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PALYNOLOGICAL DIAGRAM OF THE PEAT-BOG NEAR PAVULLO NEL FRIGNANO (MODENA, ITALY) IN THE FRAMEWORK OF TUSCAN/EMILIAN APENNINES VEGETATION HISTORY

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A pollen diagram drawn for a peat bog located at San Pellegrino, in a vast plain at 675 m a.s.l. near Pavullo nel Frignano (Modena, Italy), is of vegetation on the northern slope of the Tuscan/Emilian Apennines. This altitude is just below the lower limit of the *Fagus-Abies* belt.

The sequence, 20 m in depth, consists mostly of clayey sediments in its lower part, the upper part prevalently formed by peat. The upper complex is dated by ^{14}C at 10,790 yr B.P. and 2590 yr B.P., the lower part of the sequence is dated by chronological comparison with Chiarugi's diagram (1950) and subsequent ^{14}C updates (Bertolani Marchetti, 1985).

The sequence apparently begins after 16,950 yr B.P., because its lower part does not reach the *Salix* tundra/*Artemisia* steppe located at the bottom of Chiarugi's diagram. The period of general dominance of *Pinus* over the existing *Fagus* and oak mixed forest runs from about 20 m and 12 m. The Lanscombe (?), Dryas I and Bölling phases fall here.

After a hiatus that may contain the Dryas II from 10.9 m to 10.5 m, *Pinus* and *Quercus* alternate. The lateglacial seems to end here, with oscillation of the Alleröd and Dryas III, and the Postglacial (Preboreal and Boreal) begins.

The Atlantic period consists of mixed oak forest, well represented and separated from the Subboreal by a strong contrast of *Pinus/Abies* peaks. The beginning of the Subatlantic is marked by a strong peak of *Corylus*.

In the Subboreal, *Tilia* disappears from the oak mixed forest, that takes on the aspect of a Querceto-carpinetum of the plain and increases in percentage notwithstanding a climatic involution.

In the Subatlantic, vegetation conditions of the plain are wholly established.

KEY WORDS: Palynology, vegetational history, pollen diagram, peat-bog, Northern Italy, Tuscan/Emilian Apennines.

INTRODUCTION

The drilling site of the peat bog studied in this paper is located at 675 m a.s.l., at San Pellegrino, near the city of Pavullo nel Frignano (Modena, Italy), on the northern slope of the Tuscan-Emilian Apennines (Figure 1). The geographical coordinates of the location site are 44°19'06" N, 10°50'15" E. The northern side of the basin is bordered by the

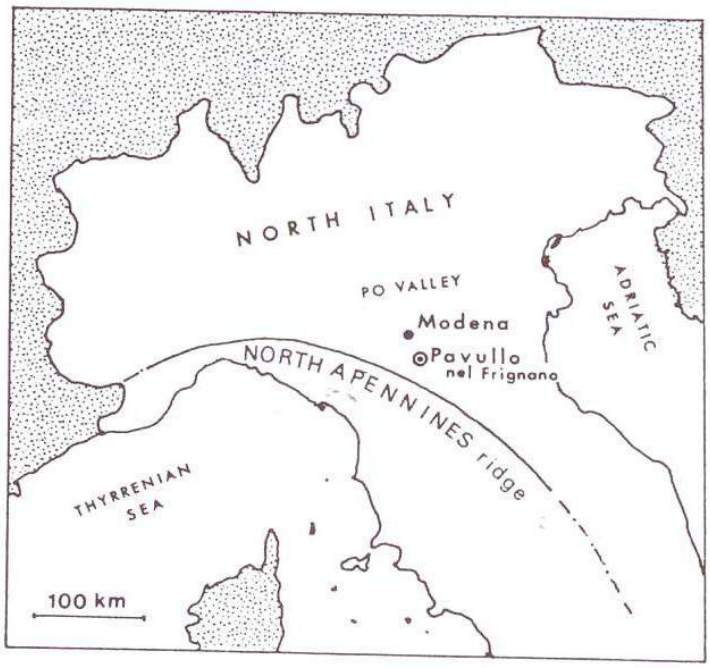

Figure 1 Location of Pavullo nel Frignano in northern Italy. Coordinates: 44°19'06" N, 10°50'15" E.

rampart of Serramazzoni. Vegetation on the plain at the foot of the mountain (Figure 2) belongs to the *Quercus pedunculata* climax (Italian: Farnia). The *Q. pubescens* climax, which tends to be more thermo-xerophilous, lies altitudinally higher from about 100 to 800 m a.s.l. These two vegetational belts have been influenced by man for centuries, and their climax is now underdeveloped. The *Fagus-Abies* belt is reached above 800 m, extending 1600–1800 m. This belt then gives way to a sub-alpine vegetation having a complex structure including pseudo-alpine meadows and niches of alpine vegetation, as recognized by means of phyto-sociological analysis and by pockets of alpine plants sheltered in refugia.

