling interval, it would follow that the charcoal data do not record single fire events but instead represent broad averages resulting from several episodes of burning and erosion. The local stands of Alnus and Fagus appear to have been the most damaged by these occurrences whereas the predominantly Abies forest remained intact.

However a major opening up of the forest occurred in PAZ CN4-b as heliophilous shrubs and herb communities became important while the forest community of Abies, Alnus and Fagus temporarily declined. Corylus, Compositae Liguliflorae, Gramineae and Cyperaceae were abundant and together with Ericaceae, Compositae Tubuliflorae, Liliaceae, they indicate a major extension of open grassland and woodland edge communities. Pollen preservation data (pollen preservation zone 2) show a decrease in the numbers of amorphous grains although corroded frequencies remain high, suggesting that while periodic drying out of the surface remained a common occurrence, there may also have been a reduction in slope and surface inwash at this time. This may have led to a reduction in clastic sedimentation rates with a concomitant rise in pollen concentrations (pollen concentration zone 3) although a rise in concentrations could conceivably be related to a reduction in the filtering capacity of the fringing vegetation (Tauber, 1965, 1967).

In CN4-c the forest canopy closed in again as Alnus recolonised the edges of the site and Abies was also important. Ferns and Filipendula probably colonised the mire surface. In reduced light conditions Cyperaceae, Compositae and finally Gramineae became less common although low frequencies of herbs such as species of Leguminosae, Plantago, Primula and Humulus t. indicate the presence of woodland edge habitats and the absence of a closed forest canopy.

Unlike earlier levels a major charcoal peak at depth 235 cm does not coincide with corresponding variations in the Alnus and Fagus curves but a reduction in Filicales spores suggests a very localised ground fire on the peat surface. This was followed by the deposition on the mire surface of wood of Abies alba type (Appendix B) but unfortunately the presence of wood in the core prohibited sampling for pollen.

By the end of PAZ CN4-c the Abies forest underwent a major decline locally although Alnus remained common in the area. The relative diagram provides few indications which could suggest an explanation for the change in frequencies of Abies although the change in lithostratigraphy at depth 228 cm not far below the pollen stratigraphical boundary may be of significance. Hyphal fragments noted in pollen preparations from the wood peat may have been produced in situ in dryer hummocks on the mire surface (van Geel, 1978) suggesting a lowering of the local water table at this time although equally they could have originated from the inwashing of humus and organic material from slopes surrounding the site and would represent penecontemporaneous redeposition of the sediments (Cushing, 1964; Birks, 1970). If the latter is the case then much of the Abies pollen between depths 212 cm and 190 cm would consist of redeposited pollen and the downward trend in the Abies curve would be more gradual than the percentage diagram suggests and by inference, may have been a response to an earlier fire event. However it is not possible to confirm this hypothesis by reference to the preservation data and a clarification of the problem would require a more detailed investigation of lithostratigraphical and pollen stratigraphical changes at this site.

Only low frequencies of Abies are recorded in CN5-a which is suggestive of localised growth at some distance from the site or long distance transport from areas of remaining dominance. Likewise Tilia is no longer recorded indicating that it had been a minor constituent of the pre-existing Abies-dominated forest. However Alnus was still very abundant around the damper margins of the site and Fagus was frequent in the area. The pollen-stratigraphical boundary is marked by temporary increases in Gramineae,Corylus and finally Fagus with a general decline in herbaceous pollen types suggesting a temporary opening up of the canopy and subsequent colonisation by Fagus. However Fagus pollen concentrations follow the main trends of the total pollen concentration curves (pollen concentration zone 4) and any expansion of Fagus woodland would appear to have been very restricted in this area. An increase in the Quercus curve combined with minor rises in the records of other anemophilous arboreal taxa such as Pinus, Betula and Juglans is probably an effect of a reduction in the local Abies forest which then allowed the deposition of pollen from long-distant sources. Rapid changes in sedimentation rates and variations in the local water-table may have occurred during CN5-a and CN5-b as suggested by fluctuating pollen concentrations (pollen concentration zone 4) and variations in the Cyperaceae and Filicales curves.

In CN5-b evidence of major disturbance of the vegetation and soils around the site is provided by a fall in Alnus values, a major rise in Compositae Liguliflorae, a decline in loss on ignition values, a rise in amorphous grains (pollen preservation zone 3) and minor increases in charcoal frequencies. The fringing area of Alnus vegetation was destroyed and the area colonised initially by Compositae and then by grass and heath communities as well as taxa indicative of disturbed ground and short turf communities such as species of Plantago, Urtica, Polygonum and Helianthemum. However Fagus remained frequent in the area probably growing on freely-draining slopes until CN5-c. Then the local forest vegetation had been replaced by herb and scrub communities comparable to the present-day landscape with Gramineae, Juniperus, Ericaceae, high frequencies of both Plantago holosteum t. and Plantago lanceolata while grasses, sedges and Typha grew on the mire surface. Olea is not generally cultivated above 800 m in eastern Liguria today (Orsino, 1969) but is a prolific pollen producer which is very easily dispersed over long distances (de Beaulieu, 1977). Hence progressive deforestation led to rises in regionally derived pollen types such as Olea and Juglans both of which would have originated from lower altitudes where tree crops were widely cultivated at that time.

11.2 Bargone

Bargone is a small, steeply sloping basin which is situated close to the coast at an altitude of 850 m. In contrast to other investigated sites where peat deposits had accumulated during the last 5000 years, the radiocarbon dates of 8450 ± 80 BP (GrN-14433) and 7330 ± 70 BP (GrN-14434) indicate that this site contains the oldest dated Holocene sediments found anywhere in eastern Liguria. The dates are internally consistant and at present there is no available evidence that might cast doubt on their validity and this anomalous situation is difficult to explain. At about 8450 yr BP there was sufficient waterlogging and depression of decomposition rates at this site to allow the formation of peat directly over bedrock. At that time (PAZ Bg1, Figure 32) the site was probably a small grassy hollow surrounded by a dense canopy of _Abies_ and possibly some _Pinus_. Deciduous woody taxa such as deciduous and evergreen oaks, _Ulmus_ and _Tilia_ were probably also present locally but the close proximity of a dense coniferous canopy may have had a filtering effect on overall pollen deposition at the site (Tauber, 1965,1967). High representation of grasses and sedges would suggest that the mire itself was open with species of Leguminosae, _Centaurea_, Cruciferae and other herbs growing in openings around the site. High pollen concentrations (pollen concentration zone 1, Figure 33) and high frequencies of amorphous grains (pollen preservation zone 1, Figure 34) indicate slow sedimentation rates possibly in association with intermittent slumping and redeposition of littoral sediments (Bryan Davis, 1973; Bryan Davis _et al._,1984).

Unfortunately the Bg1/Bg2-a pollen- stratigraphical boundary coincides with a change in the method used for sediment retrieval. The basal peat (PAZ Bg1) was sampled with a closed chamber piston corer while the remaining sediments were sampled with an open chamber "Dutch" gouge. Inspite of substantial measures against possible contamination it is probable that younger sediments were pushed down and contaminated older sediments in the employment of the open gouge corer. Therefore the statistical reliability of the remainder of the diagram is uncertain and in particular, the position and configuration of the decline in Abies frequencies requires confirmation through the use of more reliable sampling methods. However in view of the stratigraphical discontinuities thought to exist at other sites in the field area (Casanova, for example) it is also possible that the sediments at this site do not form a continuous sequence and that a substantial hiatus exists between the sediments of Bg1 and Bg2-a.

Several broad trends can be identified in the remainder of the pollen diagram. In PAZ Bg2-a the local vegetation had changed to a predominantly mixed broad-leaved woodland consisting of deciduous and evergreen Quercus with Fagus and Alnus. Low Abies frequencies are suggestive of isolated trees growing locally or long-distant pollen transport. Calluna was abundant in clearings or on the mire itself while herbs such as species of Plantago, Mercurialis, Humulus t; Primula and Linum were present in open turf communities in woodland clearings. The mire surface was dominated by sedges with pools of deeper water containing occasional Nymphaea and Nuphar. In these conditions rapid sedimentation rates could have occurred thereby leading to low pollen concentrations (pollen concentration zone 2).

During PAZ Bg2-b broad changes in the forest vegetation are reflected in the curves of the major woody taxa which display a general decline in Quercus robur t. and Fagus with a corresponding increase in Qu. cerris and Qu. ilex pollen types. A rise in Gramineae frequencies coincides with an increase in pollen concentrations (pollen concentration zone 3) and the virtual disappearance of Nuphar and Nymphaea indicating a fall in the local water-table and a possible slowing down of sedimentation rates. Melampyrum pollen type can represent several species, all of which are insect-pollinated and have low pollen production and dispersal potential (Moore et al., 1985). Some species are characteristic of disturbed woodland glades and edges and may reflect anthropogenic modification of the woodland and mire surface vegetation, while others occur as natural constituents of mire vegetation communities (Moore et al., 1985; O'Connell, 1987). At Bargone the association of Melampyrum with probable variations in hydrological conditions of the site suggest that the plant was growing on the mire surface and its proliferation was a response to a lowering of the water-table.

In PAZ Bg2-c a decline in herbs and grasses is interpreted as a result of a rise in the local water-table and a diminution of mire edge communites. This was paralleled by an increase in deciduous oaks and Fagus although evergreen oaks remained abundant in the area.

Major deforestation occurred on a regional scale during

PAZ Bg3 as suggested by a diminution of all woody taxa, while Abies and Fagus in particular disappeared from the local area. Conversely, an expansion of short turf communities is indicated by the records of Gramineae, Caryophyllaceae, Leguminosae, Cruciferae and species of Plantago, Linum and Helianthemum.

CHAPTER 12: SUMMARY OF RESULTS.

The local pollen assemblage zones from the six sites reported in this study are summarised in Figure 36 together with the available radiocarbon dates. Correlation between the various biostratigraphical zones is difficult due to the small number of radiocarbon-dated samples and the numerous site problems that were discussed in Chapters 9-11. Nevertheless Figure 36 also shows possible correlations between the different pollen assemblage zones.

As shown in Figure 36 the stratigraphical succession at most sites only date back to the last 5000 years. Thus there is no data on which to base a reconstruction of early Holocene vegetation developments in eastern Liguria. Only one site, Casanova, may contain Lateglacial or very early Holocene sediments (CN1,CN2) but it was argued in Chapter 11 that there could be a hiatus in the sedimentary record amounting to several thousand years. The earliest dated Holocene sediments were recovered from Bargone (Bg1) and these have no dated equivalent in the field area. The dating control at this site is inadequate and there are additional uncertainties concerning the sampling method. In view of the stratigraphical discontinuities thought to exist at other sites in eastern Liguria, however, it is possible that the sediments at Bargone do not form a continuous sequence. As shown in Figure 36 it is possible that a stratigraphical hiatus exists between the sediments of PAZ's Bg1 and Bg2-a and that resumption of peat growth may have ocurred at between 4000 to 5000 BP in common with most other sites in

Fig. 38 Pollen Assemblage Zones in Eastern Liguria.

^{14}C	PAZ	LAGO DELLE LAME	^{14}C	PAZ	LAGO NERO	^{14}C	PAZ	PRATO MOLLO
	LdL2-c	Abies-Fagus-NAP		LN5	Fagus-Gramineae		PM3	Fagus-Quercus NAP
	LdL2-b	Fagus-Abies-Acer		LN4	Abies-Fagus-Quercus		PM2-b	Abies-Fagus-…
3510 3025	LdL2-a	Abies-Fagus-Acer		LN3	Corylus-Alnus-Abies		PM2-a	Abies-Ulmus-… Corylus
			4610	LN2	Abies	4130		
	LdL1	Abies	4855	LN1	Abies-Pinus	4300	PM1	Abies-Corylus

PRATO MOLLO	14C	PAZ	AGORAIE	14C	PAZ	CASANOVA	14C	PAZ
Fagus-Quercus-Corylus NAP					CN5-c	NAP		
					CN5-b	Fagus-NAP		Bg3
Abies-Fagus-Corylus		Ag2-b	Fagus-Quercus-NAP					
					CN5-a	Fagus-Alnus		Bg2
Abies-Ulmus-Alnus-Corylus	2050	Ag2-a	Fagus-Quercus-Abies		CN4-c	Abies-Alnus-Fagus		Bg2·
	3510							
Abies-Corylus					CN4-b	Corylus-Abies-NAP		
					CN4-a	Abies-Alnus-Fagus		Bg2·
	4180	Ag1	Abies-Fagus-Quercus	5040	CN3	Pinus-Abies-Alnus		
							7330 8450	Bg1
					CN2	Pinus-Abies-NAP		
					CN1	Pinus-Abies		

…AIE	14C	PAZ	CASANOVA	14C	PAZ	BARGONE
		CN5-c	NAP			
					Bg3	NAP
		CN5-b	Fagus-NAP			
…us-Quercus-NAP		CN5-a	Fagus-Alnus		Bg2-c	Quercus (robur, cerris/ilex)-Fagus
…us-Quercus-Abies		CN4-c	Abies-Alnus-Fagus		Bg2-b	Quercus (cerris/ilex robur)-Fagus
		CN4-b	Corylus-Abies-NAP			
		CN4-a	Abies-Alnus-Fagus		Bg2-a	Quercus (robur, cerris/ilex)-Fagus
…us-Fagus-Quercus	5040	CN3	Pinus-Abies-Alnus			
				7330 8450	Bg1	Abies-Gramineae
		CN2	Pinus-Abies-NAP			
		CN1	Pinus-Abies			

the field area.

The six sites reported in this study are located at a range of altitudes between 831 m and 1481 m and consist of both deep basins as well as shallow shelf sites. The most detailed records of the mid- and late Holocene vegetation history were obtained from Agoraie and Casanova whereas poor stratigraphic resolution and slow sedimentation rates at Prato Mollo, Lago Nero and Lago delle Lame have provided only very generalised stratigraphic records. For example, with a counting interval of every 5 or 10 cm, a record of vegetation developments every 35 to 70 years was obtained for Agoraie as compared with approximately 250 years for Prato Mollo.

In addition to differences in resolution the pollen-stratigraphical data from the six sites show significant differences due to the effects of local variations in altitude, exposure, soils and land-use. Given the inadequacies of the dating control however, it is difficult to distinguish the effects of these purely local features on the biostratigraphical records from those of regional events of wider significance, to establish a correlation between the various biostratigraphical sequences and to construct a regional vegetation model for the mid- and late Holocene in eastern Liguria. For example in Figure 36 it is suggested that PAZ Ag1 may be correlated with PAZ'S CN4-a, CN4-b and CN4-c but whereas the pollen-stratigraphical data from Agoraie indicate a stable forest community of Abies, Fagus and Quercus, considerable forest canopy openings are suggested by the Casanova sequence. These differences are probably due to variations in exposure, local soils and the localised effects of burning and human activity which will be discussed in detail in Chapter 14. In a like manner it is difficult to make any corrlelations between the Bargone sequence and that obtained from other sites. Bargone is the only site located within the submediterranean zone and the currently available data are insufficient to enable a correlation between variations in the deciduous and evergreen oak curves (Bg2-a, Bg2-b, Bg2-c) with the vegetation sequences obtained from higher mountain sites. As shown in Figure 36 one possibility is that increases in evergreen oak frequencies in PAZ Bg2-b and a rise in pollen concentrations (pollen concentration zone 3, Figure 33) could be contemporaneous with a similar rise in concentrations in the Casanova sequence (pollen concentration zone 3, Figure 28). A significant rise in pollen concentrations was also recorded at Agoraie (Figure 8). If the concentration data from the three sites are a reflection of varying hydrological conditions and sedimentation rates in the three basins, the biostratigraphical data could reflect primarily the influence of regional rather than local site factors.

A characteristic feature of the shallow sites Prato Mollo, Lago Nero and Lago delle Lame is the disruption of the basal pollen assemblages (PM1, LN1, LN2, and LdL1) as a result of erosion of local soils, sediment mixing and differential pollen preservation. At Lago Nero difficulties were experienced in correlating the pollen assemblages derived from the basal sediments of two closely-located boreholes on the same site while the minerogenic sediments at Prato Mollo (PM1) and Lago delle Lame (LdL1) contain considerable bias due to the effects of soil erosion and differential pollen preservation. Similar problems could have affected the stratigraphic succession at Casanova (PAZ CN3) where resumption of peat growth during the mid-Holocene may have been accompanied by the slumping and redeposition of littoral sediments leading to the mixing of sediments of different ages. These site problems have major implications for the dating of both the sediments and the disturbance events which may have initiated peat formation in the area. However there are insufficient data on which to base an assessment of the relative proportions of different types of possible error that may occur in the radiocarbon dates. Erosion of soils and charcoal, as for example at Prato Mollo and Lago Nero, could have introduced older carbon into younger sediments although an additional problem which may have affected the shallow sites is that of ground water seepage which could have had a "younging" effect on the radiocarbon dates.

Nevertheless inspite of the problems that may be associated with the available radiocarbon dates they indicate that at five of the sites examined, peat sediments only began to accumulate during the last 5000 years. The factors that may account for the lack of known early Holocene peat and lake sediments in the field area, and the ways in which peat formation may have been initiated will be discussed in Chapter 13.

Despite the fact that there are considerable problems of biostratigraphical correlation between the sites, there are notable similarities in the vegetation records indicating the influence of regional events rather than variations in the local site factors. In Figure 36 it is clearly shown that there are considerable resemblances between the *Abies* curves at five of the sites, suggesting that during the mid-Holocene *Abies* forests were common at altitudes of over 1000 m but during the late Holocene *Abies* virtually disappeared from the area and woodlands were increasingly dominated by *Fagus*. Forest fragmentation appears to have occurred on a regional scale during the late Holocene as indicated by increases in herb percentages occurring in the uppermost pollen spectra of all diagrams (Figure 36). Localised variations in these vegetation developments in eastern Liguria during the mid- and late Holocene are discussed in Chapter 14. In order to provide a wider framework against which to set the major forest changes in the field area, Chapter 15 examines the main published, radiocarbon-dated Holocene records for *Abies* and *Fagus* in northern Italy and south-eastern France. Finally Chapter 16 attempts to identify those factors that led to the decline of *Abies* in the northern Apennines in general, and in eastern Liguria in particular.

PART FIVE: DISCUSSIONS

CHAPTER 13: PEAT INITIATION IN EASTERN LIGURIA

This chapter attempts to assess the factors that may account for the virtual absence of early Holocene peat or lake sediments in the field area and to identify those processes which could have promoted the development of peat during the middle and late Holocene. Peat initiation is caused by waterlogging leading to a cessation of the breakdown of organic matter. The absence of waterlogging in a depression followed by a later development of peat can be related to changes in one or more of the following variables:

(a) Climatic factors - for example, an increase in precipitation would have encouraged water-logging and peat formation.

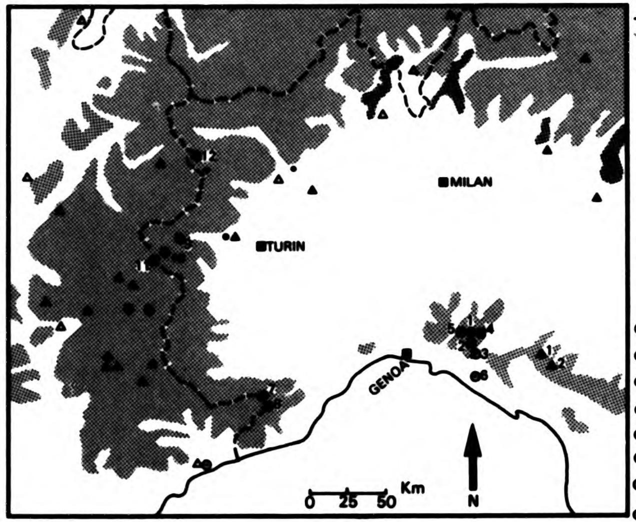
(b) Geological factors - an initially freely-draining substrate can become sealed either by natural weathering of clays and silt or by the erosion of soils and superficial deposits surrounding the sites.

(c) Anthropogenic factors - human disturbance of the vegetation could have influenced the development of peat through soil disturbance and increased surface run-off.

(a) Climatic factors

In order to evaluate the geographical extent of a possible widespread early Holocene hiatus, the location of palynologically investigated sites in northern Italy and surrounding areas are shown in Figure 37, with an indication

Fig. 37 Peat initiation in NW Italy and surrounding areas.



- International boundaries
- Land over 1000m
- Lakes
- ▲ Radiocarbon-dated full Holocene sequences
- ▲ Probable full Holocene sequences
- ● Radiocarbon-dated sites with no early Holocene peat or lake sediments
- • Undated sites with probable lack of early Holocene sediments

	SITE	DATE OF PEAT INITIATION(BP)	REF.
● 1	Agoraie	4180 ± 60	
● 2	Lago Delle Lame	3025 ± 50 ?	
● 3	Prato Mollo	4300 ± 60	
● 4	Lago Nero	4855 ± 40	
● 5	Casanova	5040 ± 100	
● 6	Bargone	8450 ± 80	
● 7	Selle di Carnino	7420 ± 120	de Beaulieu(1977)
● 8	Laghi della Perla	3160 ± 60	de Beaulieu(1977)
● 9	Lago la Manica	6290 ± 60	Scaife(1987)
● 10	Sestriere	3370 ± 50	Charrier(1970)
● 11	San Sicurio	4200	Charrier + Perreti(1977)
● 12	Rutor Glacier	6485 ± 115	Armando et al(1975)
▲ 1	Lagdei		Bertoldi(1980)
▲ 2	Prato Spilla		J.J.Lowe unpublished

of the dates at which organic sediments began to accumulate. A large number of pollen sequences from sites in the northern Apennines have not been dated and the extent to which there was continuity of sedimentation at these sites during the Holocene is uncertain. At least at the sites Lagdei (Bertoldi, 1980) and Prato Spilla (J.J. Lowe, pers. comm.) there appears to be good pollen-stratigraphical and lithostratigraphical reasons for suggesting that continuous sequences occur at those sites. However to the west of that area, twelve sites in the Ligurian Apennines and the western Italian Alps have been radiocarbon-dated but there is a dearth of known early Holocene peat and lake sediments. Most notably, at Selle di Carnino (de Beaulieu, 1977) there was a cessation of sedimentation lasting from the end of the Lateglacial until 7420 BP while at Lago la Manica (Scaife, 1987) peat failed to develop before 6290 BP. Of the remainder, eight (over 60% of the total) contain sediments which accumulated only during the last 5000 years. This assessment may be biased due to the limitations of the available data base, but the lack of any known early Holocene organic sediments in a large part of north-west Italy indicates that an interruption of sedimentation occurred on a regional scale. One possible reason for this is that a relatively dry climate prevailed for the early Holocene until 5000 yrs BP which in turn led to conditions where no peat formation was possible.

However there is little evidence in the published literature of great aridity in the region during the early

Holocene. On the basis of pollen assemblage data several workers have proposed broadly similar climatic trends for the Holocene throughout the northern Mediterranean (Bottema, 1974; de Beaulieu, 1977; Jalut, 1977; Reille, 1977; Watts, 1985). For example de Beaulieu (1977) suggested for the Maritime Alps that rises in the deciduous and evergreen oak pollen curves at the beginning of the Holocene indicated warm conditions with some summer aridity, but that records of Tilia, Ulmus and Fraxinus in the late Boreal indicated generally more humid conditions from that time. He also proposed that high percentages of Abies during the Atlantic period was representative of a forest response to increased precipitation and that records of Fagus and Pinus cembra during the subBoreal were indicative of generally cooler conditions. However this type of palaeoclimatic reconstruction based on pollen assemblage data is open to doubt. In particular the location of glacial refugia and plant migration patterns in the Mediterranean could have strongly influenced the records of early Holocene vegetational history in the region (Pons, 1984; Watts, 1985) although the data base for much of the Mediterranean is still inadequate. Nevertheless the available data suggest certain broad climatic trends during the Holocene. Although warm dry conditions with a summer moisture deficit may have lasted from approximately 10,000 BP until about 8300 BP, generally moister and/or cooler conditions prevailed until approximately 4500 BP when a further increase in precipitation or lowering of summer temperatures may have occurred. Likewise Courty's (1982) detailed examination of the cave sediments at La Poujade, southern France, indicates that generally humid conditions prevailed during the period 8500 BP to approximately 4000 BP, and speleothem growth in western Ligurian caves during the early Holocene (Biagi and Maggi, 1984) also suggests humidity and warmth. Thus there is no evidence that aridity alone was the cause of the lack of peat formation. However according to Porter and Orombelli's (1985) examination of the Rutor glacier, western Italian Alps, July temperatures during the period 8400 BP to 6000 BP would have been at least 4°C higher than at present. Guiot (1987) has also suggested on the basis of multivariate pollen time series analysis of a number of records from southern France that a thermal maximum occurred between 8500 BP and 6000 BP.

Thus it is possible that high summer temperatures with high evapotranspiration rates and possibly a lack of surface run-off due to a closed vegetation cover combined to produce rapid decomposition rates that inhibited the development of peat deposits. These conditions would have been most pronounced in small sites with limited drainage, which are characteristics typical of many of the sites in eastern Liguria. A parallel situation was discussed by Succow and Lange (1984) for mires in West Germany where a hiatus during the Boreal and Atlantic periods was typical of kettle hole and swamp mires whereas larger lake mires with a greater water-holding capacity contained no such hiatus. Therefore it can be suggested that future palynological investigations of early Holocene vegetation developments in much of north-western Italy should focus on large lake sites where the possibility of continuous sedimentation may be greatly enhanced. Cooler and/or more humid conditions in the mid-Holocene would have stimulated the development of peat during that period, although locally mire hydrology would have also been influenced by geological factors and human modification of the landscape.

(b) Geological factors.

Studies of the soil and vegetation characteristics found on serpentinites have emphasised the shallow, stoney and freely-draining nature of soils derived directly from the bedrock (Pichi-Sermolli, 1948; Spence, 1957; Martini and Orsino, 1969; Proctor and Woodell, 1971; Carter et al.,1987). Investigations into the weathering and chemical characteristics of Apennine serpentinite (Malquori and Cecconi, 1956; Veniale and van der Marel, 1963) have demonstrated that the main weathering products are clay minerals and it is possible that weathering of the underlying substrate was a prerequisite for peat formation in the field area. However, detailed micromorphological analyses of the basal sediments at Prato Mollo and Lago Nero were undertaken by R.I.Macphail (Appendix C), and these have shown that those sites had been sealed by the inwashing of silt. On the basis of the minerological and grain size characteristics of serpentinite and comparison with the nature of a local soil profile, he argues that the silt could not have been derived from weathering of local serpentinite rocks but instead appears to have originated from an upper (loessial) silty soil developed in drift deposits over the underlying bedrock. At Lago delle Lame peat formation was preceded by the deposition of 1 m of silty deposits and by comparison with Prato Mollo and Lago Nero it can be inferred that a freely-draining substrate was sealed by silt derived from local soils developed in drift deposits. Thus at these three sites water-logging, subsequent rooting by peat-forming plants and a reduction in decomposition rates occurred indirectly as a result of considerable disturbance of local soils.

(c) Anthropogenic factors

In the field area recent excavations of archaeological sites at altitudes of between 400 to 800 m have provided evidence of widespread human activity during the Chalcolithic and Bronze Ages (Maggi, 1983, 1984, in prep; Maggi and Formicola, 1978, Maggi et al.,1985). Numerous radiocarbon dates from archaeological contexts, charred cereal grains and evidence of mining suggest a major presence of human groups in eastern Liguria during the period 4540 to 3900 BP (R.Maggi, pers.comm). However the pollen sites reported in this study are located at higher altitudes where there is limited archaeological evidence of human activity. Flint assemblages in the higher mountains are most commonly found after deforestation and soil erosion have concentrated the artefacts into surface horizons so that the archaeological record is frequently fragmentary and liable to problems of differential preservation.

The colonisation and exploitation of high altitude resources in the Apennines and the western Italian Alps in prehistoric times is still not well understood (Nisbet and Biagi,1987; R.Maggi, pers. comm.) although there is mounting evidence in northern Italy of the spread of upland pastoralism during the Chalcolithic and Bronze Ages (Barfield et al., 1981; Nisbet, 1983; Greig, 1985; Nisbet and Biagi, 1987). Evidence of mixed stock-rearing and arable farming has been found at the lowest altitudes while in the highest areas there was probably limited summer transhumance between the valleys and high pastures (Nisbet and Biagi, 1987). On base-rich rocks in Liguria there is considerable faunal evidence of domestic stock rearing of sheep/goats and cattle from the Neolithic (Rowly-Conwy, 1989, in press) as well as continued hunting of Red deer until the late Bronze Age (Maggi, pers.comm.) although there is an absence of faunal evidence on more acidic substrates.

At one pollen site, Prato Mollo, the occurrence of late Chalcolithic arrowheads together with evidence of substantial soil disturbance (Appendix C) provide circumstantial evidence of human impact upon the local landscape, which in turn led to changes in the hydrology of the mire and the onset of peat formation at that site. Charcoal in the basal peat consisting of both in situ burned peat and coarse inclusions that had been transported onto the mire surface (Appendix C) indicate that disturbance at this period was associated with burning both on the site and within the catchment area. Burning of a forest can lead to improvements in both the quantity and nutritional quality of the food supplies available to herbivorous animals (Mellars, 1976). The Chalcolithic groups at Prato Mollo presumably used fire in association with hunting and possibly pastoral activites.

However charcoal in peat can occur as a consequence of several different processes in addition to deliberate forest burning by man (Moore et al., 1985, Patterson et al., 1987). A predominantly coniferous forest could have ignited periodically as a result of lightning strike or other natural causes, the mire surfaces may have burned, and soil erosion and deposition could have introduced recycled charcoal into the peat.

The high charcoal frequencies in the basal peat at Lago Nero (PAZ LN1, Figure 21) are problematical since there appears to be a lack of any clear response to fire in the basal pollen assemblages suggesting that some of the charcoal may have been introduced onto the mire surface as a result of soil erosion. There is a need here for separate dating of the peat and charcoal at this site. Similar problems could have affected the charcoal record at Casanova where the onset of Holocene peat formation may have been associated with slumping and redeposition of littoral sediments (PAZ CN3, Figure 27) although conceivably this could have occurred as a result of disruption of the local vegetation cover by fire.

Conclusion

It is probable that the lack of early Holocene sediments in the field area resulted from a combination of high summer temperatures with high evapotranspiration rates and a lack of surface run-off due to a closed vegetation cover. In these conditions small sites with limited water supply may have been prone to drying out leading to a cessation of peat formation. During the mid-Holocene peat growth probably occurred as a result of a complex of factors acting in unison. Locally (at Prato Mollo, Lago Nero and Lago delle Lame), disruption and redeposition of superficial deposits sealed initially freely-draining sites which may in some instances have been associated with Chalcolithic burning, hunting and pastoral activites. Similar processes appear to have contributed to the formation of many of the mires in the lower Rhône valley (Triat-Laval, 1978) where Neolithic deforestation and subsequent erosion were critical factors. Due to a lack of evidence of soil disturbance from the sites of Agoraie, Casanova and Bargone, the extent to which these processes affected all sites in the field area is uncertain, although a reduction in forest cover would have increased surface run-off but this would have taken place against a background of climatic change.

CHAPTER 14: MID- AND LATE HOLOCENE VEGETATION HISTORY OF EASTERN LIGURIA

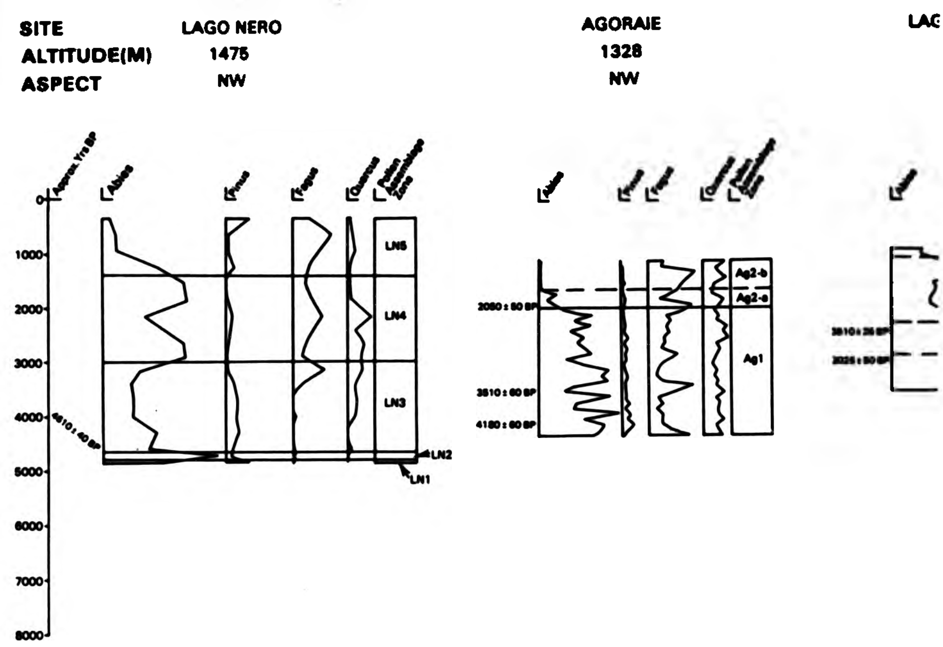
The major taxa *Abies*, *Pinus*, *Fagus* and *Quercus* from all six sites are plotted together on a common time scale in Figure 38 with the available radiocarbon dates. In order to compile the diagram it was assumed that similar biostratigraphical horizons may be broadly synchronous although that remains to be established by a secure radiocarbon-dating control.

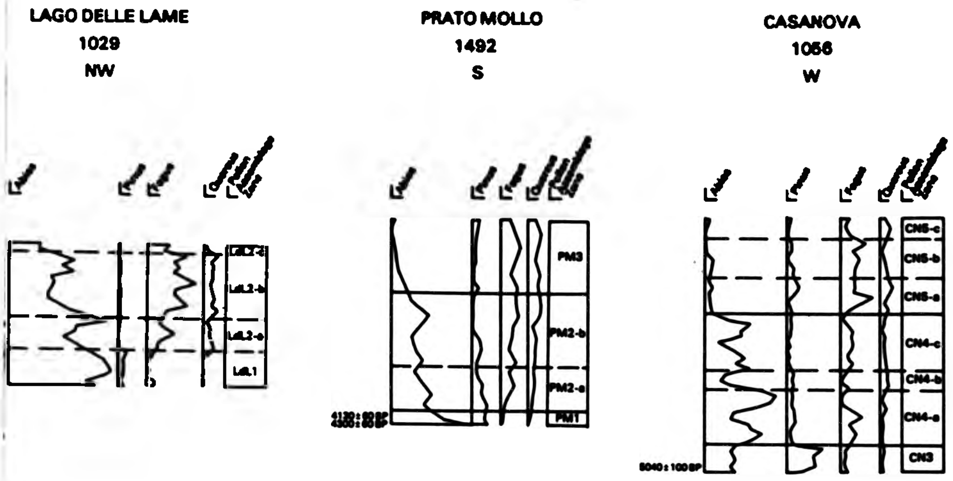
Figure 38 shows that *Abies* was the most frequently recorded taxon at sites situated at altitudes of over 1000 m with pollen percentages varying between 20% TLP and 60% TLP. During the late Holocene however, *Abies* virtually disappeared from the area and thereafter *Fagus* was abundant. The date at which *Abies* declined is uncertain although the radiocarbon date of the relevant biostratigraphical horizon at Agoraie suggests that it may have occurred around 2000 BP. In contrast to the higher, inland sites the sequence from Bargone indicates that *Abies* was abundant there during the period 8400 BP to 7500 BP but deciduous and evergreen oaks were dominant during the middle and late Holocene. Several factors have influenced the record of vegetation history as recorded in the pollen diagrams of which the most pertinent are (a) pollen preservation and (b) pollen recruitment.

(a) Pollen preservation

Pollen preservation is generally poor with 60% deterioration of all pollen and spores being typical of most

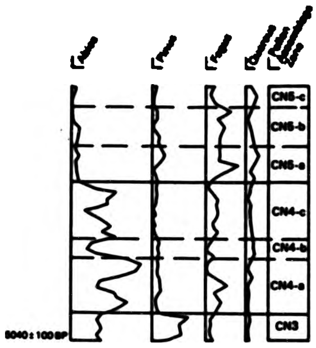
Fig. 38 Holocene vegetation developments in eastern Liguria.



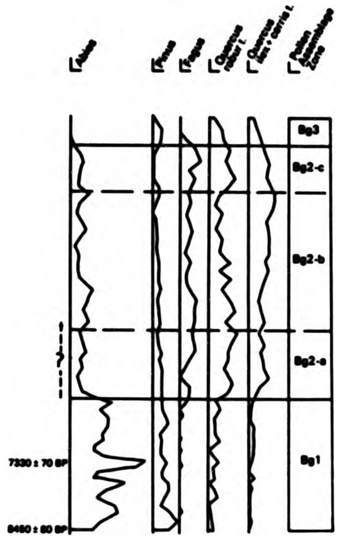


LAGO DELLE LAME
1029
NW
PRATO MOLLO
1492
S
CASANOVA
1056
W
PM3
PM2-b
PM2-a
PM1
CN5-c
CN5-b
CN5-a
CN4-c
CN4-b
CN4-a
CN3

CASANOVA
1056
W



BARGONE
831
S



samples. Differential preservation can result in the preferential removal of more easily deteriorated pollen types (Hall, 1981). As discussed in Part Four this problem appears to have affected the basal pollen assemblages of Lago delle Lame (LdL1), Prato Mollo (PM1) and Lago Nero (LN1 and LN2) where extremely high Abies percentages (over 60% TLP) together with poor pollen preservation and evidence of soil and sediment redeposition indicate that bias has been introduced into the counts which are unlikely to provide an accurate representation of the vegetation surrounding the sites at those times. Disruption of the pollen assemblages appears to have occurred at Casanova where high Pinus percentages (PAZ CN3) may have been caused by slumping and redeposition of littoral sediments which introduced older pollen assemblages into younger sediments, and are also unlikely to be a true representation of the contemporary local vegetation cover.

High frequencies of corroded pollen grains recorded, for example at Bargone and Casanova can be caused by oxidation (Havinga, 1964; Cushing, 1964, 1967; Birks, 1970; Lowe, 1982) probably due to a seasonally fluctuating water-table particularly on those sites with no stream inflow and with limited water-holding capacity. In the absence of clear stratigraphical indications of inwashed material from surface soil horizons, as for example those studied by Cushing (1964) and Birks (1970), it is likely that periodic drying out of surface horizons was a frequent occurrence. Conversely, stream-borne pollen can also undergo significant damage due to the effects of bank erosion and overland run-off (Peck, 1973) which may account for the high frequencies of both corroded and amorphous grains in the sediments at Agoraie.

While corrosion of pollen grains is due to chemical effects the cause of the amorphous condition is less certain. Cushing (1964) and Birks (1970) found that amorphous (degraded) grains were concentrated in minerogenic sediments and assumed that it indicates physical alteration but Lowe (1982) suggested that it may also result from chemical modifications. At Lago delle Lame an association of sedimentological changes and increases in amorphous grains (pollen preservation zones 1 and 3, Figure 14) suggest that they had undergone physical damage as a result of soil and sediment erosion. Likewise high frequencies of amorphous grains at Casanova (pollen preservation zone 1, Figure 29) may have occurred as a result of fires and local soil disturbance. However amorphous Abies grains in the basal sediments at Bargone (PAZ Bg1, Figure 34) are more difficult to interpret although one possibility is that littoral sediments underwent redeposition.

There are almost certainly serious discrepancies in the basal pollen assemblages from Prato Mollo (PM1), Lago delle Lame (LdL1), Lago Nero (LN1, LN2) and also in the sequence from Casanova (CN3). The preferential removal of more easily deteriorated pollen types and mixing of sediments has probably occurred and the data in these pollen zones are unlikely to be statistically reliable. However Figure 38 shows that there are striking similarities between the trends of the major taxa. The decline in Abies percentages is particuarly well marked suggesting that a fragmentation of the Abies forests had occurred on a regional scale during the late Holocene. This consistancy in the pollen diagrams together with the rich pollen assemblages (for example 140 taxonomic divisions were identified in the sequence from Casanova) suggest that the broad outline of vegetation developments has not been seriously affected by problems of poor pollen preservation.

(b) Pollen recruitment

The representation of different pollen types can vary according to the size of a site and the nature of the dominant transport mechanism (Bradshaw and Thompson Webb, 1985) with locally important but poorly dispersed pollen types being better represented in small sites (Heide and Bradshaw, 1982). Studies of modern pollen assemblages (de Beaulieu, 1977; Janssen,1981) have suggested that Abies pollen is very poorly dispersed and surface sample values remain low (6-7%) even at sites surrounded by Abies forest. Casanova and Lago delle Lame are both small sites with no or very limited stream catchments and there Abies would have been very abundant locally. Up to 90% of the pollen in the sediments at these sites would have been derived from within a few hundred metres at times of a closed forest canopy (Tauber, 1967; Jacobsen and Bradshaw, 1981) although as the canopy opened out a higher proportion of regionally-derived pollen would have been represented. In the field area, some of the highest Abies percentages were recorded at Agoraie which has a major stream input and at times of stream activity this site would have received a high proportion of pollen from both higher in the catchment area and from stream bankside communities (Peck, 1973; Bonny, 1978). Presumably Abies forest was dominant both at higher altitudes as well as in the immediate vicinity of the site. Prato Mollo is situated on a broad, exposed shelf and the mire surface could have received up to 40% of pollen influx from regional sources, this component being transported by rainfall and by winds blowing above the canopy (Jacobsen and Bradshaw, 1981). This may account for the slightly lower Abies percentages recorded at Prato Mollo although average counts of 20% TLP are not insignificant.

Therefore, Abies forest was the dominant vegetation type for much of the mid-Holocene at altitudes of at least 1000 m up to 1500 m. As shown in Figure 38, at high altitudes it was most commonly associated with Fagus whereas at the lower, more coastal site of Bargone, it may have grown locally with Fagus on north-facing slopes within a mixed deciduous-evergreen oak forest. Quercus may have been locally present at Lago Nero and possibly also at Agoraie, but in general oak frequencies are low (usually below 10%) in the sequences from the higher sites. Quercus is a prolific pollen producer and is frequently overrepresented at high altitudes (de Beaulieu, 1977; Markgraf, 1980). It is concluded, therefore, that oak was relatively unimportant in the montane forest communities. Tilia was not abundant although in sites at over 1000m this taxon was recorded only in samples with high Abies frequencies, indicating that it had been a minor element of the Abies- dominated forest. The Ulmus curves in the diagrams from Lago Nero (Figure 21), Prato Mollo (Figure 17) and Lago delle Lame (Figure 12) have striking similarities, possibly due to a periodic reduction in local water-tables enabling this tree to root in moist soils on the margins of the sites. At least at Lago Nero and Prato Mollo broad similarities in the trends of the Ulmus and Alnus curves may support this hypothesis.

The broad montane vegetation zone, therefore, consisted of Abies forest with Fagus, occasional Tilia and locally with Quercus, Ulmus and Acer. It can be seen in Figure 38 that the highest Fagus percentages (typically 10-20% TLP) were recorded at sites with north-west facing exposures (Agoraie, Lago delle Lame and Lago Nero) but were typically 10% or lower at the south and west-facing sites of Casanova and Prato Mollo. Here an abundance of light demanding shrubs and herbs occurred in the diagrams. In a region of great topographical diversity it is likely that a mosaic of plant communities existed in the past which would have been influenced by differences in altitude, insolation, edaphic conditions and variations in land-use.