The broad plain of Pavullo featuring isolated peat-bogs, extends up to the *Fagus-Abies* belt. Its vegetation reflects the particular ecology of the soil, notwithstanding stratification of the vegetational belts, *Quercus pedunculata*, typical of the plain, is present in large numbers. As in the plain, the formation is favoured by surface water and generally abundant groundwater (Figure 2). This feature is important for interpreting the pollen diagram. Many local settings, such as "Querciagrossa" (big oak), contain magnificent specimens of *Q. pedunculata*. The flat plain formed by accumulation of clay and peat over centuries, is the site of a small airport, at what would have been an optimal location for drilling (Figure 3).

Our core comes from the most southern part of the peat bog at San Pellegrino, where we found an undisturbed sequence down to a depth of 20 m. Drilling was performed by a core drill mounted on a truck, using a bit diameter of 12.5 cm, core diameter of 10 cm, and core length of 60 cm. The sediment is clayey from 20 to 10.5 m and mostly peaty in the overlying part. Two thick layers of peat, alternating with clays, occur at depths of 10.5/8.5 m and 6.4/2.4 m.

Chiarugi (1936a, 1936b, 1950, 1958) earlier carried out palynological studies in the Tuscan-Emilian Apennines. According to his findings, the slope investigated was covered during the full glacial and lateglacial by steppe containing *Salix/Artemisia*, followed by

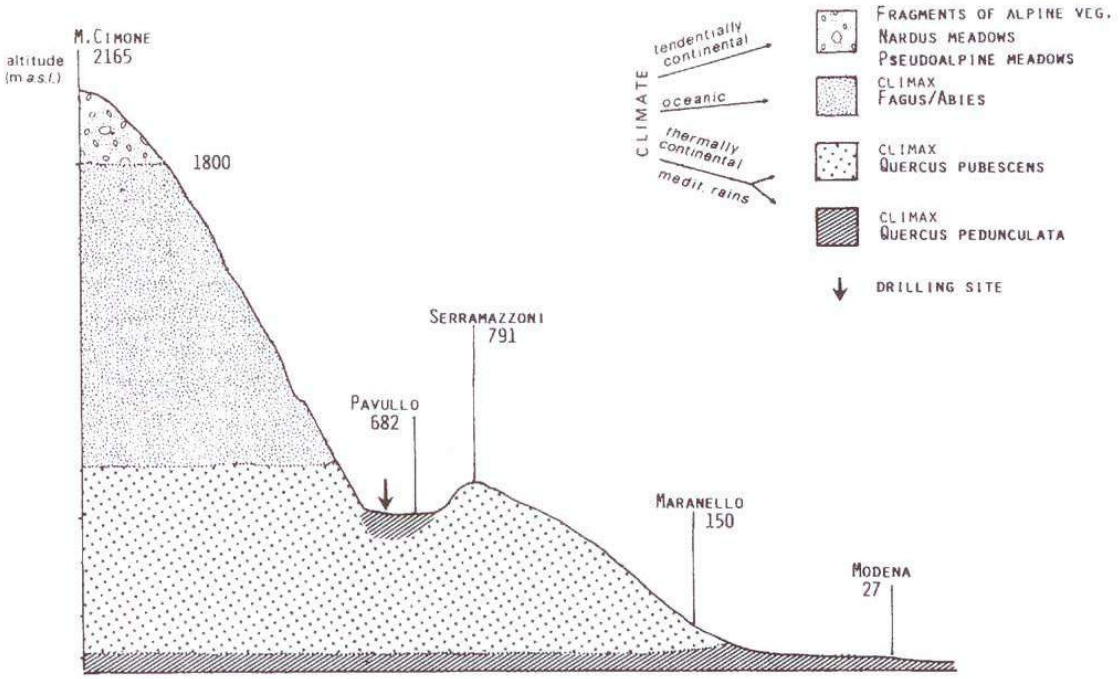

Figure 2 Northern vegetational slopes of the Tuscan/Emilian Apennines and drilling site.

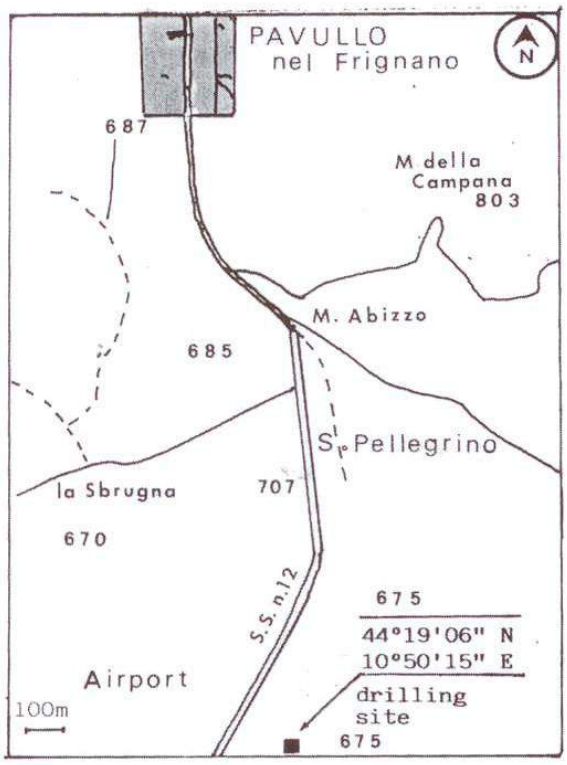

Figure 3 Location of the peat bog at San Pellegrino di Pavullo.

woodland of *Pinus/Betula* and later of mixed oak, which reached up to 1300 m (Bertolani Marchetti, 1979) at the time of the Postglacial climate "optimum".

METHODS

Radiocarbon dating was performed on wood, seeds and gyttja from the upper 10.5 m of the core. AMS dating was carried out at the R.J. Van de Graaff Laboratorium of the Department of Subatomic Physics of the University of Utrecht (NL). Below 10.5 m depth, dating was estimated by comparison with Chiarugi's general diagram of postglacial forest cycles (Chiarugi, 1950) and with two diagrams drawn from Baccioli Lake (1295 m a.s.l.) for the lower part and Greppo Lake (1442 m a.s.l) for the upper part (Chiarugi, 1936a). The top part of the sequence owing to disturbance, was not reliable and was not investigated here.

In the pollen diagram (Figures 4a-c) the curves of *Pinus, Abies, Picea, Larix, Betula, Fagus, Corylus,* are shown first (Figure 4a). Figure 4b show Quercetum mixtum (oak mixed woods) containing the principal components of the formation: *Quercus, Fraxinus, Tilia* and the sum of *Carpinus, Ostrya, Acer* and *Ulmus,* and the curves of *Castanea, Juglans* and *Salix,* followed by Vaccinietum, with small values and present especially in the upper part of the diagram. The values of the mediocrats, plants/trees living in the middle part of a climatic oscillation in palynological diagrams, are caused by the oak mixed wood, to which those of *Corylus* are added. The remaining part of the diagram (Figure 4c) is based on AP + NAP = 100. Cerealia are represented in the column of the Gramineae, and the next column traces small percentages of *Artemisia.* The sum of hygro-hydrophytes is of local ecological value: *Lemna* and *Potamogeton* are indicators of different water conditions. *Alnus* is graphically represented by values calculated outside the percentages.

According to ^{14}C datings, peat sedimentation at Pavullo began at 10,270±100 yr B.P., and is older than the 8,850 and 3,025 yr B.P. dating for Holocene peats in the Ligurean Apennines (Northwest Italy) reported by Cruise (1990).

RESULTS

Vegetation (Figures 4a–c)

Pinus predominates the oak mixed forest from 20 to 12 m and later is rather well balanced with oak mixed forest from 12 to 8.5 m. The sharp drop in *Pinus* at 20 m will be examined in the context of other woody plants at the same level. Below 8.5 m, *Pinus* declines, with an isolated episode consisting of two nearby peaks contrasting with those of *Abies,* which has two peaks alternating with those of *Pinus.*

Abies is present at low levels towards the bottom of the diagram and has maximums up to 30%. Its Apennine history is here represented on a smaller scale; the only important episode is that of the peak greater than 50% at 6 m contrasts with *Pinus.*

Fagus has a similar history, being present along most of the diagram at values below 10–12%. Below 4.5 m it reaches 20% and then declines, having only left a shrunken image of its mountain history.

Corylus is poorly represented; only at around 4.8 m does it show a sudden rise that exceeds the oak mixed forest. This fact will be discussed below.