An abundance of trees and relatively insignificant Corylus and Alnus frequencies indicate a tall forest community throughout the sequences at Agoraie (Figure 7) and Lago delle Lame (Figure 12). Herb assemblages are dominated by mire and stream edge pollen types as for example, Filipendula and Caltha type, and forest openings would have been confined largely to stream and mire edges. Frequent records of species of Plantago accompany the Abies decline at Agoraie (PAZ Ag2-a) suggesting the existence of patches of open grassland but these do not appear to have been extensive and the increase in herb percentages at the pollen-stratigraphical boundary is more likely to relate to a reduction in stream activity and an increase in mire edge habitats. Conversely Fagus reaches high values (generally over 20% TLP) suggesting a continuation of well-wooded conditions although it would be useful at Agoraie to sample the most recent sediments in order to establish whether or not the main trend continued into historical times.

Increases in Corylus and Alnus frequencies at Lago Nero (PAZ LN3, Figure 21) suggest temporary forest canopy openings at that time, possibly as a result of local soil disturbance. However the diagram shows only very limited responses from light demanding herbs and grasses and a closed forest canopy was re-established in LN4. As at Agoraie, Fagus percentages reach high values after the Abies decline (LN5) and increases in herbs suggest only a limited reduction in forest cover.

Prato Mollo is situated at a similar altitude to Lago Nero but in contrast high frequencies of heliophilous herbs and shrubs were recorded throughout the sequence (Figure 17). Major pollen influx from Gramineae growing on the mire surface would have depressed the percentages of other taxa, but high values of grasses and sedges together with Alnus and Corylus combined with low Fagus and Quercus frequencies suggest open forest conditions locally with extensive areas of grass and scrub. Figure 38 shows that in contrast to the north-west facing sites, the Abies decline at Prato Mollo is not associated with a major increase in Fagus woodland (PAZ PM3). Instead there are increases in Gramineae, Artemisia and Plantago lanceolata which indicate an expansion of open grassland communities within an increasingly open woodland canopy. This was almost certainly due to increased grazing pressures and deforestation in the area.

Similarly, at Casanova Fagus was never as abundant as on north-facing slopes. There periodic reduction of a dense fringe of Alnus around the site failed to produce a positive response in the tree pollen curves (CN4-b, Figure 27) although Corylus, grasses and Compositae Liguliflorae were abundant (PAZ's CN4-a, CN4-b). This is interpreted as indicating periodic reduction of the forest canopy with increased representation of light-demanding herb and shrub communities possibly due to the effects of burning and pastoral activities. However, unlike the Prato Mollo sequence, the Abies decline at Casanova was not immediately accompanied by a general increase in herbaceous pollen types (PAZ CN5-a) possibly due to the filtering effect of an Alnus fringe (Tauber, 1965,1967) and it was only after the diminution of the fringing vegetation that there are indications of major deforestation with increases in herbs indicative of pasture and heathland, bare ground and skeletal soils (CN5-b, CN5-c).

The available data from Bargone suggest the presence of Fagus within the oak forest during the mid- and late Holocene

(Figure 32). Fagus is absent from coastal Liguria at the present time, although charcoal analyses from prehistoric occupation levels in coastal eastern Liguria have also indicated a local Fagus presence during the Bronze and Iron Ages (Nisbet, 1985). The status of the herb assemblages are less certain due to doubts concerning the sampling procedures although the indications are of an understorey of dry heath and grassland with Calluna, Centaurea and Plantago species. In common with the higher sites major deforestation occurred comparatively recently, probably during the historical period.

While altitudinal variations and broad climatic differences determine the major vegetation stages found in mountain regions, local variations within a single vegetation zone is influenced by local site conditions and site history. Greater quantities of snow and precipitation on the northern mountain slopes of the field area (Cantu, 1977) combined with localised drift cover would have created more humid conditions and deeper soils in which soil moisture was readily available for luxuriant tree growth. In contrast, on south and west facing exposures high evapotranspiration rates combined with shallow soils would have made woodland regeneration a slower process.

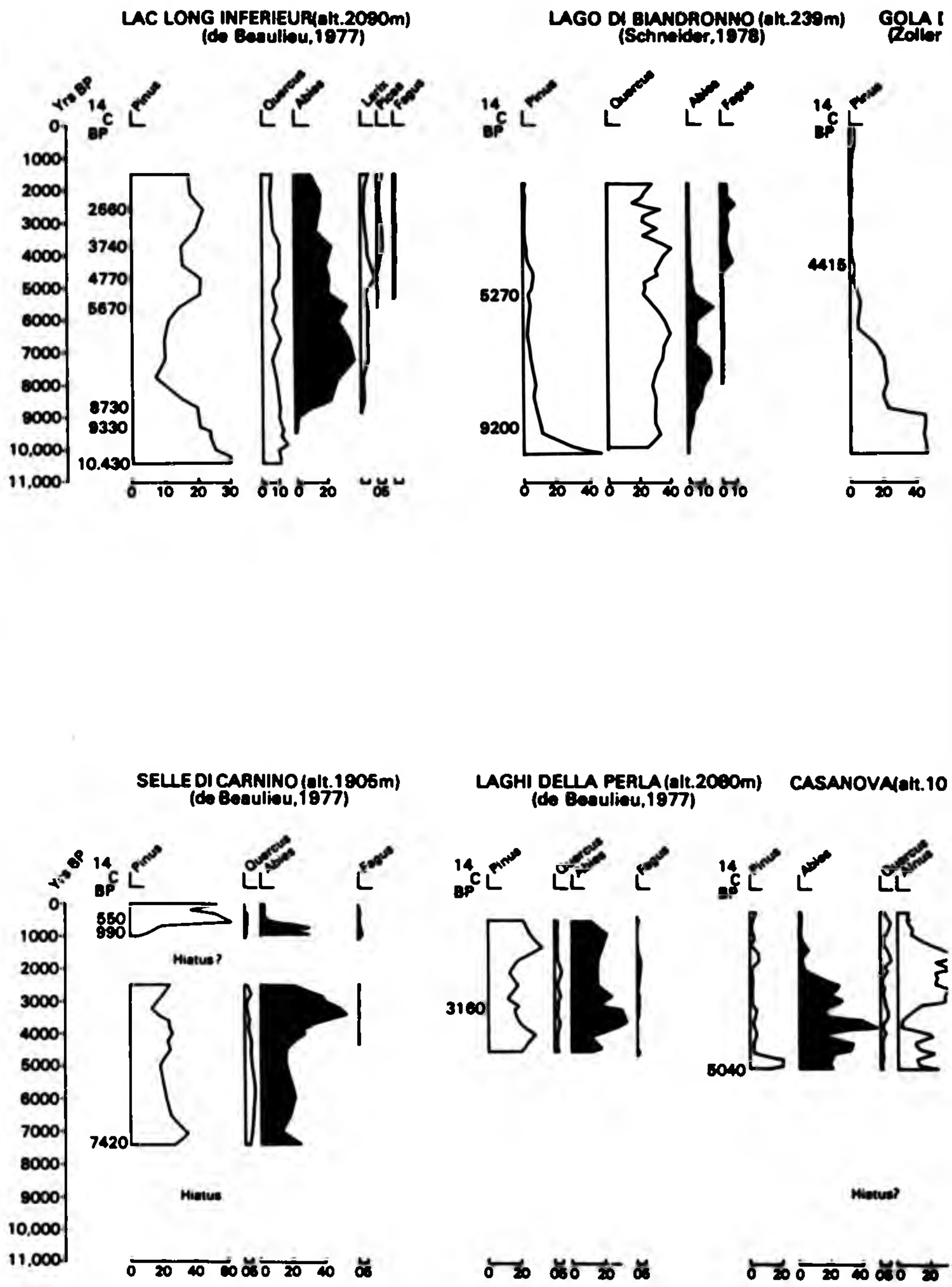
The significance of aspect on a small scale in eastern Liguria has been discussed in relation to present-day soil and vegetation (Macphail and Cruise, 1985) and on a regional scale by Barbero et al., (1975). Typically, grasslands in the north-west Mediterranean are nearly always situated on south-facing slopes (Barbero et al.,1975) where grazing and burning in the past has led to soil erosion and impoverishment leading to the development of grass and scrub as compared to the north-facing exposures where woodland regeneration is rapid. In the field area the full differentiation of these types of vegetation communities appears to have occurred during the most recent historical period as a result of localised grazing pressures and deforestation as indicated by the sequences from Prato Mollo and Casanova. Major deforestation in the field area probably occurred during the Middle Ages in common with other mountain regions in the north-western Mediterranean (de Beaulieu, 1977; Reille, 1977). However evidence of burning and soil erosion associated with Chalcolithic flints at Prato Mollo, and of burning and canopy openings at Casanova, suggest that these processes had begun during the prehistoric periods leading to gradual forest decline in the localities of those sites. The presence of deeper drift soils on northern slopes, as for example at Agoraie and Lago delle Lame, would have provided a deep rooting bed and would have protected the forests from degradation, while elsewhere, shallower soils combined with a greater intensity of land-use in the historic and prehistoric periods encouraged the development of grassland and soil impoverishment.

CHAPTER 15: THE HOLOCENE GROWTH AND DISTRIBUTION OF ABIES AND FAGUS IN NORTHERN ITALY AND SOUTH-EASTERN FRANCE

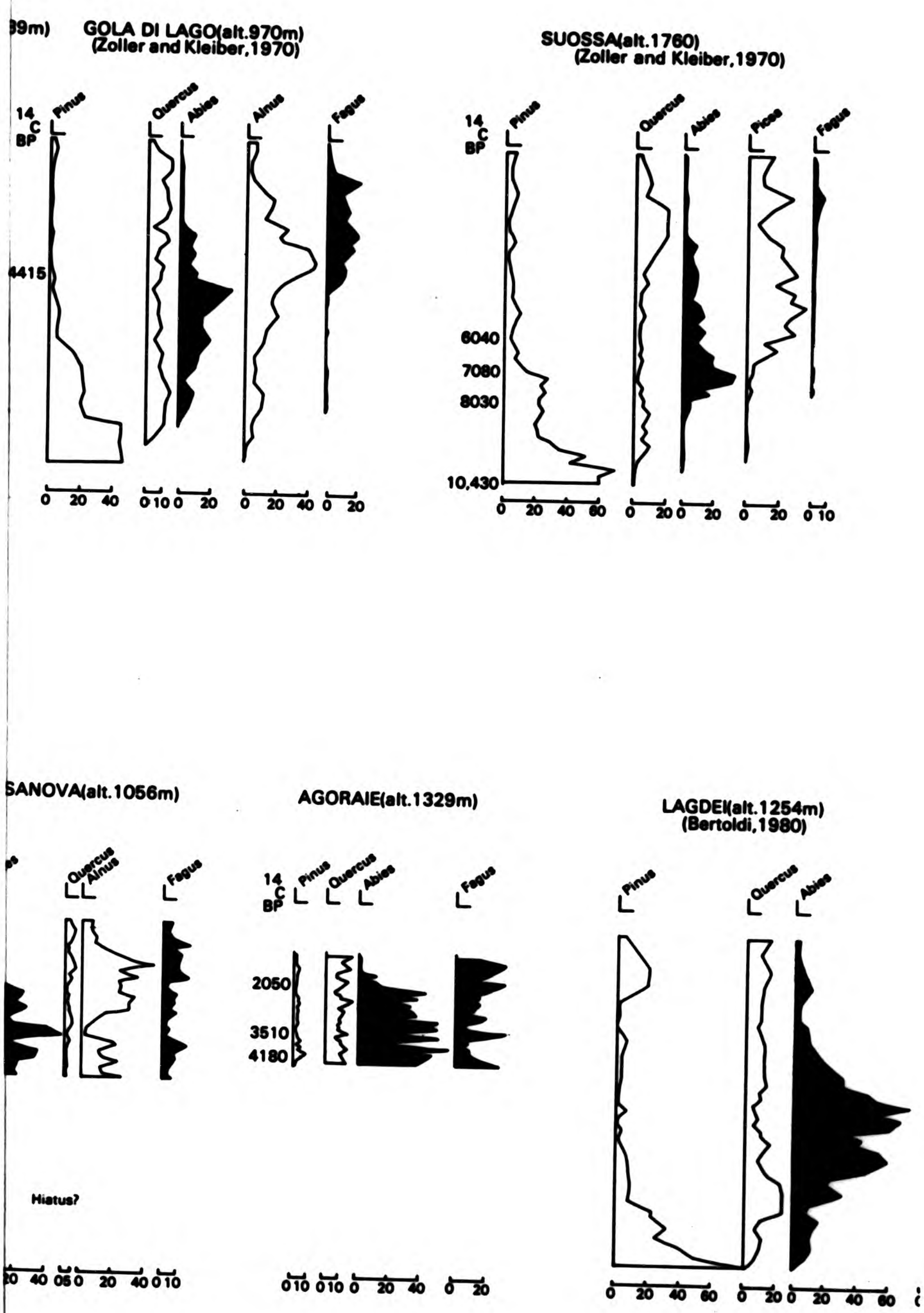
In order to review the Holocene development of *Abies* and *Fagus* in the region several radiocarbon-dated pollen sequences from the Alps and Maritime Alps have been selected for special consideration (Figure 39). Additional reference will be made to further sites in southern France and to the European pollen maps of Huntley and Birks (1983). No such detail is available for the northern Apennines but reference will be made as far as possible to what is currently known for this area.

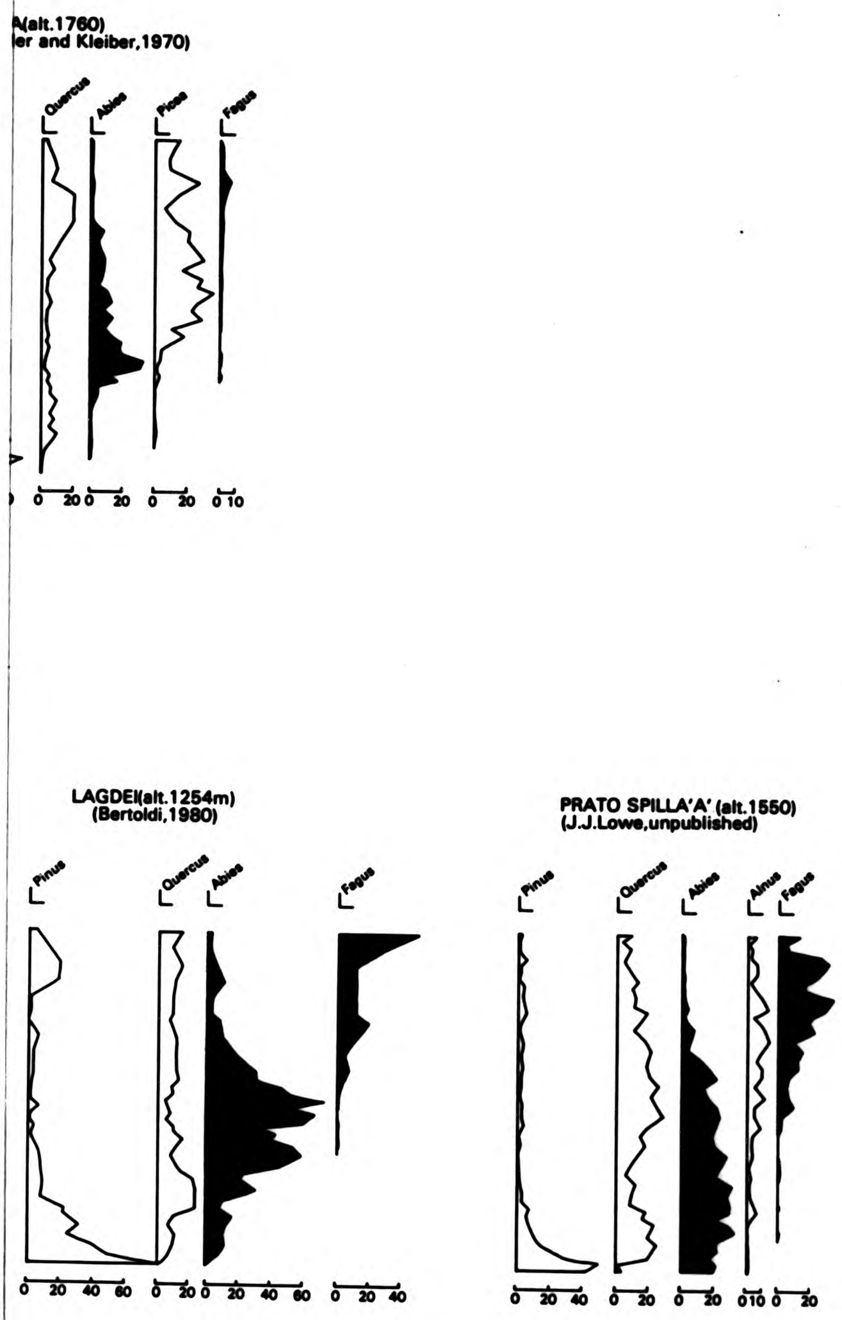
Abies has been recorded in early Holocene sediments in north-west Italy and southern Switzerland as for example at Lago di Biandronno (Schneider, 1978) and Suossa (Zoller and Kleiber, 1970). It subsequently expanded in those areas with migration rates of 40-50 m yr^{-1} (Huntley and Birks, 1983). Rapid expansion had ended by 7000 BP by which time it was well established in much of the west and central Alps, the Maritime Alps and southern France. It reached its maximum development in the montane and subalpine zones of the mountains where locally very high percentages were recorded, as shown in the summary diagrams from Lac Long Inferieur (de Beaulieu, 1977) and Gola di Lago (Zoller and Kleiber, 1970). In the Maritime Alps fir forests grew as high as at least 2000 m (de Beaulieu, 1977) and extended down to lower altitudes in northern Italy (Schneider, 1978) and almost to as far as sea-level in the lower Rhône valley (Triat-Laval,

Fig. 39 Holocene developments of Abies and Fagus in northern Italy and surrounding areas.



ling areas.


39m)
GOLA DI LAGO(alt.970m)
(Zoller and Kleiber,1970)
SUOSSA(alt.1760)
(Zoller and Kleiber,1970)
14 C BP
Pinus
Quercus
Abies
Alnus
Fagus
Picea
4415
6040
7080
8030
10,430
SANOVA(alt.1056m)
AGORAIE(alt.1329m)
LAGDEI(alt.1254m)
(Bertoldi,1980)
2050
3510
4180
Hiatus?


A(alt.1760)
ler and Kleiber,1970)
Quercus
Abies
Picea
Fagus
0 20 0 20 0 20 0 10
LAGDEI(alt.1254m)
(Bertoldi,1980)
Pinus
Quercus
Abies
Fagus
0 20 40 60 0 20 0 20 40 60 0 20 40
PRATO SPILLA'A' (alt.1550)
(J.J.Lowe,unpublished)
Pinus
Quercus
Abies
Alnus
Fagus
0 20 40 0 20 0 20 0 10 0 20

1978). In the Maritime Alps it grew with Pinus and Larix and appears to have been a major constituent of a mixed coniferous forest association (de Beaulieu, 1977). In contrast, early migration of Picea from the east (Huntley and Birks, 1983) enabled Picea to invade the highest parts of the Abies forest as at Suossa, (Zoller and Kleiber, 1970) from 7000 BP, although it remained abundant until after 4400 BP at the montane stage as shown by the pollen sequence from Gola di Lago (Zoller and Kleiber, 1970). Pollen diagrams from sites at lower altitudes on the northern edges of the Po Plain, as for example at Lago di Biandronno (Schneider, 1978), indicate that Abies occurred in a Quercus-dominated forest with Ulmus, Tilia and Fraxinus until after approximately 5000 BP. In the lower Rhône valley it would have been present in a mixed deciduous-evergreen oak and Pinus association between approximately 7000 BP and 4000 BP (Triat-Laval, 1978).

The early development of Abies in the northern Apennines is less well known due to a lack of radiocarbon-dated pollen sequences. In Figure 39 Bertoldi's (1980) diagram from Lagdei is shown in summary form. Bertoldi suggested that while Abies was present during the early Holocene it reached its maximum development during the period approximately 8000 BP to 5000 BP in common with vegetation sequences reported from the Alpine region. However as illustrated in the Prato Spilla "A" sequence in Figure 39, recent unpublished work on sites in the northern Apennines (J.J.Lowe, pers. comm.) has shown that Abies was probably abundant during the Lateglacial and was dominant from the earliest Holocene. This conflict with Bertoldi's interpretation of the sequence at Lagdei highlights the need for detailed work involving radiocarbon dating in the region. Nevertheless both sequences indicate that in the northern Apennines Quercus was also abundant with Tilia, Ulmus and Fraxinus which is possibly a reflection of the more southern location as compared to the more northerly Alpine sequences.

By 5000 BP Abies had undergone a second phase of rapid expansion into the central European mountains (Huntley and Birks, 1983) after which it was abundant in those areas, but it is clearly shown in Figure 39 that in southern Europe Abies experienced a decline during the mid- and late Holocene beginning from about 5000 BP. At Suossa the continued extension of Picea helped to reduce the Abies forest (Zoller and Kleiber, 1970). The pollen sequences from the Maritime Alps, for example Lac Long Inferieur, indicate that the development of Pinus cembra and Picea in the subalpine zone and the development of Fagus in the montane zone led to a reduction in the Abies forests, although it remained abundant in that area until major deforestation during the historical period (de Beaulieu, 1977).

In contrast to Abies, Fagus has been recorded in early Holocene sediments in the lower Rhône valley (Triat-Laval, 1978) as well as in southern Italy (Watts, 1985) and in cave sediments in the Maritime Alps (Renault-Miskovsky, 1972; Vernet, 1970). Nevertheless it failed to expand from these areas until the period 5000 to 6000 yrs BP when it migrated at rates of up to 250-300 m yr^{-1} (Huntley and Birks, 1983) into the European mountains and formed a continuous belt from the Carpathians to the Massif Central. Its greatest development was in the montane zone as at Gola di Lago (Zoller and Kleiber, 1970) but it also extended into lower altitudes of northern Italy (Schneider, 1978) and southern France (Triat-Laval, 1978).