Quercetum mixtum has an interesting evolution. Its curve rises from the lowest level, showing significant oscillations at 15 m, which may be the basis for identifying a climatic

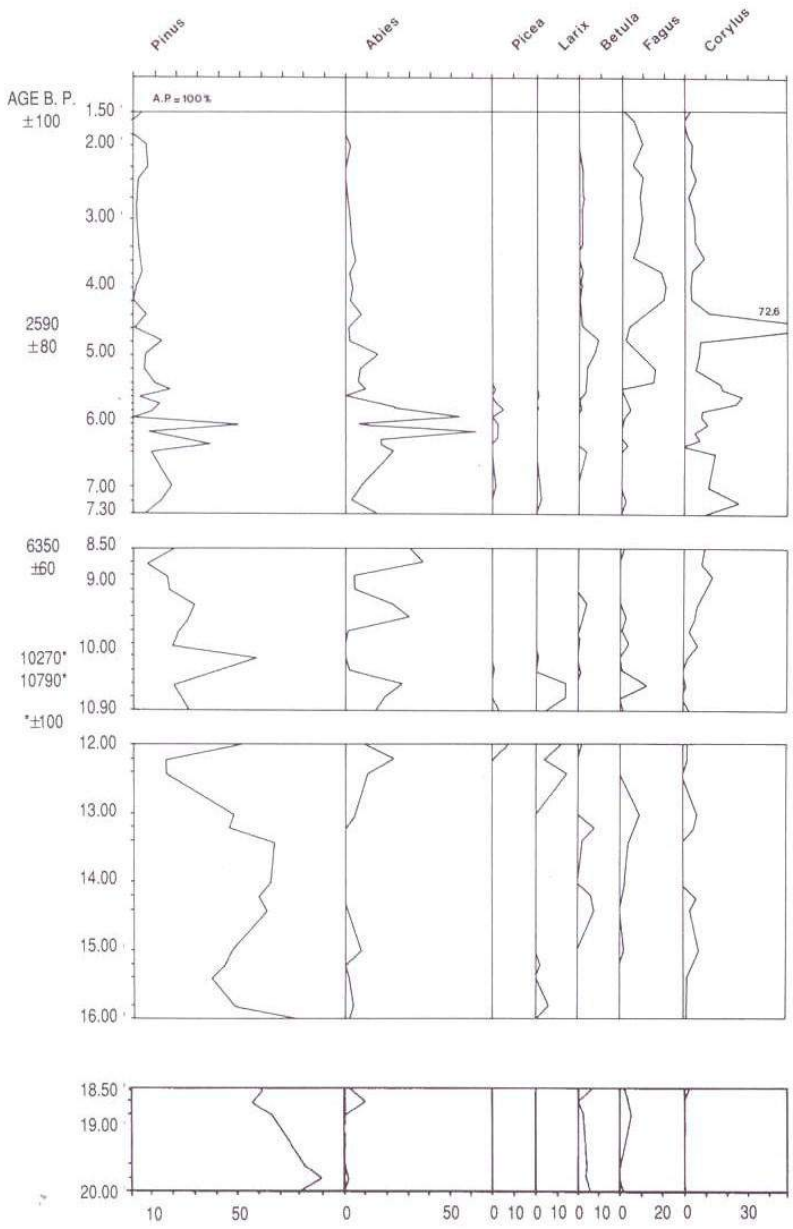

Figure 4a Pollen diagram of the peat bog in San Pellegrino near Pavullo nel Frignano (Modena, Italy). The curves of the arboreal plants (AP) were drawn taking AP= 100%. The curves of the non-arboreal plants (NAP) were drawn taking AP + NAP = 100%. See text for details.

thermal improvement earlier than the Dryas stade (Lanscombe?). The supremacy of the oak mixed forest begins above 10.5 m (with a peak at 9.5 m). The oak mixed forest from 9.5 m and 6/7 m contains a great deal of *Tilia* and is rich in other woody plants; it has a diverse composition and *Quercus* is less represented. The picture is that of a mountain oak mixed forest that does not, however, follow the rule of decreasing after the climatic postglacial optimum, as in the other diagrams but continues to rise, lose *Tilia*, gain *Fraxinus*, with persisting *Carpinus*. Above 4 m, we recognise the Querceto-carpinetum of the plain.

Juglans and *Castanea* show their indigenous character. However, *Castanea,* of certain anthropogenic origin, is significantly represented above 3 m.

Salix in our diagram does not represent the glacial steppe, if not at the deepest