The extension of Fagus into low altitudes and the decline of Abies in northern Italy, as for example at Lago di Biandronno (Schneider, 1978), was accompanied by additional changes within oak-dominated forests. Increases in Carpinus and Ostrya and declines of Tilia and Ulmus were interpreted by Schneider as responses to climatic deterioration at that time, but a close correspondence between changes in forest composition and good evidence of forest clearance suggest that anthropogenic clearance and secondary forest colonisation is a more likely explanation. Similar processes probably occurred in the lower Rhône valley (Triat-Laval, 1978).

At the lowest altitudes Abies may have been eliminated as a result of man's activities but at higher altitudes it was almost certainly affected by migration and penetration of the subalpine zone by Picea and Pinus cembra, and the montane zone by Fagus. The expansion of these trees is problematical as changes in forest composition could have been as a consequence of climatic deterioration but equally could relate to man's activities in the upper forest zones. The enigmatic nature of the extension of Picea into the western

Alps has been discussed by Markgraf (1970) and Tallantire (1973). Likewise the decline of Abies in montane zones could be interpreted in various ways. Firstly, the expansion of beech would have resulted in a depression of Abies percentages as beech pollen was added to the pollen sum. Secondly, Abies may have been displaced by Fagus as a result of climatic change, and thirdly, the Abies decline may have resulted from anthropogenic forest clearance, allowing beech to expanded into secondary woodlands.

As shown in Figure 39 the pollen sequences from Lagdei (Bertoldi, 1980) and Prato Spilla "A" (J.J.Lowe, pers.comm.) indicate that Fagus probably expanded in the northern Apennines during the mid-Holocene. It is uncertain when the Fagus population began to increase in this area although both workers have assumed, in common with dated sequences from neighbouring regions, that it would have occurred during the period 4000 to 5000 BP. It would appear that in the Apennines of Emilia-Romagna, Fagus had behaved very aggressively at the expense of the pre-existing Abies forest. In contrast however, the pollen sequences from eastern Liguria (for example Agoraie and Casanova, Figure 39) indicate that Fagus was present in the area for much of the mid-Holocene but it encountered considerable competition from Abies. This situation lasted until approximately 2000 BP at Agoraie, while beech was never so abundant at Casanova probably due to the effects of exposure and land-use as discussed in Chapter 14. The broad trend observed in diagrams from the Apennines of Emilia-Romagna and eastern Liguria appears to continue into western Liguria where the available diagrams (Figure 39) indicate that Abies was dominant until the Middle ages (de Beaulieu, 1977). Likewise Abies remained a prominant constituent of both subalpine and montane vegetation communities in the Maritime Alps while Fagus was always of secondary importance (de Beaulieu, 1977).

While the available data from the northern Apennines in general, is unsatisfactory, this does however, raise the possibility that the Abies decline in different parts of the region may have been significantly diachronous and as a consequence, the subsequent behaviour of Fagus was equally variable. The virtual disappearance of Abies from the northern Apennines suggests major environmental change in the region during the mid- and late Holocene. The manner in which such changes could have occurred is discussed in Chapter 16.

CHAPTER 16: THE ABIES DECLINE IN THE NORTHERN APENNINES AND EASTERN LIGURIA.

Several workers in the northern Apennines have ascribed the decline in *Abies* frequencies to displacement by *Fagus* due to cooler temperatures, increasing humidity and more evenly distributed rainfall patterns during the mid- and late Holocene (Chiarugi, 1936,1950; Ferrarini, 1962; Braggio Morucchio and Guido, 1975; Braggio Morucchio *et al*. 1978,1980; Bertoldi, 1980). This assumption has been based on the sensitivity of *Fagus* to atmospheric humidity which is necessary for its regeneration. In contrast to Italian workers, Guiot (1987), on the basis of multivariate time series analysis of a number of records from southern France, proposed that rainfall patterns were increasingly seasonally distributed from approximately 4500 yrs BP. The trend of late Holocene climatic changes in the north-western Mediterranean is not yet fully understood and it is difficult to account for the vegetation changes in the region on the basis of climatic change alone. Moreover the geographical pattern of present-day populations of *Abies* and *Fagus* in northern Italy and south-eastern France cannot easily be explained by climatic parameters.

There are two native species of *Abies* in Italy, both of which are included in the *Abies* pollen taxon. Only one species, *Abies alba*, is widespread throughout much of Italy while the other species,*Abies nebrodensis* is highly restricted to a single locality in Sicily (Pignatti, 1982).

The widespread Abies alba is abundant in the Italian Alps (Pignatti, 1982) and particuarly well-developed in the Maritime Alps (Barbero and Bono, 1970) but is infrequent in the northern Apennines except where planted (Giacobbe, 1950a). In south-eastern France Abies alba is predominant in the highest rainfall areas (generally over 1000 mm per annum) of the Maritime Alps where it extends from altitudes of between 500 m to 2100 m and occurs in a wide variety of vegetation associations (Barbero and Bono, 1970). Above approximately 1500 m it grows with Picea and Larix while between 800 m and 1500 m Abies frequently grows in pure stands or in a mixed association with Fagus. Below 800 m it occurs with a wide range of broad-leaved species including Quercus pubescens, Quercus ilex and Ostrya carpinifolia (Barbero and Bono, 1970). Fagus sylvatica is highly fragmented in the Maritime Alps and is generally more abundant at lower altitudes to the west and east of the main mountain chains (Ozenda, 1966, Barbero, 1970). In contrast, in the northern Apennines Fagus forest occurs as a continuous belt of vegetation above approximately 1000 m, and the few remaining fragments of Abies forests are generally, but not exclusively, located below the dominant beech zone (Giacobbe, 1950b,1969; Barbero and Bono, 1970).

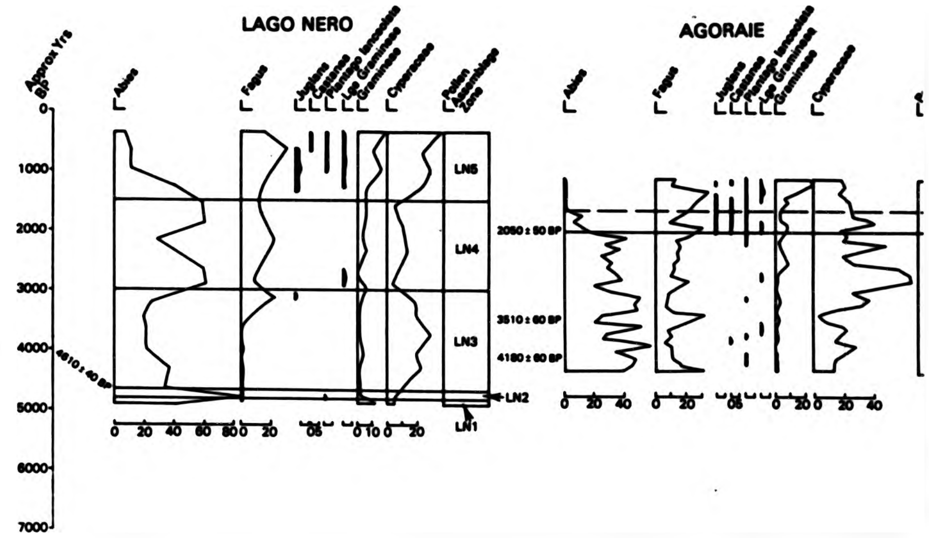
In order to explain the apparent affinity of the Italian Abies to dryer conditions at low altitudes, Giacobbe proposed the existence of an Italian subspecies Abies alba "apennina". This he argued, is more tolerant of drought than both the Alpine Abies alba and Fagus sylvatica. However, while it is possible that different genotypes exist within the Mediterranean fir populations (Huntley and Birks, 1983) it remains to be demonstrated that this can explain the present-day geographical distribution of those populations. More recently, it has been shown that Fagus also grows in submediterranean broad-leaved woods in the northern Apennines (Ubaldi and Speranza, 1985) and in southern France where it exhibits ecological and genetic adaptions to Mediterranean conditions (Thiebaut, 1972, 1982; Thiebaut et al. 1982). Therefore it is more likely that both Abies alba and Fagus sylvatica are highly adaptable species and that the ability to thrive in Mediterranean conditions is not a characteristic unique to the Italian fir.

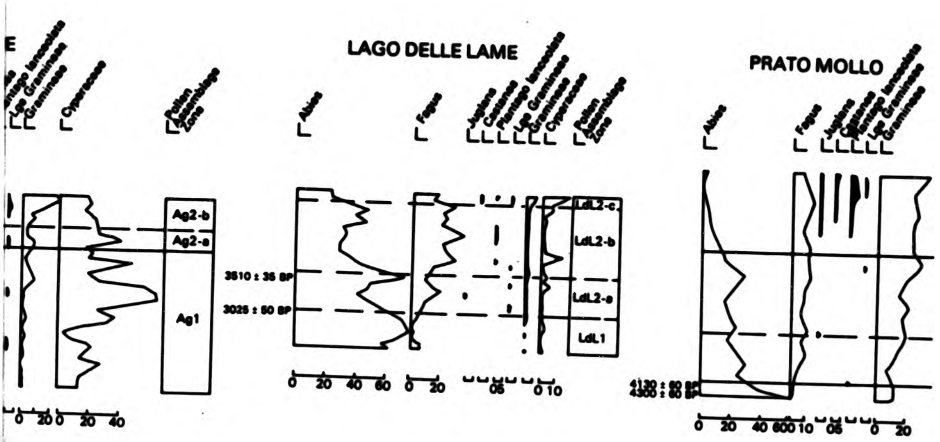
If the Abies decline in the northern Apennines had occurred as a result of immigration by Fagus and subsequent competition, the initial rate of Fagus growth would have been limited by the time needed for dispersal and maturation of a sufficient number of seed plants (Watts, 1973). Fagus is capable of rapid growth both by seedling establishment and by "sprouting" from the base, frequently colonising woodland gaps with close-set saplings to the exclusion of other species (Tansley, 1949; Probst and Baudière, 1984; Lemée, 1985; Koop and Hilgen, 1987). Woodland species with these characteristics are placed in a position to capitalise on a favourable set of environmental conditions and are able to close gaps rapidly (Shugart et al. 1981) and once established Fagus would have been highly competitive. However, as shown in Figure 38, the pollen sequences from eastern Liguria indicate that although the Abies decline was a regional phenomenon, it is not always associated with a major increase of Fagus percentages (Chapter 14) suggesting that diminution of the Abies forests was unlikely to have occurred solely as a result of an expanding Fagus population. Rather the pollen and macrofossil evidence suggest a considerable Fagus presence for much of the mid- and late Holocene but its development was probably inhibited by an extensive Abies forest already occupying suitable sites. Unpublished pollen stratigraphical data from two sites in the Apennines of Emilia-Romagna (J.J.Lowe, pers.comm., see Figure 39) have shown a close correspondance between the decline in Abies percentages, increase in Fagus and the first appearance of possible indicators of human activity, most notably cereal-type pollen, Olea type and Plantago species including Plantago lanceolata. Any forest disturbances for example as a result of human activity, would in favourable circumstances have enabled Fagus to occupy niches previously occupied by Abies.

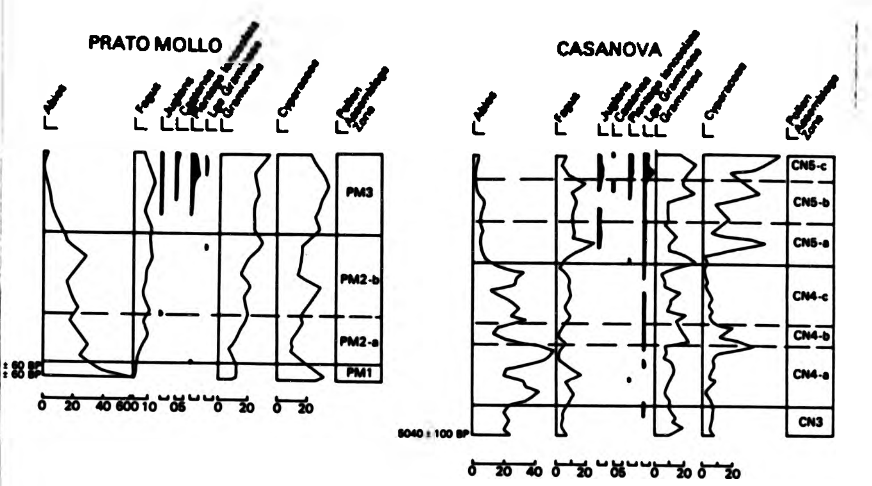
The stratigraphical position of several pollen taxa that may reflect anthropogenic activity (Bottema, 1980; Behre, 1981) are summarised in Figure 40 for the sites reported in this study. In general frequencies of these pollen types are low and their significance is problematical.

With the exception of a few rare grains Juglans and Castanea are only recorded at or above the decline in Abies frequencies. These tree types were probably present in Italy from 5000 BP (Huntley and Birks, 1983) but have only been

Fig. 40 Selected Anthropogenic indicators in eastern Liguria.



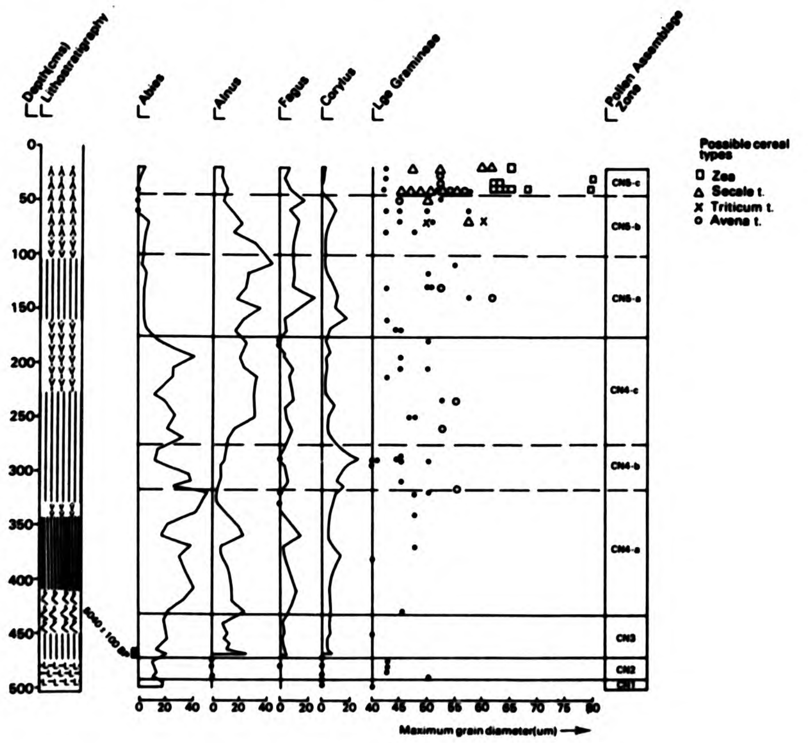

LAGO DELLE LAME
PRATO MOLLO
Ag2-b
Ag2-a
Ag1
LdL2-c
LdL2-b
LdL2-a
LdL1
3510 ± 35 BP
3025 ± 50 BP


PRATO MOLLO
PM3
PM2-b
PM2-a
PM1
0 20 40 60 0 10
05
0 20
0 20
CASANOVA
CN5-c
CN5-b
CN5-a
CN4-c
CN4-b
CN4-a
CN3
8040 ± 100 BP
0 20 40 0 20
05
0 20 0 20

recorded at high frequencies from the Roman period at which time they may have been cultivated (Zoller and kleiber, 1970; Schneider, 1978). Castanea charcoal has been recovered from archaeological sites in the northern Apennines but only from the Roman period, probably indicating cultivation from that time (Castelletti, 1986). Castanea and Juglans pollen can be poorly dispersed with high values only occurring close to the area in which it grows (Bottema,1974; Couteaux, 1981) although studies of pollen dispersal in mountain areas (Markgraf, 1980; Janssen, 1981) have shown that they can be transported upslope and recorded at low frequencies at high altitudes. The low frequencies at which Juglans and Castanea are recorded in the diagrams from eastern Liguria (Figure 40) are more likely to relate to changing pollen recruitment and enhanced long-distance pollen transport as the Abies canopy was opened up around the sites rather than to an abundance of the trees in the local vicinity. However Figure 40 shows that one or both taxa were nearly always recorded at the Abies decline (PAZ's LN5, Ag2-a, LdL2-c, PM3 and CN5-a) suggesting a considerable regional presence and probably cultivation within the field area at that time.

Large grasses are recorded throughout some of the pollen sequences but are problematical since both wild grasses and cereals can produce large grains of similar morphology (Faegri and Iversen, 1975; O'Connell, 1987). However during routine pollen counting it was noted that large Gramineae grains tended to increase in size upwards in the pollen profiles. Therefore the data were re-examined in detail from one site, Casanova, using a combination of diameter and annulus measurements. The results are presented in Figure 41. Size measurements are presented with tentative identifications of Secale, Zea, Triticum and Avena types. All others are likely to be of Hordeum type or were so badly deteriorated as to be indistinguishable. Figure 41 shows that grasses in the size range 40-48 microns are widely distributed throughout much of the core and are therefore considered to be grains from wild grasses in the area, possibly of the Hordeum group. Increases in size ranges are recorded in PAZ's CN4-b, CN5-a and CN5-c and are broadly coincidental with major changes in the frequencies of woody pollen types. If some of the large grasses represent cereal grains the changing size distribution could relate to the development of new strains and species being developed for agricultural purposes through time. Nevertheless there is no other evidence in the pollen diagram (Figure 27) to suggest cultivation in the immediate vicinity of the site so these grasses may be the weed flora associated with grazing and trampling or transported into the site by wind or on the feet of grazing animals. However Figure 41 indicates that there is a broad correlation between changes in the frequencies of the major woody taxa and the size range of the large grasses suggesting that changes in woodland composition could have been associated with such activities. If the distribution of grasses at this site is typical of other sites in the region there may be implications for the vegetation history as a whole and future work in the northern Apennines should

Fig. 41 Casanova-Large Gramineae.



investigate this point further in order to clarify the significance of these pollen types.

Low frequencies of Plantago lanceolata were recorded throughout the sequences from Bargone and Agoraie, although, in general, records at most sites increase after the Abies decline. Figure 40 also shows an increase in Gramineae percentages in PAZ's LN5, Ag2-b, PM3 and CN5-c, which together with records of Plantago lanceolata, suggest an extension of damp pasture and a reduction in the forest canopy possibly as a result of increased grazing pressures. Therefore, it is suggested that increases in Gramineae frequencies and records of Plantago lanceolata together with possible cereal pollen types, Juglans and Castanea all point to significant human activity in the region as a whole.

However, whether the impact of man in the study area was great enough to explain the changes in forest composition remains questionable. In some parts of the field area woodland conditions continued throughout the period covered by the pollen sequences and there is a lack of forest succesion phases of the sort observed in north European pollen diagrams (Iversen, 1949) that can be clearly related to human activity. Given the topographical, altitudinal and climatic characteristics of the sites in eastern Liguria it is probable that they were peripheral to the main areas of human activity during the prehistoric and historical periods. High altitude resources would have been exploited as seasonal pasture and for wood-cutting while agriculture was concentrated into valleys on terraces constructed for the purpose (Biagi, pers. comm., Maggi, pers. comm.). In these circumstances there are difficulties in distinguishing between the effects of man and purely natural phenomena as fewer obligate species occur in grassland than in arable land (Behre,1981). For example, as shown in Figure 40 increases in sedge pollen frequencies occur after the Abies decline at Lago Nero (LN5), Lago delle Lame (LdL2-c), Prato Mollo (PM3) and Casanova (CN5-a,b,c). These are likely to represent changes in mire vegetation as a result of increased light and higher water-tables. Whether this would have occurred as a result of increased rainfall and humidity or as a result of increased surface run-off due to a reduced canopy and reduced evapotranspiration rates is not possible to determine at present.

It is probable that some anthropogenic disruption of the Abies forest had occurred through either pastoralism or possibly even through cutting. This may have improved the statistical representation of Fagus and enabled beech to occupy previously held niches. Nevertheless evidence of major anthropogenic forest clearance is lacking and is inadequate to explain the virtual elimination of Abies from the pollen diagrams.

Workers in both the Apennines and the Maritime Alps have stressed that soil moisture is critical to Abies as seedlings are only able to germinate in cool, moist soil conditions (Giacobbe, 1969, Barbero and Bono, 1970). In contrast Fagus is highly sensitive to atmospheric humidity (Barbero, 1970; Thiebaut, 1972,1982) and as a result is able to thrive in freely draining situations but where atmospheric humidity is high. According to studies of present-day vegetation in the Maritime Alps below approximately 1500 m (Barbero, 1970, Barbero and Bono, 1970), at least locally, the distribution of Abies and Fagus is determined by edaphic conditions particuarly soil moisture and soil temperature. It is possible that near the southern limit of their tolerance ranges, variability in soil moisture regimes would have stimulated the development of Fagus in some areas but enabled Abies to survive in others, and that changes in the nature of local soils in the past would have led to permanent changes in the vegetation cover.