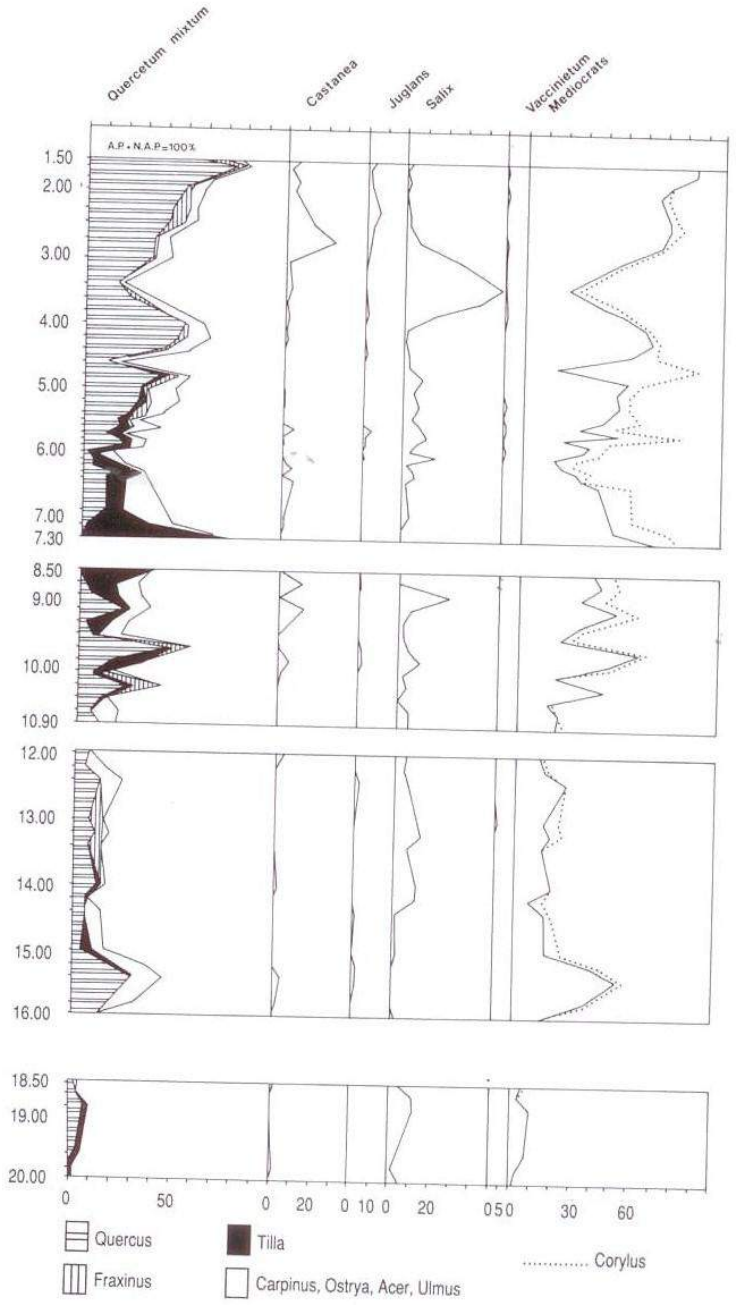

Figure 4b Pollen diagram of the peat bog in San Pellegrino near Pavullo nel Frignano (Modena, Italy). The curves of the arboreal plants (AP) were drawn taking AP= 100%. The curves of the non-arboreal plants (NAP) were drawn taking AP + NAP = 100%. See text for details.

level, where it is accompained by *Artemisia*. The situation only vague resembles Chiarugi's diagram, where a glacial steppe is clearly represented at high altitude. *Salix* along the profile, has a local character related to wet conditions. Its maximum lies around 3/3.6 m, contemporaneous with an *Alnus* maximum and a drop in the oak mixed forest.

Alnus informs us on the hydrological situation. This type is poorly represented in the lower levels and has considerable maximums from about 9 and 3 m. The curve of *Alnus* and of *Salix* drop off near the top of the diagram.