The northern Apennines is typically an area of steep slopes and deeply incised river valleys and any minor forest openings could have caused very considerable soil disruption and permanent changes in edaphic regimes. The impact of such soil disturbance on vegetation at various times during the mid- and late Holocene would have been determined not only by the intensity of human activity and resultant removal of the soil cover, but also by the presence of any superficial deposits and the nature of the underlying substrate after removal of those deposits. The pollen diagrams cited from Emilia-Romagna (Figure 39) are located in a region of flysh and sandstones (Moullade, 1978) where any disturbance of local soils and superficial deposits would have led to major changes in soil moisture regimes. This may account for the inability of Abies to compete with Fagus in that situation. Erosion of local drift soils in eastern Liguria was instrumental to the onset of peat formation at some sites (Chapter 13) but the underlying serpentinite lithology is rich in clay (Malquori and Cecconi, 1956; Veniale and van der Marel, 1963; R.I.Macphail, Appendix C) and would have retained some moisture-holding capacity thus enabling Abies to proliferate until erosion of the deeper serpentinite soils created the present-day situation of freely-draining, shallow rocky soils. Freely draining substrates would have been colonised by Fagus while Abies would have been prevented from competing and regenerating by soil conditions inimical to its development. Natural regeneration of Abies alba in the present-day environment of the Apennines is infrequent (Giacobbe, 1969) probably as a result of a long history of landscape degradation in the region. Should such changes have occurred against a background of increasing seasonality of rainfall as suggested by Guiot (1987), Abies would have been under conditions of considerable summer moisture stress leading to its eventual elimination.

While this hypothesis is conjectural at the present time, it would be possible to test it by a more thorough investigation of lithostratigraphical and pollen-stratigraphical variations within the region. Particular attention should be paid to radiocarbon dating of major pollen-stratigraphical horizons and the relationship between changes in vegetation, underlying lithology and mineral bands and inwashed material already known to exist within the sites of the northern Apennines.

CONCLUSIONS

It has been shown in this thesis that there is a lack of sedimentary successions in eastern Liguria which span the whole of the Holocene. Many of the peat sequences reported in this study only date back to 4000 to 5000 BP and at one site, Casanova, there is the strong probability of an interruption of sedimentation between the Late Glacial and the mid-Holocene. There is, therefore, an inadequate basic framework for the reconstruction of the former vegetation of the Ligurian Apennines since the end of the last glacial period.

The six sites reported in this study are located within a limited altitudinal and climatic range and most notably there is a lack of reliable biostratigraphical data from lowland areas. Many of the known sites in the field area are located within moraines and glacial drift deposits which are most commonly found on the highest mountain slopes. At lower altitudes there is frequently a lack of basins in which sediments could accumulate and although some deeply buried organic deposits have been discovered recently, these could not be sampled using the available manually-operated equipment.

The doubtful nature of some of the available radiocarbon dates and the scarcity of dated samples also prevent the establishment of a regional assessment of the vegetation history. Erosion of soils and charcoal at Prato Mollo, Lago Nero and Lago delle Lame suggest that the radiocarbon dates at those sites could have been contaminated by older carbon but equally, a "younging" effect could have occurred as a result of ground water contamination. At Casanova resumption of peat growth during the mid-Holocene may have been associated with slumping and redeposition of littoral sediments resulting in the mixing of sediments of differing ages. These problems may be typical of sites where human activity has disrupted local soils and sediments, but there is a lack of any studies of this question in the north-western Mediterranean and how widespread these problems may be in the region is unknown at present.

Poor stratigraphic resolution and slow sedimentation rates at Prato Mollo, Lago Nero and Lago delle Lame have resulted in only very generalised records whereas more detailed sequences were obtained from Agoraie and Casanova. However the most recent sediments at Agoraie were not sampled and there is a lack of records for the late Holocene from this site. Given the lack of radiocarbon-dated samples it is difficult to distinguish between the purely local effects of altitude, aspect, soils and land-use on the one hand from those of wider regional significance on the other. The various biostratigraphical zones from the six sites therefore provide a somewhat crude model of vegetation developments in eastern Liguria during the mid- and late Holocene.

In spite of these problems however, some conclusions can be drawn from the available data. The present-day montane vegetation in the field area consists of a continuous belt of Fagus woodland above approximately 1000 m but the pollen sequences reported in this study have shown that the present-day vegetation is a comparatively recent development. The mid-Holocene montane vegetation consisted of Abies forest with Fagus and occasionally Tilia, Quercus, Ulmus and Acer. However during the late Holocene (probably from about 2000 BP) there was major fragmentation of the Abies forests in the field area after which the woodlands were dominated by Fagus. In contrast the pollen sequence from the lower, more coastal site of Bargone indicates that Abies was abundant there during the period 8450 to 7330 BP but that deciduous and evergreen oaks were more frequent during the mid- and late Holocene. Major deforestation occurred on a regional scale in the study area, probably during the Middle Ages.

The lack of known early Holocene peat and lake sediments in a large part of north-western Italy suggests widespread climatic conditions inimical to peat development during that period. The concurrent development of peat deposits in the field area from 4000 to 5000 BP and the major forest changes widely reported in pollen sequences from the southern Alps and south-eastern France together suggest that peat initiation during the mid-Holocene could have occurred as a result of widespread cooler and/or moister conditions. However at Prato Mollo, Lago Nero and Lago delle Lame there are strong indications that peat formation only occurred after major disruption of local soils. At one site, Prato Mollo, the occurrence of late Chalcolithic flints together with evidence of soil disturbance and burning provide circumstantial evidence of human impact upon the local landscape which in turn led to changes in the hydrology of the site. Nevertheless the pollen sequences from eastern

Liguria do not provide evidence for vegetation developments during the early Holocene nor for the initial disturbances of that vegetation cover. Until these can be assessed it is difficult to separate climatic from man-induced effects on the vegetation and landscape.

A mid- and late Holocene decline in *Abies* forests has been widely reported throughout the north-western Mediterranean region. However it is probable that forest responses in the various altitudinal and climatic zones would have been highly variable and that the *Abies* decline was not the result of a single event throughout the region. In the highest parts of the mountains in the southern Alps and south-eastern France expansion of *Picea* and *Pinus cembra* would have led to a decrease in *Abies* percentages although this taxon remained abundant in the Maritime Alps until the present-day. In contrast pollen-stratigraphical data from lower altitudes in northern Italy and southern France suggest that *Abies* was eliminated as a result of man's activities in those areas. Although there is an overall lack of radiocarbon-dated pollen sequences from the northern Apennines, available data indicate that the fragmentation of *Abies* forests could have been significantly diachronous throughout the area and as a consequence the subsequent behaviour of *Fagus* was equally variable. Available data from the northern Apennines suggest that significant soil disruption was a major feature of the mid- and late Holocene and this together with the occurrence of human "indicator" pollen types at critical levels in the sequences from both

Liguria and Emilia-Romagna suggests that human activity could have had a major influence on forest changes in the region as a result of significant disruption of local soils. It is possible that near the southern limit of their tolerance ranges, variability in soil moisture regimes would have stimulated the development of Fagus in some areas but enabled Abies to survive in others, and that changes in the nature of local soils would have led to permanent changes in the vegetation cover.

However the critical problem at the present time is the lack of continuous dated Holocene records from a representative range of altitudinal and climatic environments. The existence of long stratigraphical sequences in Emilia-Romagna suggest that continuous botanical records do exist in the northern Apennines. Given a secure radiocarbon-dating control these sites could provide the basic framework with which to reconstruct the development of major forest stands in the region during the early Holocene and to identify the earliest phases of significant human impact on the vegetation and the landscape. In order to distinguish the influence of regional (possibly climatic) events from purely local site factors it is necessary to establish a temporal record of sedimentation characteristics across a range of sites in the region, including those sites containing stratigraphical discontinuities. Climatic fluctuations during the Holocene should be reflected in regional patterns of varying growth rates of peat sediments in addition to variations in pollen concentration (and possibly pollen preservation) data. Given this background information it would be possible to establish a more conclusive evaluation of the timing and nature of man's impact upon the vegetation and landscape. Biostratigraphical records from sites on a variety of bedrock lithologies situated within a wider altitudinal range would permit an assessment of the extent to which the mid- and late Holocene forest changes were time-transgressive throughout the region. At those sites where "bulk" radiocarbon dates may be unreliable due to the recycling of older carbon (resulting from disruption of local soils), accelerator dating of separate chemical fractions (e.g charcoal and humic acids) might lead to the identification of errors incurred as a result of such complications.

BIBLIOGRAPHY

ACCORSI, C.A. and FORLANI, L. (1976). Schede per una Flora Palinologica Italiana. contributo n.4: Schede di nuova impostazione. Archivio Botanico e Biogeografico Italiano, 52(1/2), 58-111.

AITA, L., MARTINI, E. and ORSINO, F. (1979). Flora e vegetazione dei laghetti delle Agoraie e zone limitrofe (Appennino Ligure orientale). Lavori della Società Italiano di Biogeografia, nuova serie, 4, 163-230.

ANDERSEN, S.T. (1960). Silicon oil as mounting medium for pollen grains. Danmarks Geologiske Undersøgelse Ser. IV, 4(1), 1-24.

ANDERSEN, S.T. (1970). The relative pollen productivity and pollen representation of North European trees, and correction factors for the tree pollen spectra. Danmarks Geologiske Undersøgelse, 96, 1-87.

ANDERSEN, S.T. (1974). Wind conditions and pollen deposition in a mixed deciduous forest II. Seasonal and annual pollen deposition 1967-1972. Grana, 14, 64-77.

ANDREW, R. (1984). A Practical Pollen Guide to the British Flora. Quaternary Research Association Technical Guide No. 1., Cambridge.

ARMANDO, E., CHARRIER, G., PERETTI, L. and PIOVANO, G. (1975). Richerche sull'evoluzione del clima e dell'ambiente durante il Quaternario nel settore delle alpi occidentali italiane. Bollettino del Comitato Glaciologico Italiano, 23, 7-25.

AROBBA, D. (1976). Schede per una Flora Palinologica Italiana. Contributo n.3: Raccolte della costa tirrenica. Archivio Botanico e Biogeografico Italiano, 52(1/2), 9-57.

AUBERT, J., CHARPIN, H. and CHARPIN, J. (1959). Étude palynologique de quelques Oléacées de Provence. Pollen et Spores, 1, 7-13.

AUBERT, J., CHARPIN, H., CHARPIN, J. and HEYDACKER, F. (1962). Morphologie des pollens de quelques plantains de Provence. Pollens et Spores, IV(2), 273-282.

BAFFICO, O., BIAGI, P. and MAGGI, R. (1983). Il Mesolitco. In MAGGI, R. (ed). 33-44.

BARBERO, M. (1970). A propos des Hêtraies des Alpes maritimes et ligures. Ann. Fac. Sc. Marseilles, 44, 43-78.

BARBERO, M. and BONO , G. (1970). Les sapinières des Alpes maritimes, de l'Authion à la Ligurie et de la Stura au Tanaro. Veröff. des Geobot. Inst. E.T.H. Rubel Zürich. 43, 140-168.

BARBERO, M., BONIN, G. and QUÉZEL, P. (1975). Les pelouses ecorchées des montagnes Circum-mediterranéenes. Phytocoenologia. 1(4), 421-459.

BARFIELD, L.H., BARKER, G.W.W., CHESTERMAN, J.T., PALS, J.P. and VOORRIPS, A. (1981). Excavations at Monte Covolo, Villanuova sul Clisi, Brescia (1972-73). Part II. Annali del Museo di Gavardo. 13, 6-89.

de BEAULIEU, J.L. (1977). Contribution pollenanalytique à l'histoire tardiglaciaire et holocène de la végétation des Alpes méridionales française. Thèse présentée a l'Université d'Aix-Marseille III. C.N.R.S. No. A.O. 12669.

de BEAULIEU, J.L. (1982). Palynological subdivisions of the Holocene in France. Striae. 16, 106-110.

BEHRE, K.E. (1981). The interpretation of anthropogenic indicators in pollen diagrams. Pollen et Spores. XXIII(2), 225-245.

BENGTSSON, L. (1979). Chemical Analysis In BERGLUND, B.E. (ed). Palaeohydrological Changes in the Temperate Zone in the Last 15,000 years. Subproject B. Lake and Mire Environments, Vol.II. Specific Methods. International Geological Correlation Programme, Project 158, 113-131.

BENNINGHOFF, W.S. (1962). Calculation of pollen and spore density in sediments by addition of exotic pollen in known quantities. Pollen et Spores, 4, 332-333.

BERNINI, M., CREMASCHI, M. and TELLINI, C. (1980). La Paleosuperficie di Sélvapiana (Appennino Reggiano): aspetti geomorfologici e paleopedologici. Università degli Studi di Parma, Volume dedicato a Sergio Venzo. 77-97.

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.

BIAGGI, P. and MAGGI, R. (1984). Aspects of the Mesolithic age in Liguria. Preistoria Alpina - Museo Tridentino di Scienze Naturali. 19, 159-168.

BIAGI, P. and NISBET, R. (1986). Popolazione e territorio in Liguria tra il XII e il IV millennio b.c. In Scritti in ricordo di Graziella Massari Gamballo e di Umberto Tocchetti Pollini. Comune di Milano, Milan, 19-27.

BIRKS, H.J.B. (1970). Inwashed pollen spectra at Loch Fada, Isle of Skye. New Phytologist. 69, 807-820.

BONNY, A.P. (1978). The effect of pollen recruitment processes on pollen distribution over the sediment surface of a small lake in Cumbria. J. Ecology. 66. 385-416.

BOTTEMA, S. (1974). Late Quaternary vegetation history of Northwestern Greece. Ph.d thesis, University of Groningen.

BOTTEMA, S. (1980). On the history of the Walnut (Juglans regia L.) in southeastern Europe. Acta Botanica Neelandica. 29(5-6), 343-349.

BRADSHAW, R. and THOMPSON WEBB III, (1985). Relationships between contemporary pollen and vegetation data from Wisconsin and Michigan, U.S.A. Ecology. 66(3). 721-737.

BRAGGIO MORUCCHIO, G. and GUIDO, M.A. (1975). Analisi palinologica dei depositi lacustri postglaciali del lago delle Agoraie di Mezzo (Appennino ligure). Archivio Botanico e Biogeografica Italiano. 51, 48-73.

BRAGGIO MORUCCHIO, G., GUIDO, M.A. and MONTANARI, C. (1978). Studio palinologico e vegetazione della torbiera del Lajone presso Piampaludo (Gruppo M.Beigua, Appennino ligure occidentale). Archivio Botanico e Biogeografico Italiano. 54(3/4), 115-136.

BRAGGIO MORUCCHIO, G., GUIDO, M.A. and MONTANARI, C. (1980). Studio palinologico dei sedimenti postglaciali dei Fociomboli (Alpi Apuane). Atti Società Toscana Scientifica Naturale. Serie B. 87, 219-227.

BRAGGIO MORUCCHIO, G. and DE VINCENZI, L. (1980). Schede per una Flora Palinolgica Italiana. N.61-66. Archivio Botanico e Biogeografico Italiano. 56(1/2), 55-69.

BRAGGIO MORUCCHIO, G. and DE VINCENZI, L. (1981). Schede per una Flora Palinologica Italiana N.80-84. Archivio Botanico e Biogeografico Italiano. 57(1/2), 17-28.

BRYAN DAVIS, M. (1965). A method for determination of absolute pollen frequency. In KUMMEL, B.G. and RAUP, D.M. (eds). Handbook of Palaeontological techniques. Freeman, San Francisco, 674-686.

BRYAN DAVIS, M. (1973). Redeposition of pollen grains in lake sediment. Limnology and Oceanography. 18, 44-52.

BRYAN DAVIS, M., MOELLER, R.E. and FORD, J. (1984). Sediment focusing and pollen influx. In HAWORTH, E.Y and LUND, J.W.G (eds). Lake Sediments and Environmental History. Leicester University Press, 261-294.

CANTU, V. (1977). The climate of Italy. In WALLEN, C.C. (ed). Climates of central and southen Europe. World Survey of Climatology 6. Elsevier, 127-173.

CARTER, S.P., PROCTOR, J. and SLINGSBY, D.R. (1987). Soil and vegetation of the Keen of Hamar serpentine, Shetland. J. Ecology. 75, 21-42.

CASTELLETTI, L. (1986). Ricerche sui carboni provenienti da scavi archeologici nel bacino del fiume Magra (province di La Spezia, Lucca e Massa Carrara). In Scritti in ricordo di Graziella Massari Gaballo e di Umberto Tocchetti Pollini. Commune di Milano, 41-45.

CHARRIER, G. (1970). Ricerche sull'evoluzione del clima e dell'ambiente durante il Quaternario nel settore delle Alpi Occidentali Italiane. 1.I legni fossili di larice del Colle di Sestriere (Torino) datati con il metodo C14. Allionia. 16, 155-164.

CHARRIER, G. and PERETTI, L. (1977). Ricerche sull'evoluzione del clima e dell'ambiente durante il Quaternario nel settore delle Alpi occidentali Italiane. VI. Nuovi contributi allo studio del Neoglaciale nell'alta Valle della Dora Riparia: la serie di San Sicario (Cesana). Allionia. 22, 130-156.

CHIARUGI, A. (1936). Ricerche sulla vegetazione dell'Etruria Maritima. 1. Cicli forestali postglaciali nell'Appennino Etrusco attraverso l'analisi pollinica di torbe e depositi lacustri presso l'Alpe delle Tre Potenze e il M.Rondaio. Nuova Giornale Botanico Italiano. Nuova serie, 43, 3-61.

CHIARUGI, A. (1950). Le epoche glaciali dal punto di vista botanico. Problemi attuali di Scienze e Cultura. 16, 55-110.

CLARK, R.L. (1982). Point count estimation of charcoal in pollen preparations and thin sections of sediments. Pollen and Spores. XXIV, (3-4), 523-535.

COURTY, M.A. (1982). Etude géologique de sites archéologiques Holocènes: définition des processes sédimentaires et post-sedimentaires, caracterisation de l'impact anthropique. Essai de méthodologie. Thèse presentée a l'Université de Bordeaux I. No. 1726.

COUTEAUX, M. (1981). A propos de la signification pollinique de Castanea en Dordogne. Sa dispersion actuelle et sa signification dans les sediments. Pollen et Spores, XXIII(3-4), 433-439.

CREMASCHI, M. and PAPANI, G. (1975). Contributo preliminare alla Neotettonica del margine Padano dell'Appennino: le forme terrazzatte comprese tra Cavriago e Quattro Castella (Reggio E). Ateneo Parmense. 2. acta naturalia, 11, 335-371.

CREMASCHI, M., BIAGI, P., ACCORSI, C., MAZZANTI, M., RODOLFI, G., CASTELLETTI, L. and LEONI, L. (1982). Il sito Mesolitico di Monte Bagioletto (Appennino Reggiano) nel quadro delle variazioni ambientali Oloceniche dell'Appennino Tosco-Emiliano. Emilia Preromana - Rivista di Preistoria e protostoria per l'Emilia Romagna. 9/10, 11-45.

CUSHING, E.J. (1964). Redeposited pollen in late-Wisconsin pollen spectra from east-central Minnesota. American J. of Science. 262, 1075-1088.

CUSHING, E.J. (1967). Evidence for differential pollen preservation in late Quaternary sediments in Minnesota. Review of Palaeobotany and Palynology. 4, 87-101.

ELTER, P. (1975). Introduction à la géologie de l'Apennin septentrional. Bulletin de la Société Géologique de France. 6, 956-962.

ERDTMAN, G., BERGLUND, B. and NILSSON, S. (1961). An Introduction to a Scandinavian Pollen Flora. Vol. I, Almqvist and Wicksell, Stockholm.

FAEGRI, K. and IVERSEN, J. (1975). Textbook of Pollen Analysis, Blackwell Scientific Publications, Oxford.

FAO-UNESCO, (1981). Soil map of the world. 1:5,000,000. Volume V. Europe. Unesco, Paris.

FEDERICI, P.R. and TELLINI, C. (1983). La geomorfologia dell'alta Val Parma. Rivista Geografica Italiana. 90(3-4), 393-428.

FERRARINI, E. (1962). Analisi polliniche di depositi lacustri dell'Appennino lunigianese con osservazioni sulla vegetazione attuale. Accademia Italiana di Scienze Forestali. 11, 61-95.

FRANCIS, E. and HALL, V. (1985). Preliminary investigations into the causes of "clumping" during standard pre-treatments using Lycopodium spore tablets in absolute pollen analysis. Circaea. 3(4), 151-152.

GATTI, L. (1976). L'economia agricola del Chiavarese nei basso medioevo. In Studi Genuensi X (1973-74). Istituto Internazionale di Studi Liguri, 75-120.

van GEEL, B. (1978). A palaeoecological study of Holocene peat bog sections in Germany and The Netherlands, based on remains of fungi, algae, cormophytes and animals. Review of Palaeobotany and Palynology. 25(1), 1-120.

GENTILE, S. (1974). Ricerche sui faggeti dell'Appennino ligure. Nota Fitosociologica. 9, 131-138.

GIACOBBE, A. (1950)a. L'ecologia dell'Abete Bianco. Nota II. Ricerche storiche e geografiche sull'Abete bianco. Archivio Botanico e Biogeografico Italiano. 26(1), 1-149.

GIACOBBE, A. (1950)b. L'ecologia dell'Abete Bianco. Nota III. Caratteri floristici e climatici dell'Abete bianco. Archivio Botanico e Biogeografico Italiano. 26, 186-221.

GIACOBBE, A. (1969). La rinnovazione naturale dell'abete appennino. Annali Accademia Italiana di Scienze Forestale. 18, 227-289.

GOLA, G. (1912). La vegetazione dell'Appennino piemontese. Annali di Botani. X, 189-338.

GOSSEAUME, E. (1979). Le relief de l'Apennin septentrional. L'Information Geographique. 43(5), 229-238.

GREIG, J. (1985). Agricultural diversity and sub-alpine colonisation; the story from pollen analyses at Fiavé. In MALONE, C. and STODDART, S. (eds). Papers in Italian Archaeology IV. Part ii. Prehistory. BAR International Series 244. 296-315.

GRIFFIN, J.J. and GOLDBERG, E.D. (1979). Morphologies and origin of elemental carbon. Science. 206, 563-565.

GRUPPO DI STUDIO DELLE UNIVERSITA EMILIANE PER LA GEOMORFOLOGIA (1976). Geomorfologia dell'area circostante La Pietra di Bismantova (Appennino reggiano). Bollettino del Servizio Geologico d'Italia. XCVII, 107-214.

GUIOT, J. (1987). Late Quaternary climatic change in France estimated from multivariate pollen time series. Quaternary Research. 28, 100-118.

HALL, S.A. (1981). Deteriorated pollen grains and the interpretation of Quaternary pollen diagrams. Review of Palaeobotany and Palynology. 32, 193-206.

HAVINGA, A.J. (1964). Investigation into the differential corrosion susceptibility of pollen and spores. Pollen et Spores, 6, 621-635.

HEIDE, K.M. and BRADSHAW, R. (1982). The pollen-tree relationship within forests of Wisconsin and Upper Michigan, U.S.A. Review of Palaeobotany and Palynology, 36, 1-23.

HUNTLEY, B. and BIRKS, H.J.B. (1983). An atlas of past and present pollen for Europe 0-13.000 years ago. Cambridge University Press, Cambridge.

IVERSEN, J. (1949). The influence of prehistoric man on vegetation. Danmarks Geologiske Undersøgelse IV. Raekke. 3(6), 6-25.

JACOBSON, G.L. and BRADSHAW, R.H.W. (1981). The selection of sites for paleovegetational studies. Quaternary Research. 16, 80-96.

JALUT, G. (1977). Végétation et climat des Pyrénées méditerranéennes depuis quinze mille ans. Archives d'Ecolgie Prehistorique, Toulouse.

JANSSEN, C.R. (1981). Contemporary pollen assemblages from the Vosges (France). Review of Palaeobotany and Palynology. 33, 183-313.

JøRGENSEN, S. (1967). A method of absolute pollen counting. New Phytologist, 66, 489-493.

KERNEY, M.P., PREECE, R.C. and TURNER, C. (1980). Molluscan and plant biostratigraphy of some late Devensian and Flandrian deposits in Kent. Proceedings of the Royal Society, B, 291, 1-43.

KOOP, H. and HILGEN, P. (1987). Forest dynamics and regeneration mosaic shifts in unexploited Beech (Fagus sylvatica) stands at Fontainebleu (France). Forest Ecology and Management. 20, 135-150.

LEMÉE, G. (1985). Role des arbres intolérants à l'ombrage dans la dynamique d'une hêtraie naturelle (forêt de Fontainebleu). Acta Oecologica/Oecologica Plantarum, 6(20)1, 3-20.

LO SACCO, U. (1949). La glaciazione quaternaria dell'Appennino settentrionale. Rivista Geografica Italiana. 56, 90-152.

LO SACCO, U. (1982). Gli antichi ghiacciaci dell'Appennino settentrionale. Atti della Società dei Naturalisti e Matematici di Modena. CXIII, 1-224.

LOWE, J.J. (1982). Three Flandrian pollen profiles from the Teith valley, Perthshire, Scotland. II. Analysis of deteriorated pollen. New Phytologist. 90, 371-385.

MACPHAIL, R.I. (1989, in press). Soil report on Pianacchia di Suvero, near Rochetta, GE, Liguria. Archeologia in Liguria III. Soprintendenza Archeological della Liguria.

MACPHAIL, R.I. and CRUISE, G.M. (1985) Preliminary soil and vegetation report on Castellaro di Uscio. In MAGGI, R. et al., 73-80.

MAGGI, R. (1983). Dall'Età del Rame fino alla fine dell'Età del Bronzo. In MAGGI, R. (ed). Preistoria nella Liguria Orientale. Soprintendenza Archeologica della Liguria, 59-78.

MAGGI, R. (1984). Aspetti del popolamento della Liguria orientale nell'Eta del Bronzo: gli insediamenti d'altura. In WALDREN, W.H., CHAPMAN, R., LEWTHWAITE, J. and KENNARD, R. (eds). Early Settlement in the Western Mediterranean Islands and the Peripheral Areas. BAR International Series 229, 423-434.

MAGGI, R. and FORMICOLA, V. (1978). Una grotticella sepolcrale dell'inizio dell'età del bronzo in Val Frascarese (Genova). Preistoria Alpina - Museo Tridentino di Scienze Naturali, 14, 87-113.

MAGGI, R., MELLI, P., MACPHAIL, R.I., CRUISE, G.M., NISBET, R., DEL SOLDATO, M. and PINTUS, S. (1985). Note sugli scavi del Castellaro di Uscio (GE), 1981-1985. Preistoria Alpina - Museo Tridentino di Scienze Naturali, 21, 59-83.

MAGGI, R., BAFFICO, O., CRUISE, G.M., MACPHAIL, R.I. and NISBET, R. (1989, in press). Monte Aiona - Prato Mollo. Archeolgia in Liguria III, 57-66.

MALQUORI, A. and CECCONI, S. (1956). Minerali argillosi e di terreni provenienti da rocce ofiolitiche. Ricerca Scientifica, 26, 1154-1159.

MANGERUD, J., ANDERSEN, S.T., BERGLUND, B.E. AND DONNER, J.J. (1974). Quaternary stratigraphy of Norden, a proposal for terminology and classification. Boreas, 3, 109-127.

MARINI, M. and TERRANOVA, R. (1980). I complessi Ofiolitiferi dei Monti Aiona e Penna e loro rapporti con le serie sedimentarie (Appennino Ligure-Emiliano). Bollettino Società Geologico Italiano, 99, 183-203.

MARKGRAF, V. (1970). Palaeohistory of the Spruce in Switzerland. Nature, 228, 249-251.

MARKGRAF, V. (1980). Pollen dispersal in a mountain area. Grana. 19, 127-146.

MARTINI, E. and ORSINO, F. (1969). Flora e vegetazione delle valli dei torrenti Acquabona, Scorza e Lerca (Gruppo del M. Beigua, Appennino Ligure). Webbia. 23(2), 397-511.

MELLARS, P. (1976). Fire ecology, animal populations and man: a study of some ecological relationships in prehistory. Proceedings of the Prehistoric Society. 42, 15-45.

MELLI, P. (1983). L'Età del Ferro. In MAGGI, R. (ed). 83-88.

METEOROLOGICAL OFFICE (1962). Weather in the Mediterranean. Volume 1. General Meteorology. H.M.S.O.

MOORE, P.D. and WEBB, J.A. (1978). An illustrated guide to pollen analysis. Hodder and Stoughton, London.

MOORE, P.D., EVANS, A.T. and CHATER, M. (1985). Palynological and stratigraphic evidence for hydrological changes in mires associated with human activity. In BEHRE, K.E. (ed). Anthropogenic Indicators in Pollen diagrams. A.A. Balkema, Rotterdam. 209-219.

MORENO, D. (1971). La Selva d'Orba (Appennino Ligure): note sulle variazioni antropiche della sua vegetazione. Rivista Geografica Italiana. 78, 311-345.

MOULLADE, M. (1978). The Ligurian Sea and the adjacent areas. In NAIRN, A; KAMES, W. and STEHLI, F. (eds). The Ocean Basins and Margins. Volume 4B. The Western Mediterranean Plenum Press, New York, 67-148.

NAYLOR, M.A. (1982). The Casanova Complex of the northern Apennines: a mélange formed on a distal passive continental margin. Journal of Structural Geology. 4(1), 1-18.

NISBET, R. (1983). Vislario: Archeologia e Paleoecologia di un terrazamento Alpino. Orco Anthropologica 3. Edizioni Corsac, Torino.

NISBET, R. (1985). Analisi preliminari sui macroresti vegetali carbonizzati del castellaro di Uscio. In MAGGI, R. et al.. 80-82.

NISBET, R. (1989, in press). Analisi dei carboni. In MAGGI et al., 65.

NISBET, R. and BIAGI, P. (eds), (1987). Balm' Chanto: Un riparo sottoroccia dell'età del rame nelle Alpi Cozie. Museo Civico Archeologico "Giovio", Como.

OBERDORFER, E. and HOFMANN, A. (1967). Beitrag zur Kenntnis der Vegetation des nordapennin. Beitr. naturk. Forsch. Südw.-Dtl. XXVI(1) 83-139.

O'CONNELL, M. (1987). Early cereal-type pollen records from Connemara, W.Ireland and their possible significance. Pollen et Spores. XXIX(2-3), 207-224.

ORSINO, F. (1969). Lineamenti geobotanici della Liguria. Archivio Botanico e Biogeografico Italiano. 45, 207-234.

OZENDA, P. (1966). Perspectives nouvelles pour l'étude phytogeographique des Alpes du Sud. Documents pour la carte de la végétation des Alpes. 4, 1-198.

PAOLI, P. and CELLAI CIUFFI, G. (1976). Schede per una Flora Palinologica Italiana. Contributo n.2: Raccolte dell'Isola di Montecristo. Archivio Botanico e Biogeografico Italiano. 52(1/2), 3-8.

PATTERSON, W.A; EDWARDS, K.J. and MAGUIRE, D.J. (1987). Microscopic charcoal as a fossil indicator of fire. Quaternary Science Reviews. 6, 3-23.

PECK, R.M. (1973). Pollen budget studies in a small Yorkshire catchment. In BIRKS, H.J.B. and WEST, R.G. (eds). Quaternary Plant Ecology. Blackwell Publications, Oxford, 43-60.

PENNINGTON, W. (1979). The origin of pollen in lake sediments: an enclosed lake compared with one receiving inflow streams. New Phytologist. 83, 189-213.

PICHI-SERMOLLI, R. (1948). Flora e vegetazione delle Serpentine e delle altre ofioliti dell'alta valle del Tevere (Toscana). Webbia. 6, 1-380.

PIGNATTI, S. (1982). Flora d'Italia. Edagricle, Bologna.

PLANCHAIS, N. (1962). Le pollen de quelques Chênes du domaine Méditerranéen Occidental. Pollen et Spores. IV(1), 87-93.

PONS, A. (1984). La paléoécologie face aux variations spatiales du bioclimat méditerranéen. Bulletin de la Societe Botanique de France. 131(2/3/4), 77-83.

PORTER, S.C. and OROMBELLI, G. (1985). Glacier contraction during the middle Holocene in the western Italian Alps: evidence and implications. Geology. 13, 296-298.

PROBST, A. and BAUDIERE, A. (1984). Les relations Hêtre-Sapin-Pin à crochets dans les peuplements forestiers de la vallée de Gavarnie. Botanica Helvetica. 94(2), 371-383.

PROCTOR, J. and WOODELL, S.R.J. (1971) The Ecology of Serpentine soils. Advances in Ecological Research, 9, 255-366.

PUNT, W. and CLARKE, G.C.E.(eds) (1976). The Northwest European Pollen Flora, vol. I. Elsevier Scientific Publishing Company, Amsterdam.

" " (1980). The Northwest European Pollen Flora, vol. II.

" " (1981). The Northwest European Pollen Flora, vol. III.

" " (1984). The Northwest European Pollen Flora, vol. IV.

REILLE, M. (1977). Quelques aspects de l'activité humaine en Corse durant le SubAtlantique et ses conséquences sur la végétation. In LAILLE, H. and RENAULT-MISKOVSKY, J. (eds). Approche Ecologique de l'Homme Fossile. 329-342.

RENAULT-MISKOVSKY, J. (1972). Contribution à la paléoclimatologie du Midi Méditerranéen pendant la dernière glaciation et le post-glaciaire, d'après l'étude palynologique du remplissage des grottes et abris sous roche. Musée d'Anthropologie Prehistorique de Monaco. 18, 145-210.

REUTTER, K.J., GÜNTHER, K. and GROSCURTH, J. (1978). An approach to the Geodynamics of the Corsica-Northern Apennines double orogene. In CLOOS, H., ROEDER, D. and SCHMIDT, K. (eds). Alps, Apennines and Hellenides, Interunion Commission on Geodynamics Scientific report. 38, 299-311.

ROWLY-CONWY, P. (1989). Faunal remains from Arene Candide: preliminary report on the Neolithic and later material from the 1940-42 and 1948-50 excavations. Archeologia in Liguria III. in press.

SCAIFE, R. (1987). Pollen analysis and the later prehistoric vegetational changes of the Val Chisone. In NISBET, R. and BIAGGI, P. (eds), 89-102.

SCHNEIDER, R. (1978). Pollenanalytische Untersuchungen zur Kenntis der spät-und postglazialen Vegetationsgeschichte am Südrand der Alpen zwischen Turin und Varese (Italien). Botanische Jahrbücher. 100(1), 26-109.

SERVIZIO IDROGRAFICO (1966a). Distribuzione della temperatura dell'aria in Italia nel trenennio 1926-1955, I, Italia Settentrionale. Ministero dei Lavori Pubblici, Roma.

SERVIZIO IDROGRAFICO (1966b). Precipitazioni medie mensili ed annue e numero dei giorni piovosi per il trentennio 1921-1950. Affluenti Appenninici del Po a valle del Tanaro. Ministero dei Lavori Pubblici, Roma.

SESTINI, A. (1936). Forme glaciali ed antico limite delle nevi l'Appenino settentrionale. Rivista Geografica Italiana, 43, 293-298.

SHUGART, H.H., WEST, D.C. and EMANUEL, W.R. (1981). Patterns and dynamics of forests: an application of simulation models. In WEST, D., SHUGART, H.H. and BOTKIN, D.B. (eds). Forest Succession: Concepts and Application. Springer-Verlag, New York.

SPENCE, D.H.N. (1957). Studies on the vegetation of Shetland. 1. The Serpentine debris vegetation in Unst. Journal of Ecology, 45, 917-945.

STEVENSON, A.C. (1981). Pollen studies in semi-arid areas: north east Iran and south west Spain. Unpublished Ph.d thesis, King's College, University of London.

STOCKMARR, (1971). Tablets with spores used in absolute pollen analysis. Pollen et Spores, XIII(4), 615-621.

SUCCOW, M. and LANGE, E. (1984). The mire types of the German Democratic Republic. In MOORE, P.D. (ed). European Mires. Academic Press, 149-175.

TALLANTIRE, P.A. (1973). Apropos the post-glacial spread of Spruce in Switzerland. 13, 79-84.

TAUBER, H. (1965). Differential pollen dispersion and the interpretation of pollen diagrams. Danmarks Geologiske Undersøgelse, Serie II, 89, 7-76.

TAUBER, H. (1967). Differential pollen dispersion and filtration. In CUSHING, E.J. and WRIGHT, H.E (eds). Quaternary Paleoecology. Yale University Press, New Haven, 131-141.

THIEBAUT, B. (1972). De la répartition du Hêtre et du Chêne sessile dans le massif de l'Agoût. Vie et Milieu, XX, 1-13.

THIEBAUT, B. (1982). Existe-t-il une hêtraie "Méditerranéenne" distincte des autres forêts de hêtre en Europe occidentale? Vegetatio, 50, 23-42.

THIEBAUT, B., LUMARET, R. and VERNET, P. (1982). The bud enzymes of Beech (Fagus sylvatica L.). Genetic distinction and analysis of polymorphism in several French populations. Silvae Genetica, 31(2-3), 51-60.

TIPPING, R. (1984). Late Devensian and early Flandrian vegetational history and deglacial chronology of western Argyll. Unpublished Ph.d thesis, City of London Polytechnic

TIPPING, R. (1985). A problem with pollen concentration procedures. Pollen et Spores. XXVII(1), 121-130.

TOMASELLI, R. (1970). Note illustrative della carta della vegetazione naturalle potenziale d'Italia. Collana Verde. 27, 4-63.

TRIAT-LAVAL, H. (1978). Contribution pollenanalytique a l'histoire tardi- et postglaciaire de la vegetation de la basse vallee du Rhone. Thèse présentée a l'Université d'Aix-Marseille III.

UBALDI, D. and SPERANZA, M. (1985). Quelques hetraies du Fagion et du Laburno-Ostryon dans l'Apennin septentrional (Italie). Documents Phytosociologiques. IX, 51-71.

VENIALE, F. and VAN DER MAREL, H.W. (1963). An interstratified saponite-swelling chlorite mineral as a weathering product of Lizardite rock from St. Margherita Staffora (Pavia Province), Italy. Beitrage zur Mineralogie und Petrographie. 9, 198-243.

VERNET, J.L. (1970). Analyse de charbons de bois de niveaux tardiglaciaires et post-glaciaires de l'Arma du Stefanin (Savone, Italie). Naturalia Monspeliensia, sér. B. 21, 243-246.

VICINO, G. (1983). Il Paleolitico. In MAGGI, R. (ed). 25-32.

WATTS, W.A. (1973). Rates of change and stability in vegetation in the perspectives of long periods of time. In BIRKS, H.J.B. and WEST, R.G. (eds). Quaternary Plant Ecology. Blackwell Publications, Oxford, 195-206.

WATTS, W.A. (1985). A long pollen record from Laghi di Monticchio, southern Italy: a preliminary account. Journal of the Geological Society. 142(3), 491-499.

van ZEIST, W. and BOTTEMA, S. (1977). Palynological investigations in western Iran. Palaeohistoria. XIX, 20-95.

ZOLLER, H. and KLEIBER, H. (1970). Vegetationsgeschichtliche Untersuchungen in der montanen und subalpinen Stufe der Tessintäler. Verhandlungen - Natur - forschenden Gesellschaft. 81(1), 90-154.

APPENDICES

APPENDIX A: Additional pollen data

This appendix shows all pollen percentage data not included in the relative pollen diagrams.

+ denotes frequencies of less than 1%.

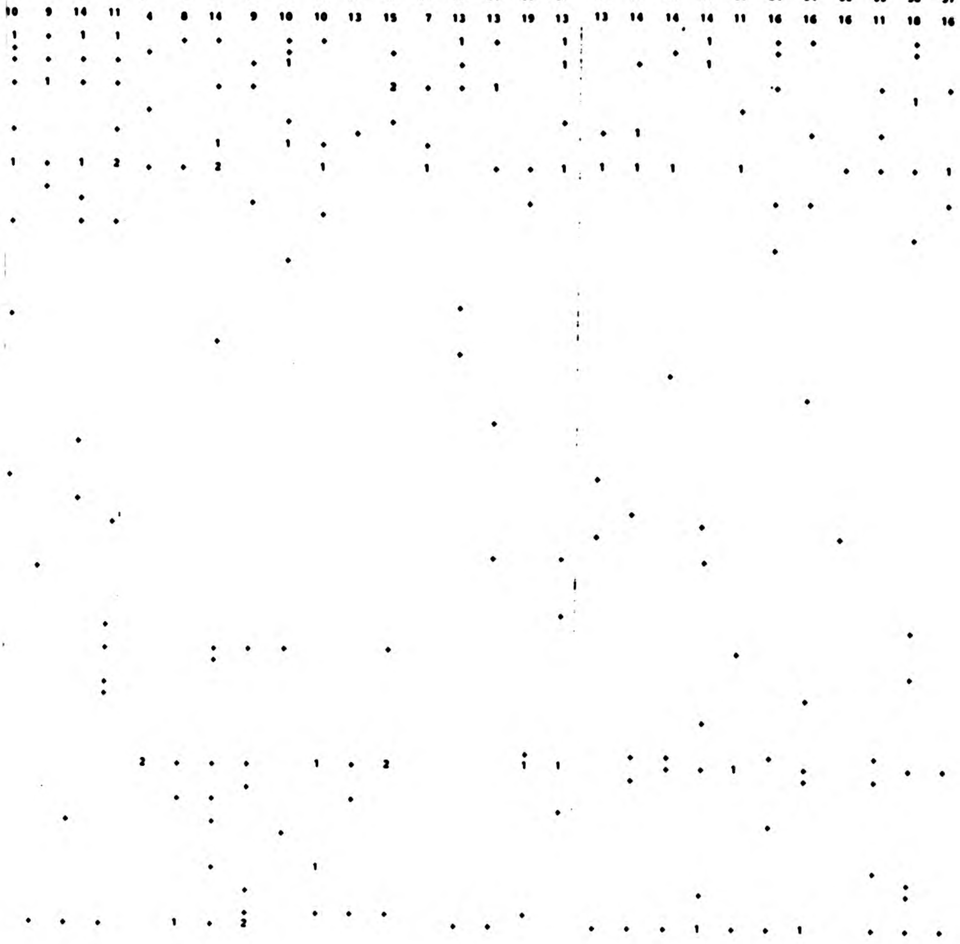
A (i): Agoraie
A (ii): Lago delle Lame
A (iii): Prato Mollo
A (iv): Lago Nero
A (v): Casanova
A (vi): Bargone

A (i) Ageraie.