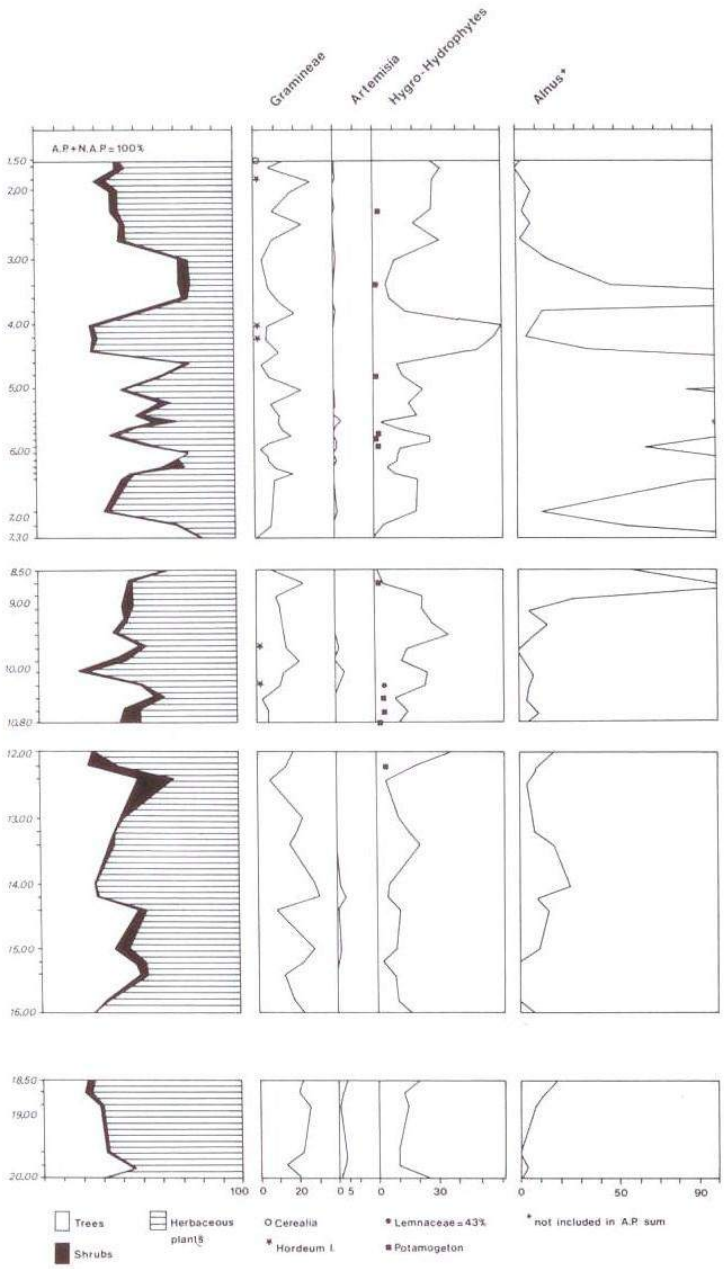

Figure 4c Pollen diagram of the peat bog in San Pellegrino near Pavullo nel Frignano (Modena, Italy). The curves of the arboreal plants (AP) were drawn taking AP= 100%. The curves of the non-arboreal plants (NAP) were drawn taking AP + NAP = 100%. See text for details.

The mediocrats follow the improvement in postglacial climate, but these do not decrease during the Subboreal/Subatlantic, sustained by Quercetum mixtum, in the manner described above. Thus, the *Pinus* curve better represents the climatic pattern.

Among the NAP, the Gramineae have an oscillating curve that reaches maximums of 20–30%. Cerealia are only occasional detected, limited to the upper part of the profile with some *Avena*-type and *Hordeum*-type pollen grains.

Vaccinietum is a community of well known ecological and phytosociological importance. Our diagram shows a low percentage at 13 m (5%). The upper part of the

diagram gives percentages ranging from 1.5 and 4% and a composition similar to that of present-day Vaccinietum, with dominant *Vaccinium myrtillus*, some *Empetrum* and sometimes *Calluna*.

Between the hygro-hydrophytes, a group of plants that indicates open water conditions. *Lemna*, inferring nearly stagnant water, appears discontinuously in the lower part of the profile. The behaviour of *Lemna*, in terms of flowering, still poorly known (Bertolani Marchetti *et al.*, 1991), is perhaps the cause of this discontinuous presence of pollen. *Lemna* is almost always present and reaches its maximum at 10.3 m, accompanied by other hydrophytes (*Myriophyllum, Nymphaea, Nuphar, Potamogeton*). Above 6 m, there is a nearly constant presence of *Potamogeton* along with *Lemna*, while plants from swamp environments (for example: *Typha, Phragmites, Alisma, Lythrum, Lysimachia*) can be observed.

Overview of the Pollen diagram

The profile of the San Pellegrino di Pavullo peat bog (Figures 4a–c) depicts the climatic-vegetational events occurring from the lateglacial to the Subatlantic *sensu strictu*. Its history begins about 1000 yr after that of Chiarugi, cited above. The glacial steppe is poorly represented in our diagram. The pine period runs below 11 m, already in competition with the oak forest that covers about 20% of the AP.

Above 9 m, the mixed oak forest dominate the woody vegetation and has more irregular features due to the presence of *Tilia* that gives a less thermophilous aspect from 7.5 to 5 m.

Higher in the diagram, beginning at 4 m, is the only strong peak of *Corylus* (72.6%); *Corylus* reduces the oak curve, and marks the horizon of the Subboreal to Subatlantic boundary. *Fraxinus* in small amounts of 9–14% in the oak mixed forest of the pine period makes up part of the oak forest in the Boreal. *Fraxinus* was also found by Cremaschi (1982) in coal from a mesolithic site in the nearby Reggio Emilia Apennines. The Subboreal/Subatlantic boundary can also be recognized near Pavullo in Chioggiola's peat bog diagram (Bertolani Marchetti *et al.*, 1981). This profile supplements the record in the San Pellegrino di Pavullo diagram up to recent times.

The modest values of *Abies* and *Fagus*, seemingly unrelated to the San Pellegrino peat bog, provide little evidence of the events that occurred in the slopes overlying the basin.

The percentages of *Juglans* and *Castanea*, which occur to the base of the core, indicate that these plants are indigenous. *Castanea* reaches higher percentages at about 2.5 m, certainly due to anthropic intervention. Conditions that caused an invasion of *Alnus* are related to episodes of running and stagnant water draining the basin.

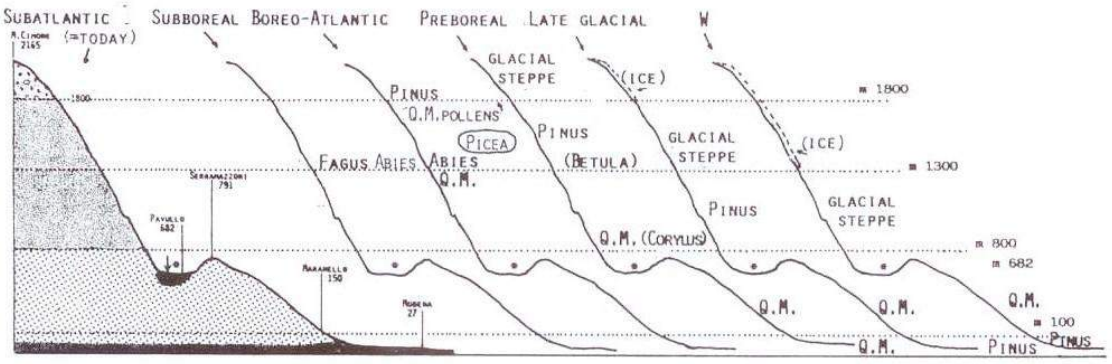

Figure 5 Sketch of the vegetational belts in the different postglacial periods.

EVENTS AND CONCLUSIONS

Some relationships can be drawn between our diagram and the Preboreal (10,150/8750 yr B.P.), Boreal (8750/7450 yr B.P.), Atlantic (7450/3150 yr B.P.), Subboreal (4450/2750 yr B.P.) and Subatlantic (2750 yr B.P. to present). Lateglacial relationships are also apparent, according to the known scheme: Lascaux (?) (before 15,950 yr B.P.), Dryas I (15,950/13,250 yr B.P), Bölling (13,250/12,300 yr B.P.), Dryas II (12,300/11,750 yr B.P.), Alleröd (11,750/10,750 yr B.P.). Dryas III (10,750/10,250 yr B.P.).

Our record almost touches on the Late Würm. While the Dryas I seems to run from 16 m, the top interval should be dated around 12,000 yr B.P., at the start of the Bölling. The level from 12.5 to 12.2 m, presenting a decline of *Pinus* and a small increase in *Abies* and oak mixed forest, may be attributed to the Bölling. The Dryas II situation is unclear due to a discontinuity in the diagram. An important event that occurs at 15 m, with a small warming episode, is the fall in the *Pinus* and *Abies* curve and rise in the oak mixed forest. It could represent an event such as the Lascaux (Nilsson, 1983).

Chronological correlations up to this point were made by relating the diagram events with the dates hypothesized by Chiarugi (1950), and taking into consideration the variations obtained after ^{14}C dating (see Bertolani Marchetti, 1985, pp. 539, Figure 24.6).