AGERAIE																					
PAS																				AG1	
DEPTH (CM)	680	675	670	660	650	640	630	620	610	600	590	580	570	560	550	540	530	520	510	500	490
TOTAL TAXA	33	30	32	35	24	28	28	29	27	29	29	23	31	29	29	30	34	32	33	28	32
TOTAL HERBS	14	10	14	11	9	10	9	10	10	13	11	8	9	16	14	12	13	15	10	9	14
Conifers undiff.				•	•			•	•		•	•	•	•	•	1		1	1	•	1
Picea																•			•		
Acer	•							•		•						1	•		•	•	•
Betula	•																				
Carpinus									•		•				•	•		1	•	1	•
Carpinus/Ostrya																					
Fraxinus spp?														•							
Fr.excelsior									•		•		•			•		•			
Fr.ornus t.							•			•						•			•		
Oleaceae undiff.									•												
Larix							•														
Ostrya t.		•		•			•		•				•	•		•			1	•	1
Populus																					
Buxus																				•	
Crataegus t.								•					•								•
Daphne?								•									•				
Ephedra fragilis t.																•			•		•
Frangula?																					
Hedera																					
Ilex																					
Phillyrea?																					
Pistacia																					
Rhamnus																					
Rubus																					
Sambucus							•												•		
Taxus																					
Aconitum																					
Campanulaceae				•																	
Cynoglossum t.																					
Convallaria																					
Frankenia?																					
Gentianella																					
Glaucium																					
Helleborus																					
Lamium t.					•																
Leguminosae undiff.																					•
Astragalus t.																					
Genista t.																					
Medicago sativa t.	•																		•		
Onobrychis t.																					
Ononis t.																					•
Linum catharticum t.				•																	
Melampyrum t.																					
Mentha t.																					
Myosotis t?																					
Plantago undiff.																					
Pl.coronopus t.																				•	
Pl.crassifolia t.																					
Pl.maritima t.																					
Polygonaceae undiff.																		•			
Rhinanthus t.																					
Rosaceae undiff.																•					
Rumex acetosella t.																					
Saxifraga nivalis t?	•	•											•			•		•	•		
S.stellaris													•								
S.oppositifolia																					
Scabiosa							•														
Scrophularia																		•			
Stachys t.																					
Succisa t.																					
Pinguicula																					
Potentilla																					
Thalictrum								•								•					
Unknowns								•		•	•			•	•	•	2		•		
Callitriche	•																				
Equisetum							•												•		
Myriophyllum spicatum		•								•							•				
Nuphar																•					
Typha latifolia t.																•					•
Blechnum spicant		•																			
Cystopteris																					
Isoetes		•						•													
Dryopteris filix-mas		•																			
Lycopodium undiff.																	1				
Polypodium vulgare				•				•	•			•				•					
Sphagnum		•																			
Unknown spores		•															1				
Hepaticae	1			1	•		•	1		•	1	1	1				1		•	•	•

AG1 / Ag2-a

10	500	490	480	470	460	450	440	430	420	410	400	390	380	375	370	365	360	355	350	345	340	335	330	325	320	310	300
33	28	32	33	24	19	37	30	30	28	31	29	21	29	30	35	31	31	31	30	30	26	34	34	33	33	38	37
10	9	14	11	4	8	14	9	10	10	13	15	7	13	13	19	13	13	14	14	14	11	16	16	16	11	10	16



							/				Ag2-a			/					Ag2-b					
165	360	355	350	345	340	335	330	325	320	310	300	290	280	270	260	250	240	230	220	210	200	190	180	170
31	31	31	30	30	26	34	34	33	33	38	37	32	35	40	30	34	34	35	34	33	31	35	40	38
13	13	14	14	14	11	16	16	16	11	18	16	11	15	18	15	15	15	18	16	16	14	15	20	18
1				1		•	•			•		•	•	•			•							
			•			•				•				•										
1		•		1									•	•	•	•	•					•		•
																							•	
						•			•		•	•	•	•				•						
										1														
					•																			
																			1					
•	•	1					•		•			1					•		•	•				
													•		•			•						
												•												
1	1	1	1		1			•	•	•	1	•	•	1				1	2		•		•	
																	•							
																						•	•	
						•	•				•			•	•	•	•			•				
										•														
						•																		
												•												
																			•					
																					•			
																								•
																							•	
																•								
			•																					
							•					•				•								
												•												
																							•	
																			•					
	•																							
																•								
		•																						
				•																				
	•							•																
																				•				
•				•																				
																			•					
																			•					
•																								•
									•															
																							•	2
					•													•						
															•									
									•															
							•																	
													•										•	
				•								•												
															•									
																								•
		•	•			•			•								•							
1			•	•	1		•			•	•	•		•				•	•			•		
		•					•		•			•												•
•												•												
						•						•												
																		•						
												•												
									•			•								•				
										•			•	•										
				•						•			•											
																				•				
														•				•						
	•	•	•	1	•	•	1		•	•	•	1		•	•	1	•	•	•	•	•	2	2	2

A (ii) Lago delle Lame.

LAGO DELLE LAME

PAZ						LdL1						/							LdL2-a			
DEPTH (CM)	230	220	210	200	190	180	175	170	165	160	155	150	145	140	135	130	125	120	115	110	105	100
TOTAL TAXA	23	19	36	20	20	28	24	26	24	25	28	22	28	31	26	39	28	37	39	28	30	34
TOTAL HERBS	6	5	10	5	7	9	7	7	3	6	7	6	9	11	5	15	9	10	11	8	9	8
Conifers undiff.	4	5	•	2	9	9	•	9	8	6	5	5	1	•	3		•			4		1
Picea	•															•						
Betula	•					•			•		•			•		•		•	1	•	•	•
Carpinus															•		•	•				
Fraxinus excelsior			•					•										•	•			•
Fraxinus ornus t.		•						•						•				•			2	
Fraxinus spp?			•																			
Oleaceae																						
Ostrya t.	•								•	•	•	•	•				•	•		•		•
Prunus t.								•														
Quercus cerris t.							•		•				1	2	•	•	•	1	2	•	3	3
Qu.ilex t.			1				•	•	•	•	•	1	1	1		3	1	3	3	1	3	1
Qu.robur t.			1	1			1		•			•	•	3	•	1	4	1	1	2	2	1
Quercus undiff.	1	1	1	•	•	1		•		•	1	•	•	2	•	1	1	1	3	1	2	1
Ephedra fragilis t.															•							•
Morus alba t?																						
Phillyrea?																						
Pistacia?																						
Rubus																						
Calluna			•													•			1		•	•
Erica tetralix t.	2	1	•	1	1	1	•	1	•		•		2	1	1	1	1	1	•		1	1
Ericaceae undiff.		•	1	1	•	1	1		•	2		1		1	•	•		•	1	•		1
Campanulaceae																						
Caryophyllaceae				•				•									•					
Centaurea cyanus?																						
C.nigra t.																						
Chenopodiaceae	•				•	•		•		•	•	•			•	•	•	•	•	•		
Circaea t.																						
Compositae tub.	•		•	•	•	•	•	1	•	•	•	1	•	•	1			1		1		•
Diapensia																						
Dryas octapetala																						
Galium t.			•					•												•	•	
Herniaria?														•								
Hornungia t.			•																			
Leguminosae undiff.																						
Genista t.																						
Vicia sylvatica t.																•						
Marrubium?																	•					
Melampyrum																						
Narthecium t.																			•			
Potentilla t.																	•					
Plantago undiff.											•											
Plantago coronopus																						
Polygonum bist.t.																						
Primula vulgaris t.																						
Ranunculaceae			•				•															
Rosaceae undiff.																		•	•			
Rumex acetosella t.																					•	
Stachys t.																					•	
Umbelliferae					•															•		
Alisma																						
Gentianella							•															
Parnassia palustris																						
Thalictrum													•					•				
Unknowns					•					•						1	•	•	•	•	•	•
Callitriche										•				•		•						
Menyanthes									•										•		•	
Botrychium			•																			
Butomus																•						
Isoetes			•													1						
Lycopodium selago						•					•		•									
Polypodium vulgare	•	•	•	•		•	•	•		•	•			•	•	•		•	•	•	•	•
Pteridium	1	•	1	•	1	•		•	•	1	•	•	1	1	•	•			1	1	•	
Sphagnum													•									
Unknown spores					•								•							•		
Hepaticae	•		1	•	•	2		•	•	•	•	•	1	1	•		•	•		•		

		LdL2-a						/						LdL2-b						/LdL2-c		
[illegible]	120	115	110	105	100	95	90	85	80	75	70	65	60	55	50	46	43	39	36	30	25	20
[illegible]	37	39	28	30	34	33	18	27	27	39	25	28	33	36	24	31	31	28	26	31	38	41
[illegible]	10	11	8	9	8	9	3	6	8	14	8	6	10	13	7	8	12	8	7	8	16	19
•			4		1		1			•	2				•	•	•	•	1	•	1	1
										•										•		
	•	1	•	•	•				•	•			•	•	•	•		•	•	•	•	
•	•					1		•	•	•					•				•	•	•	
	•	•			•							•	•	•					•	1		
	•			2				•	•			•	•	•					•		•	
																•	•			•		
																			•			
•	•		•		•							•		•	•	•	•	•		•		
																						•
•	1	2	•	3	3	•		1	1	2		1	•	1	•	1	1	2	2	3	1	1
[illegible]	3	3	1	3	1	1	1	•	2	1	2	1	3	1	1	1	1	2		1	•	•
[illegible]	1	1	2	2	1	2	1	3	2	5	•	5	2	3	4	4	3	3		5	1	3
[illegible]	1	3	1	2	1	1	1	3	1	2	1	1	3	•	•	1	•	2	2		1	1
					•																	
																					•	
																						•
																•						
													•									
		1		•	•					•		1		•			1	1		•	•	1
[illegible]	1	•		1	1		•		1	•		•	1	•	1		•		3			
	•	1	•		1	•							•	•		•		1				•
													•									
•										•	•			•	•		•				•	•
																	•					
																					•	
•	•	•	•			•			•	•											•	•
									•													
	1		1		•				•		•	•							1	•	•	
																•						
																			•			
			•	•									•									
																						•
													•									
•																						
										•												
		•																				
•																						
																				•		1
																			•			
																					•	
																					•	
																	•			•		
	•	•											•								•	
				•		•																
				•						•			•									•
			•					•									•				•	1
								•													•	
										•												
	•					•																
•	•	•	•	•	•	•		•	•	•		•	1				1	1	•	•	•	
							•															
		•		•																		
																						•
						1																
																						•
	•	•	•	•	•	•			1	•	1	•		•	•			1	•	•		•
		1	1	•		•			1	1			•			1	1	•	1	•	1	1
			•																			
•	•		•			•		•		•	•		•	•		•						•

A (iii) Prato Mollo.

PRATO MOLLO																						
PAS			PM1			/			PM2-a	/			PM2-b				/		PM3			
DEPTH (CM)	90	88	86	83	81	79	77	73	68	63	58	53	48	43	38	33	28	23	18	13	8	3
TOTAL TAXA	26	24	14	18	23	22	28	30	28	36	36	19	31	34	25	43	30	38	40	23	36	33
TOTAL HERBS	7	5	4	3	7	6	10	15	8	14	18	12	14	15	10	22	13	18	19	15	18	17
Conifers undiff.	1	1	1	1	1	◆			◆	1		1		◆					◆		1	◆
Acer					◆		1			◆						◆		◆		◆		
Betula	◆	◆					◆			◆		1	◆	◆	1				◆	◆	1	◆
Carpinus					◆				◆	◆			◆		◆	2	1		◆	◆	◆	◆
Buxus																◆			◆			
Daphne		◆																				
Ephedra frag.t.								◆	◆		◆					◆				◆		
Juniperus																			◆			
Lonicera?													◆	◆								
Rubus										◆							◆					
Sambucus																			◆			
Taxus													◆									
Anagallis tenella t.																				◆		
Anthericum t.									◆		◆		◆	◆		◆						
Campanulaceae																				◆		
Centaurea nigra t.					◆															◆		
Chenopodiaceae			◆					◆	◆		◆		◆	◆	◆	◆			◆		◆	◆
Cynoglossum?																			◆			
Dryas octopetala		◆																				
Helianthemum																			◆			
Hypericum perforatum																				◆		
Galium t.														◆		◆			◆	◆	◆	
Glaucium										◆				◆								
Leguminosae undiff.																◆			◆			
Marrubium?																					◆	
Odontites																	◆					
Oxyria t.								◆								◆						
Plantago undiff.																◆				◆	◆	◆
Pl. maritima																				◆		
Polygala																		◆				
Polygonum bist.t.																						◆
Poterium sang.																◆						
Rumex undiff.																◆						
Saxifraga								◆														
Sax.stellaris?														◆								
Succisa																◆					◆	
Alisma																		◆		◆		
Parnassia palustris															◆					◆		
Pinguicula																		◆				
Potentilla																		◆	◆		◆	◆
Thalictrum											◆					◆					◆	
Unknowns		◆					◆	◆			◆			◆	◆	◆		◆		◆	◆	◆
Nymphaea											◆											
Typha angust.								◆					◆								◆	
Athyrium		◆																		◆		
Botrychium			◆						◆								◆					
Lycopodium selago										◆												
Polypod. vulgare	◆	◆		◆		◆	◆			◆			◆	◆	◆	◆		◆		◆		
Polystichum?	◆						◆															
Sphagnum		◆								◆												◆
Unknown spores						◆			◆									◆				
Hepaticae		◆	◆	◆	◆	◆	◆		◆	◆	◆	1		◆								

A (iv) Lago Nero.

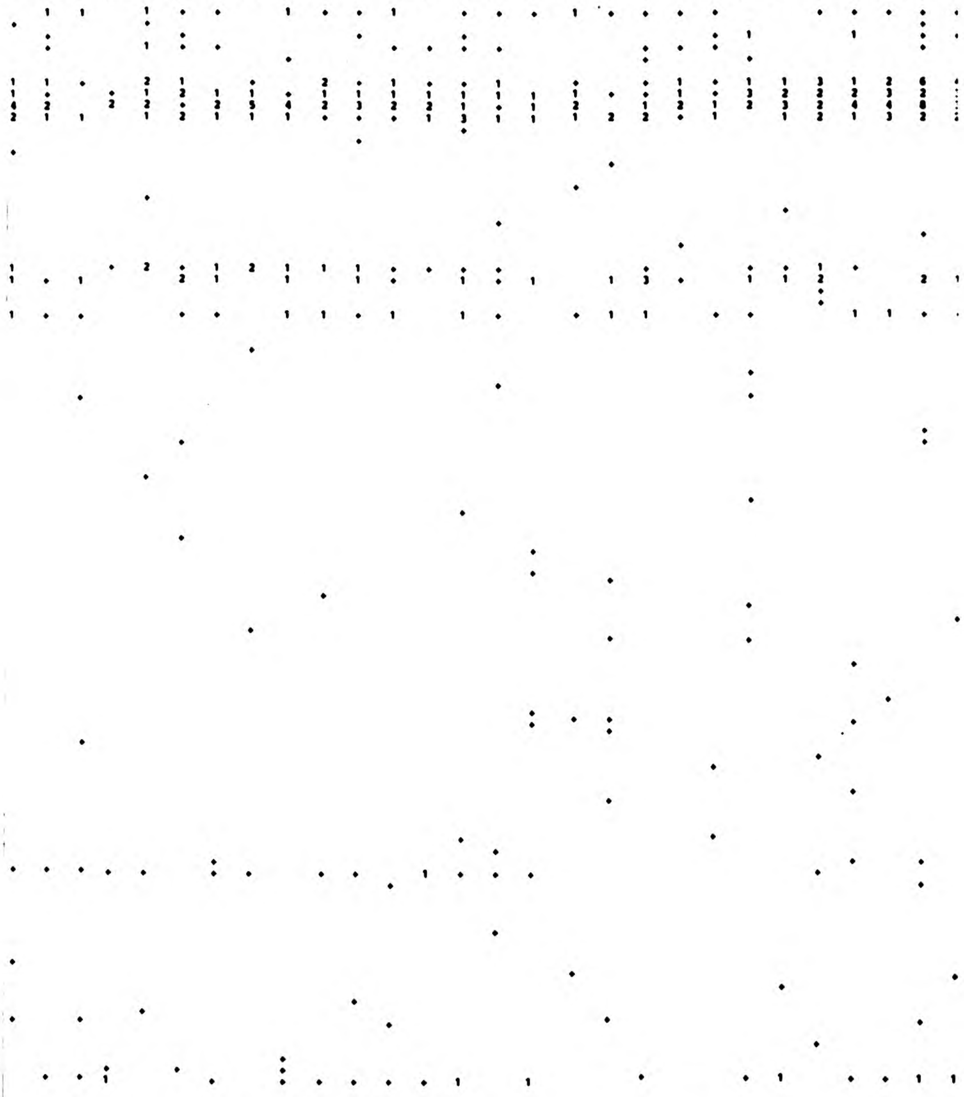
LAGO NERO																						
PAZ	LN1	/		LN2		/			LN3			/			LN4			/		LN5		
DEPTH (CM)	100	98	95	92	87	82	77	72	67	62	57	52	47	42	37	32	27	22	17	12	7	2
TOTAL TAXA	29	13	13	15	21	14	21	24	23	24	25	23	25	21	22	22	15	25	29	38	38	33
TOTAL HERBS	12	3	3	4	8	3	8	8	9	7	8	7	9	8	8	8	3	10	13	14	19	17
Conifers undiff.	3	1	2	2	◆	◆	◆	2		1	◆				1							◆
Picea							◆					◆								◆		
Acer											◆	◆										
Carpinus										◆	◆		◆			◆						
Fraxinus excelsior																					◆	
Fraxinus ornus t.	◆									◆	◆				◆	◆			◆	◆		◆
Ostrya t.								◆		◆					◆	◆	◆	◆	1	1	1	◆
Quercus cerris t.																						
Qu. ilex t.																						
Qu. robur t.																						
Quercus undiff.																						
Salix	◆																				◆	
Daphne	◆																					
Ephedra fragilis t.											◆											
Ilex										◆												
Agrimonia					◆																	
Anthericum t.								◆														
Chenopodiaceae							◆		◆	◆			◆					◆	◆			1
Galium t.											◆											
Lamium t.								◆														
Hippocrepis t.																		◆				
Medicago sativa t.																			◆			
Lathyrus palustris t.																				◆		
Lotus t.																				◆		
Linum spp.													◆									
Lobelia t.																						◆
Melampyrum	◆																					
Narthecium t.											◆											
Oxyria t.																						◆
Plantago undiff.																					◆	1
Polygonum bist.t.??	5														◆	◆						
Polygonum bist.t.				◆	◆	◆		◆										◆	◆			◆
Ranunculaceae																				◆	◆	
Rhinanthus t.														◆								
Rosaceae undiff.																					◆	
Geum t.														◆							◆	
Potentilla t.																						1
Sinapis t.																					◆	
Alisma												◆										
Gentianella	◆																					
Unknowns	◆								◆							◆				1		◆
Typha latifolia											◆											
Botrychium	◆								◆													
Sphagnum					◆															◆		
Unknown spores	1					◆																
Hepaticae	◆	◆			◆			◆	◆		◆	◆	◆			◆						1

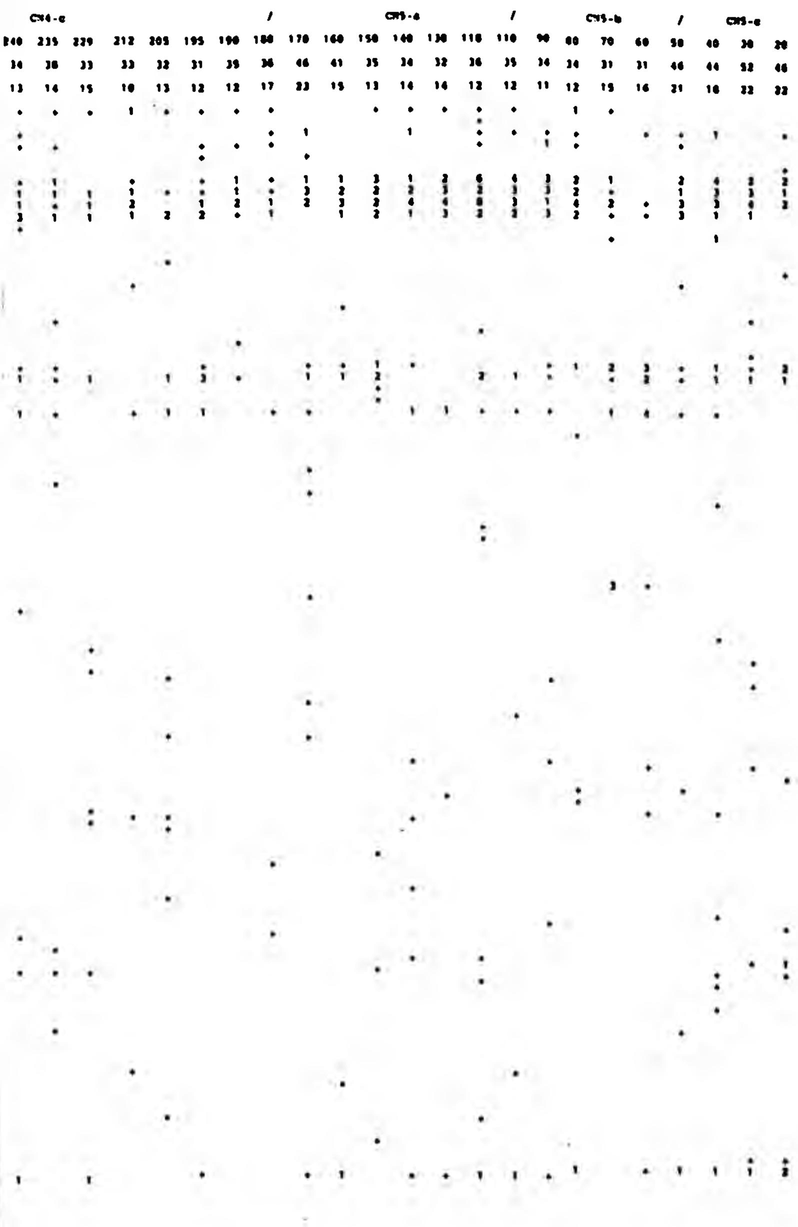
A (v) Casanova.