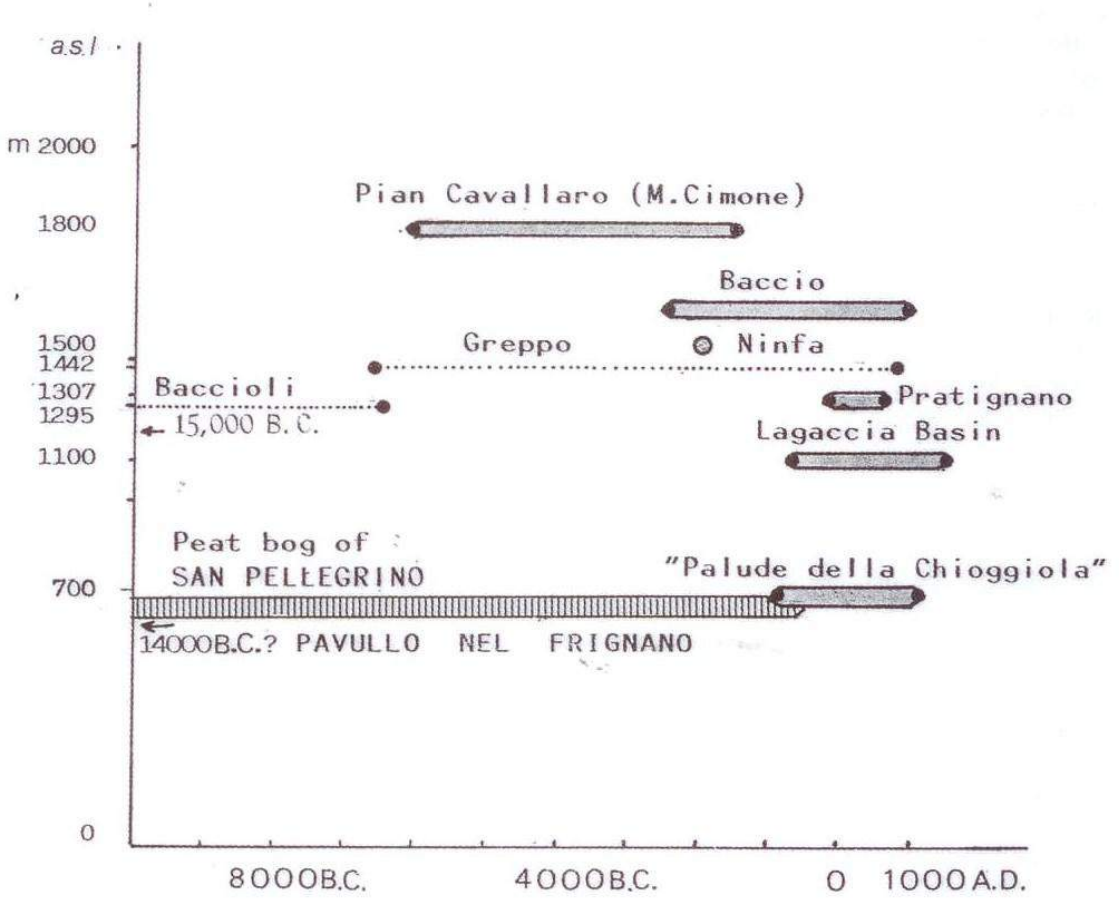

Figure 6 The peat bog/lake basins palynologically studied in the mountainous regions of Modena. The dotted lines represent the basin of the Baccioli and Greppo Lake, which are located towards Tuscany (see: Accorsi *et al.*, 1981; Bertolani Marchetti, 1963; Bertolani Marchetti *et al.*, 1981; Chiarugi, 1936a, 1950; Mori and Bertolani Marchetti, 1992).

We now enter into the part of the sequence supported by ^{14}C dating. The Dryas III is located between 10.5 m (10,790 yr B.P.)and 10.2 m (10,270 yr B.P.). with *Pinus* increasing, *Abies* absent and oak mixed forest decreasing. Subsequently, *Tilia* shows a small Preboreal peak.

The Atlantic period dated at 6370 yr B.P. at 8.5 m contains percentages of *Pinus* and *Fagus*, accompanied by a limited development of mixed oak forest. *Quercus* is not the principal component when compared to *Tilia* and other arboreals.

At about 6 m, events follow the transition from warm — wet Atlantic to the drier Subboreal. Two peaks of *Pinus* and two peaks of *Abies* strictly alternate. The oak mixed forest drops sharply, at first, followed by a fall and then a general increase in *Tilia*. *Picea*, previously absent, appears with low values. The Subboreal/Subatlantic boundary is marked by a strong peak of *Corylus*, coinciding with a sharp drop in the oak mixed forest curve.

The San Pellegrino di Pavullo sequence, because of its low altitude location near the bottom of the *Fagus* belt and protected position, was less influenced by the climatic and vegetational events that affected the high altitude peat bogs. The sequence is diversified by a unique oak mixed forest profile, that instead of falling due to climatic worsening, increased and evolved towards a Querceto-carpinetum similar to that of the Po valley climax. Many typical non-arboreal plants accompany this type of oak mixed forest. *Humulus lupulus*, a typical plant of Querceto-carpinetum clearings that today survives in isolated stations, is part of the herbaceous flora of the Pavullo area and appears in the upper part of the peat bog diagram. According to the stratigraphy of the sequence and the ^{14}C dating, the age that the peat layers started to grow in Pavullo lies around 10,000 B.P.

COMMEMORATION

We would like to remember our close friend, the late Mr. Sante Montanari from Rivalta (Reggio Emilia, Italy). He performed with exemplary dedication the drilling and continuous sampling, using the equipment of his drilling business. With keen scientific interest, Mr. Sante always wanted to be informed of the findings. We dedicate these pages to the memory of his friendship and noteworthy ability.

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