CASANOVA

PAZ	CN1	/		CN2		/			CN3			/						CN4-a				
DEPTH (CM)	500	495	490	485	480	475	470	465	460	455	450	440	430	420	410	390	380	370	360	350	340	330
TOTAL TAXA	21	13	31	19	27	30	36	31	27	30	35	35	35	29	32	27	28	31	30	39	29	32
TOTAL HERBS	11	6	13	9	14	13	12	12	6	13	13	13	13	11	10	10	11	10	9	14	9	11
Conifers undiff.	3	4		2	2	2	+	1	1		+		+	+			1	+	1		1	1
Fraxinus spp?													+							+		
Fr.ornus t.							+								+	+			+		+	
Fr.excelsior							+					+		+					+		+	
Ostrya/Carpinus?																						
Populus			+				+															
Quercus cerris t.			+		+	+		+		+		+	+			+		1	+	1	1	+
Qu.ilex t.											+			1	1	1	1	2		1	+	
Qu.robur t.	+		+		+	+	1	+	+	+	2	2	+		+	1	1	1	1	4	2	
Quercus undiff.						+	1	+	3			1	1	1	+	4	4	+	3	2	1	1
Qu.ilex/cerris?																						
Buxus																						
Hedera																				+		
Ilex																						
Morus?																						
Phillyrea?																						
Pistacia																						
Rubus															+							
Sambucus																						
Taxus						+																
Viburnum																						
Andromeda/Corema?																						
Calluna					+		+				+						+			1		
Erica tetralix t.							1	+	+	+	1		+	1	2		+	+		1	+	1
E.vagans t.																						
Vacc.vitis-idaea?																						
Ericaceae undiff.	+				+		1				+	+		+	1		1	+	1	1	+	+
Allium t.																			+			
Anagallis tenella t.																						
Boraginaceae undiff.																						
Cynoglossum							+															
Pentaglottis																						
Caltha/Papaver?																						
Campanulaceae					+																	+
Centaurea cyanus?																						
Centaurea nigra t.			+																			
Centaurium																						
Chelidonium																						
Dryas octapetala														+								
Epilobium																		+				
Euphorbia																						
Gentiana																						
Glaucium																						
Hornungia t.							+															
Hypericum perforatum t.																						
Lamium t.																						
Leguminosae undiff.			+																			
Genista										+												
Onobrychis t.								+														
Ononis t.																						
Trifolium t.																						
Trifolium arvense																						
Vicia cracca t.																						
Linum catharticum t.											+											
Mentha t.																		+				
Mercurialis	+		+																			
Oxyria t.										+												
Papaver												+										
Plantago maritima?																						
Polygonum bistorta t.						+						+										
Ranunculaceae																		+				
Rosaceae undiff.											+						+					
Rumex undiff.																						
Saxifragaceae																						+
S.nivalis t?																						
Scilla t.																						
Scrophularia												+										
Sedum						+																
Teucrium?																						
Umbil icus												+										
Urtica t.																						
Alisma									+													
Hydrocotyle																						
Thalictrum																						
Unknowns	+													+	1		1	+	+	+	+	+
Callitriche						+			+	+	+	+										
Hydrocharis?																						
Isoetes								2														
Scheuchzeria?																						
Typha angustifolia																						
Athyrium							1	2	4				+									
Blechnum spicant							+	1														
Botrychium									+											+		
Dryopteris filix-mas								+														
Dryopteris undiff.																						
Lycopodium annotinum																						
Lycopodium selago																						
Polypodium vulgare							+						+	+			+		+	+		+
Polystichum t.							+															
Sphagnum																						
Thelypteris palustris t.																						
Unknown spores																						
Hepaticae	+						+		+	+		+	+		+	+	+	+	+		+	+

			/			CN4-b			/					CN4-c						/				CN5-a			/
[illegible]0	340	330	320	315	310	305	295	290	280	270	260	250	240	235	229	212	205	195	190	180	170	160	150	140	130	118	11[illegible]
[illegible]9	29	32	26	39	27	26	28	32	30	27	34	27	34	38	33	33	32	31	35	36	46	41	35	34	32	36	3[illegible]
[illegible]4	9	11	10	14	11	10	11	14	9	8	15	11	13	14	15	10	13	12	12	17	23	15	13	14	14	12	1[illegible]

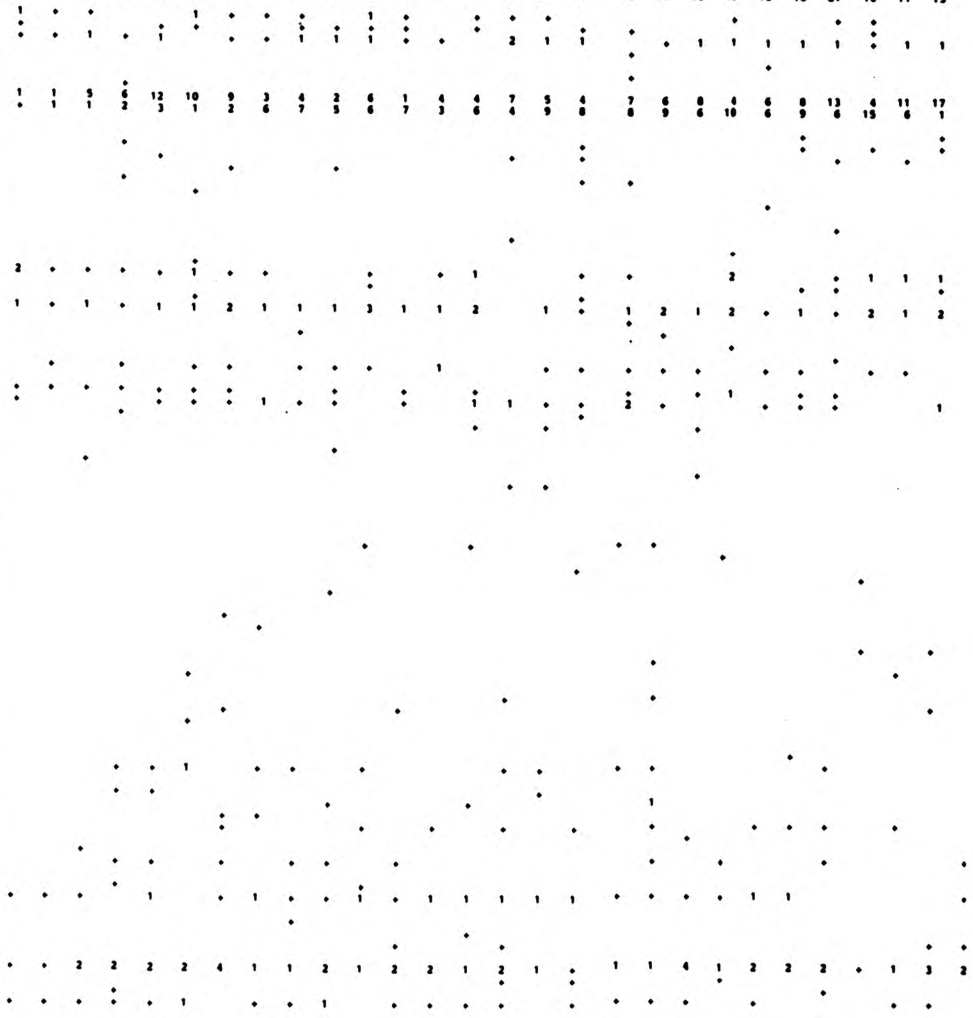



CN4-c
CN5-a
CN5-b
CN5-c
240 235 229 212 205 195 190 180 170 160 150 140 130 118 110 90 80 70 60 50 40 30 20
34 38 33 33 32 31 35 36 46 41 35 34 32 36 35 34 34 31 31 46 44 52 46
13 14 15 10 13 12 12 17 23 15 13 14 14 12 12 11 12 15 16 21 10 22 22

A (vi) Bargone.

BARGONE																					
PAZ										Bg1										/	
DEPTH (CM)	380	376	372	368	364	360	356	352	350	346	344	340	336	332	328	324	320	316	312	308	304
TOTAL TAXA	27	22	20	21	23	28	25	19	27	27	21	27	22	25	21	25	25	21	23	25	33
TOTAL HERBS	12	8	8	7	11	10	9	7	11	11	7	13	10	9	5	6	13	9	9	7	15
Conifers undiff.	•	2	•	•	1	1	1		•		•	•	•		•		1		1	•	•
Picea		•				•								•	•		•		•		
Betula	•	1	•	•	•	•		•	1	•	•	•		•		1	•		•	•	1
Carpinus/Ostrya?																					
Ostrya/Corylus?																					
Fraxinus undiff.																					
Oleaceae undiff.																					
Quercus cerris t.	•			•	1	•	•	3	1			3	3	3	2	1	2	•	1	1	5
Quercus ilex t.	1	2	1	•		1	•	2		•	2	•	1	1	2	1	1		•	1	1
Populus?	•																				
Salix (k)																					
Crataegus t.																					
Ephedra frag.t.							•				•										
Ephedra dist.t.						•															
Phillyrea?																					
Pistacia																					
Rubus																•					
Sambucus																					
Taxus																					
Viburnum opulus t.																					
Erica arborea t.																					
E.lusitanica t?																					
E.tetralix t.					•	•	1		1			•	1				•	•	2	•	•
E.vagans t.																					
Vacc. vitis-idaea																					
Ericaceae undiff.			•			•	1	•	•	•	•	1	1	1	•	•	•	1	1	•	1
Anemone t.																					
Anthericum t.		•																			
Centaurea undiff.																					
Chelidonium																					
Chenopodiaceae	•		•						•	•			•		•					•	
Circaea																					
Compositae Lig.	•		1	•	•		•	•	•		•	1						•	•	•	•
Compositae Tub.	•	•		•	•	•	•							•		•	•		•		
Galium t.	•					•								•							
Gentiana																					
Gentiana pneumonanthe t.													•								
Helianthemum																					
Helleborus																					•
Hypericum perforatum t.																					
Leguminosae undiff.													•				•				
Lathyrus t.									•									•			
Lotus t.																					
Medicago sativa t.																					
Melilotis t.																					
Onobrychis t.			•																		
Ononis t.																					
Vicia cracca t.																					
Vicia sylvatica t.																					
Vicia t.				•	•																
Limonium										•											
Linum bienne t.																					
Linum catharticum t.																					
Plantago coronopus																					
Plantago undiff.																					
Poterium sanguisorba															•						
Ranunculaceae					•																
Rhinanthus t.																					
Rosaceae undiff.																					
Rumex acetosella t.																					
Sanguisorba dodecandra?																					
Saxifraga nivalis t??																					
Scabiosa t.	•																				
Scrophulariaceae?																					
Umbelliferae	•		•		•					•							•				
Urtica t.																					
Alisma																					
Gentianella												•									
Mentha																					
Parnassia palustris																					
Thalictrum																					
Umbil icus																					•
Unknowns													•	•							
Typha latifolia													•								
Dryopteris filix-mas																					
Filicales	•	•				•	1		1	•	•			•	1			•	•	•	•
Lycopodium innundatum																					
Lycopodium selago																					
Ophioglossum																					
Polypodium vulgare																					
Polystichum									•												
Pteridium		•	•	•	•	•			1	•			•	•	•	•		•	•	•	2
Sphagnum																					
Unknown spores												•									
Hepaticae	•	•		•	•		•		•	•	1								•	•	•

Bg2-a																	Bg2-b									
312	308	304	296	288	280	272	264	256	248	240	232	224	216	208	200	192	184	176	168	160	152	144	136	120	112	104
23	25	33	38	40	42	40	34	33	37	37	36	32	39	41	40	43	38	40	36	34	35	36	39	29	35	37
9	7	15	16	17	22	19	15	13	17	15	14	10	19	19	20	17	16	17	15	13	15	18	21	10	11	13



					Bg2-b							/			Bg2-c		/	Bg3		
224	216	208	200	192	184	176	168	160	152	144	136	120	112	104	96	88	76	64	56	48
32	39	41	40	43	38	40	36	34	35	36	39	29	35	37	33	43	38	40	44	56
10	19	19	20	17	16	17	15	13	15	18	21	10	11	13	9	14	16	17	21	31
•		2	1	1		•	1	1	1	1	1	•	1	1	3	2	2	1	1	•
4	4	7	5	4	7	6	8	4	6	8	13	4	11	17	13	7	6	6	2	1
3	6	4	9	8	8	9	6	10	6	9	6	15	6	1	5	8	6	4	4	2
1	2		1	•	1	2	1	2	•	1	•	2	1	2	•		•	•	2	4
1	1	1	1	1	•	•	•	•	1	1					•	•		1	1	•
2	1	2	1	•	1	1	4	1	2	2	2	•	1	3	2	•	2	•	1	•

APPENDIX B

WOOD AND MACROFOSSIL IDENTIFICATION REPORT FOR THE SITES OF LAGO DELLE LAME AND CASANOVA

A. Clapham, Department of Botany, University of Glasgow.

1987.

All identifications were carried out on a stereomicroscope (x 50 magnification) and an epi-illuminating microscope with reference to the keys and photographs in Schweingrube (1978).

Lago delle Lame

depth (cm)	
28 to 32	Abies alba t. trunk wood.
60 to 65	Fagus sylvatica branch and trunkwood.
68	Abies alba t. sporophyll.
71 to 97	Abies alba t. needles.
100	Fagus sylvatica twig.
117	Fagus sylvatica nut.
127 to 138	Abies alba t. twig and very decomposed trunk wood.
152	Abies alba t. bark.
212 to 220	Abies alba t. sporophyll, trunk wood and needles:Fagus sylvatica twig and mast.
220 to 230	Fagus sylvatica leaf and mast; Abies alba t. needles, twig, trunkwood, sporophyll and seeds. Some of the trunk wood contains traumatic resin canals suggesting injury.
230 to 240	Fagus sylvatica mast; Abies alba t. trunk wood, twigs and bark.
240 to 250	Abies alba t. trunk wood with traumatic resin canals again suggesting injury.

When examined under high intensity light, wood samples were not entirely opaque and parenchymal cells were absent. Thus no charcoal was found amongst the samples. Preservation of Abies wood was variable, some being soft and poorly preserved but other samples were well preserved. Fagus wood was soft but well preserved.

Casanova

The preservation of almost all samples was poor. In most cases the wood had been compressed making identification impossible. In other samples there had been considerable decay, excluding that of lignaceous tracheids, possibly indicative of aerobic conditions at some time. Of the identifiable pieces, in most cases it was only possible to specify that they were of coniferous/Gymnosperm wood.

depth (cm)	
119 to 121	Badly decayed, twisted and contorted wood; it was only possible to deduce that it was coniferous in nature (tracheids not vessels being present).
127 to 133	Twig wood; coniferous.
141 to 144	Coniferous twig wood; either _Abies_ or _Picea_
216 to 229	_Abies alba_ t. wood
282 to 285	Degraded and distorted coniferous wood.
293 to 297	As above.
331 to 338	_Abies alba_ t. wood; partially burned.

References

SCHWEINGRUBER, F.H. (1978). _Microscopic Wood Anatomy_. Swiss Federal Institute of Forestry Research, 2nd Edition.

APPENDIX C

MICROMORPHOLOGICAL REPORT ON THE SOILS AND BASAL PEATS AT PRATO MOLLO AND LAGO NERO, EASTERN LIGURIA

R.I.Macphail BSc MSc PhD 1987

Introduction

In 1985/87 a soil study was undertaken to (1) elucidate the basal sedimentation of the shallow peats at Prato Mollo and Lago Nero and (2) to appreciate the nature of the local soils at Prato Mollo which were both shallow and yielding flint (Chalcolithic) artefacts.

Methods

Undisturbed soil monoliths were impregnated and thin sections were manufactured according to Guillorée (1985) at the Institut National Agronomique, Paris-Grignon. These were described employing Bullock et al.. (1985) and interpreted with the aid of Courty et al (1989, in press). The methods described in Avery and Bascomb (1974) were used for grain size and chemical analyses.

Results

Full results are presented in two unpublished reports (Macphail, 1987 and 1988) housed at the Soprintendenza Archaeologica della Liguria, Genoa.

Interpretation and Discussion

1. THE SOIL AT PRATO MOLLO

The profile which is a complex moderately acid and shallow (0-30 cm) soil, being a clay loam at depth and a sandy loam nearer the surface. In thin section the soil can be more accurately divided into four major fabric types, although horizonation is not always clear.

a) bB't (depth approx. 24-30 cm). The earliest soil development on the site appears to have been a rubified and ferruginous argillic palaeosol formed on weathered serpentinite probably during an interglacial period. Other examples of similar fabrics can be cited from Cremaschi (1987).

b) Bt (depth 17-24 cm). A disturbed horizon of moderately dense banded silty soil also containing mica and quartz. Silt, mica and quartz are absent from the weathered serpentinite but almost certainly derive from an overlying drift deposit which may be of aeolian origin. The banded silty fabric itself contains typical periglacial soil granules (van Vliet-Lanöe, 1982) and is moderately well preserved and only coarsely fragmented suggesting that the deposit is a Late Glacial phenomenon.

In short possible loessial drift buried the serpentinite palaeosol during the Late Glacial and was itself affected by periglacial activity. These two major fabric types have been strongly broken up, producing patches of palaeosol and patches of banded fabric. Break-up also led to the local mobilisation and movement of fine soil to form textural features, properly oriented to the present day vertical. It is possible to differentiate between recent biological disturbance and earlier disruption of the lower profile, because at depth areas of soil are still oriented to the surface and feature dusty clay infills. These suggest that the soil disruption preserved at the base of the profile was caused by tree throw or clearance, a phenomenon common to many soils (Macphail, 1986, 1987).

c) A12 (depth 10-17 cm). A partially biologically worked fabric containing many stone size ferruginous nodules with fewer fragments of serpentinite rock and subsoil material.

d) Ah (depth 0-10 cm). A mixed H and Ah silty horizon, stone free but rich in organic matter and very highly biologically worked.

The upper part of the soil profile developed in the soliflucted/colluvial material and was reworked by biological activity. Nevertheless the lack of biological homogenisation at any great depth is probably indicative of relatively recent erosion and the telescoped nature of the complex soil profile clearly indicates that pre-existing soils were considerably deeper than at present. Although the upper part of the profile may feature some evidence of weak podzolisation, it appears that the main pedological process in the past was clay translocation and it is probable that the *Abies* forest produced an argillic profile mainly in an upper (loessial) silty soil developed in Late Glacial drift over pre-Devensian clay loam palaeosols.

2. THE BASAL PEAT AT PRATO MOLLO

The thin section of the base of the peat at Prato Mollo exhibits distinctive banding.

1) depth 91-92.5 cm. The lowest part of the section comprises poorly organic silts and clays as low energy inwash material. These are succeeded by the deposition of very coarse serpentinite soil material that has continued to weather. Depletion features give evidence of waterlogging, whereas textural features indicate both *in situ* weathering and clay movement suggesting only intermittent waterlogging of the site.

2) depth 85-91 cm. Primary peat formation took place alongside intermittent very fine mineral deposition producing a fine laminated fabric. Marked reddening and blackening of the amorphous organic matter and charred roots clearly indicate in situ burning of the peat while charcoal fragments including coniferous wood charcoal also indicate off-site fires.

3) depth 82-85 cm. Increased mineral sedimentation rates are indicated by fine and coarse mineral bands suggesting higher energy deposition possibly due to stream channnel migration.

4) depth 79-82 cm. Renewed peat growth during a period of low energy sedimentation. Once more the layer features evidence of on and off-site fires.

Lastly, continued rooting of these basal peat layers has allowed moderately organic silt and clay originating in the overlying sediments to be washed down into these lower levels.

A comparison of the basal peat section with the local soil profile suggest several major points. Inwashed silts at the base of the peat can be ascribed to the erosion of local drift deposits. However, serpentinite soil derived from subsoil of local complex profiles, was also deposited pointing to deep disturbance of local subsoils. It is also arguable that much of the upper soil formed in the drift must have been eroded as well. If this was the case then the soil ecology probably markedly changed at this time from a complex (silty argillic drift soil over a clay loam palaeosol) profile to a shallow cover of thin drift and relic stoney clay loam palaeosol on serpentinite.

3. THE BASAL PEAT AT LAGO NERO

1) depth approx. 101-104 cm. A coarse serpentinite substrate. Coarse fissures around serpentinite rock fragments have been infilled by silt containing mica, quartz, diatoms, phytoliths and charcoal. The silt is markedly perforated by fine roots which have destroyed any original lamination. Most of the roots, except for their margins, have disappeared leaving a channel porosity pseudomorphic of rooting.

2) depth approx. 101-97 cm. The peat itself still contains fine laminae (less perforated than the silt) but more commonly fine c. 10 um organic detrital material - possibly some being charcoal. The peat also includes coarse "colluvial" fragments of burned peat and soils developed out of mainly silt size soil material.

Probable alluvial silt was deposited over a weathering substrate of serpentinite rock fragments, infilling the coarse fissures. By comparison with the available evidence from Prato Mollo, it is probable that the silts, or more accurately the silty clay loam, originated from a fine superficial cover that has been eroded, rather than directly originating from the serpentinite rock itself. In fact the latter only comprises rock fragments and weathering clay. Any disturbance of the local soil cover would readily have exposed this fine upper soil stratum to erosion. Fine organic detritus and soil fragments in the basal peat together with fragments of burned peat and charcoal suggest colluvial as well as alluvial inputs to the site at a time of local soil disturbance and burning.

References

AVERY, B.W. and BASCOMB, C.L. (Eds) (1974). Soil Survey Laboratory Methods. Soil Survey Technical Monograph, No.6. Harpenden.

BULLOCK, P., FEDEROFF, N., JONGERIUS, A., STOOPS, G. and TURSINA, T. (1985). Handbook for soil thin section description. Waine Research Publications.

CREMASCHI, M. (1987). Paleosols and Vetusols in the central Po Plain (Northern Italy). A study in Quaternary geology development. Edizioni Unicpoli, Milano.

COURTY, M.A., GOLDBERG, P., and MACPHAIL, R.I. (1989, in press). Soils and Micromorphology in Archaeology. Manuals in Archaeology Series, University Press, Cambridge.

GUILLORÉE, P. (1985). Mèthode de Fabrication Mechanique et en Sèrie des Lames Minces. Institut National Agronomique, Departement des Sols, Paris.

MACPHAIL, R.I. (1986). Paleosols in Archaeology: their role in understanding Flandrian pedogenesis. In WRIGHT, V.P. (ed). Paleosols: their recognition and interpretation. Blackwell Scientific Publications, Oxford, 263-290.

MACPHAIL, R.I. (1987). The soil micromorphology of tree subsoil hollows. Circaea. 5(1), 14-17.

van VLIET-LANÖE, B. (1982) Structures et microstructures associées à la formation de glace de ségrégation: leurs conséquences. Proc. 4th Canadian Permafrost Conference. National Resource Council of Canada, Ottawa.

TITLE Pollen stratigraphy of Holocene peat sites in Eastern Liguria, Northern Italy

AUTHOR G.M. Macphail

INSTITUTION and DATE City of London Polytechnic 1988