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Gli effetti delle variazioni climatiche pleistoceniche sulla dinamica
dei popolamenti animali e vegetali nella Penisola italiana

Quaternary vegetation landscapes in Piedmont and in the Aosta Valley with particular reference to the Holocene

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SUMMARY

Reconstruction of some Piedmontese plant landscapes during the Quaternary is proposed on the bases of the palaeobotanical data on the Italian side of Western Alps and on the adjoining flatlands.

Studies starts with the informations that can be drawn from the Villafranchian typical deposits and the deposits regarded as Villafranchian *sensu lato:* these data allow to reconstruction of thermophilous forests and of hydrophilous herbaceous vegetation communities. Data are then referred to the progressive extinction of thermophilous elements based both on palynological and on palaeocarpological data from Upper Pliocene to Lower and Middle Pleistocene and to the beginning of the glaciations.

The literature is very poor with regard to the Middle Pleistocene and it is necessary to arrive to the Riss-Würm interglacial to have data on vegetation with the presence of a mesophilous deciduous forest, characterised by an absence of archaic entities.

Numerous plant landscapes are then proposed for the last interglacial and to the interstadials, both at high and at low altitudes; some are referred to the old Penck and Bruckner nomenclature, some refer to a more recent division in glacial peaks and interstadials.

Literature becomes very rich for the Post-Glacial, for which reconstruction of landscapes is possible and easier than for the previous periods. Particular detail is so far dedicated to the last 13,000 years plant landscapes in Piedmont also comparing our data to the other Central and Eastern Alps observations and to the migration of tree species.

Completion of the temporal panorama and quantitative and qualitative correlation of the vegetational data with the changes in the climate will allow the formulation of hypotheses concerning its variations in the decades ahead.

Data on recent small temperature swings of the order of 1-1,5 °C have been correlated to relatively rapid altitudinal oscillations of vegetation, especially of the timberline. The concepts of stability of plant communities may be modified by reconsidering the extensive potential of rapid vegetational dynamism.

Reconstruction of Piedmontese plant landscapes during the Quaternary is based on consultation of the palaeobotanical studies of the Italian side of the Western Alps and the adjoining flatlands.

The geology of this sector has been the subject of numerous in-depth investigations. Works on vegetation, on the other hand, have been sporadic and frequently confined to specific points. Discussion of the results in the light of the latest chronological knowledge is rare.

Years	Divisions	Periods
0		Olocene
10,000		
	Upper	
132,000		
	Medium	Pleistocene
788,000		
	Lower	
165,000 [1]		
1,800,000 [2]		
	Upper	
260,000		
	Medium	Pliocene
360,000		
	Lower	
5,400,000		

Fig. 1 - Chronological table proposed by Richmond and Fullerton (1986) and by Rio et al. (1993).
(1) Following Richmond and Fullerton, 1986; (2) Following Rio et al.,1993.

Palaeobotanical studies dealing with the Upper Pleistocene are quite numerous, whereas much less has been written about its Lower and Middle periods. Most publications are concerned with the Riss-Würm interglacial, corresponding to the Eemian and the subsequent Würmian properly so called.

Palaeobotanical and particularly palynological studies of the Holocene are more numerous and detailed. It is these that have been used in reconstruction of post-glacial plant landscapes.

A critical feature is the definition of the time periods, since recent findings have gone well beyond the presumed precision in the chronological divisions of the Quaternary adopted in the past. In what follows, reference will be made to the chronological table proposed by Richmond and Fullerton (1986) and Rio et al. (1993). This is presented in its more concise form as "periods" and "epochs" (Fig. 1).

Most papers consulted still refer to the four classic "glaciations" proposed by Penck and Bruckner in 1909, often accompanied by numbered datings. Work published over the last twenty years, however, while continuing to refer to this general pattern, has identified numerous glacial peaks and interstadials within each glaciation. Recent palaeobotanical papers illustrate the presence of vegetation cycles interpreted as sequences of glacial and interglacial fluctuations (Ravazzi and Strick, 1995) that cannot be directly related to the classic glacial chronology.

Recent international studies of the geology of the Quaternary (e.g. Billard and Orombelli, 1986; Dansgaard et al., 1993; Johnsen et al., 1995) have proposed as many as 10 to 15 glacial peaks of varying duration and intensity, each of which has been tentatively assigned to divisions of the Quaternary mainly founded on palaeomagnetic data.

Despite these recent acquisitions, in this paper, which is based on bibliographical data, the terminology used by each author is maintained. Whenever possible, reference is made to the numerical datings in Fig. 1.

Studies relating to Piedmont start with the information that can be drawn from the Villafranchian deposits. These have been critically reviewed in their entirety and the results were presented at a congress in 1994 (Carraro et al., 1996). This review covered both the "Villafranca d'Asti" Villafranchian typical deposits and deposits regarded as Villafranchian *sensu lato*. The most significant part of the Villafranchian type zone (e.g. the RDB quarry) corresponds to the Middle Pleistocene according to Bertoldi (1996). Its landscape as reconstructed from the pollen data corresponds to a thermophilous forest with typical marsh vegetation, with *Taxodium* and *Glyptostrobus*, together with *Carya, Pterocarya*, Ulmaceae, etc., and hydrophilous and hygrophilous herbaceous plants. The botanical evidence is in keeping with the results of studies of mammal remains and the palaeomagnetic data (Ambrosetti et al., 1996).

The same stratigraphic sequence has yielded other floristic complexes referable to a dry, flatland forest (*Platycarya, Liquidambar, Liriodendron*, Palmae). Traces of submontane and montane landscapes with *Picea, Abies, Betula* and *Fagus* are also present.

This succession of plant landscapes can be assigned to the Pre-Tiberian phase (2,500,000-2,400,000 B.P.).

In the same monographic review (Caramiello and Siniscalco, 1996) sediments forming the so-called "Upper Complex" are examined. This is also part of the Villafranchian type area and rests on the previous sequence via an erosion surface. These sediments have yielded very few pollens and their interpretation leaves many questions unanswered. The specimens examined have none the less shown the presence of an autochthonous flora already very poor in Tertiary plants. There remain solely traces of Taxodiacae, and of *Carya* and *Tsuga*, the latter being regarded by some workers as an ancient Quaternary element (Paganelli, 1961; Lona and Bertoldi, 1972). The other finds point to a deciduous mixed oak landscape.

The floristic groupings identified in the light of many other surveys conducted outside the type area and outside Piedmont (Caramiello et al., 1996), are regarded

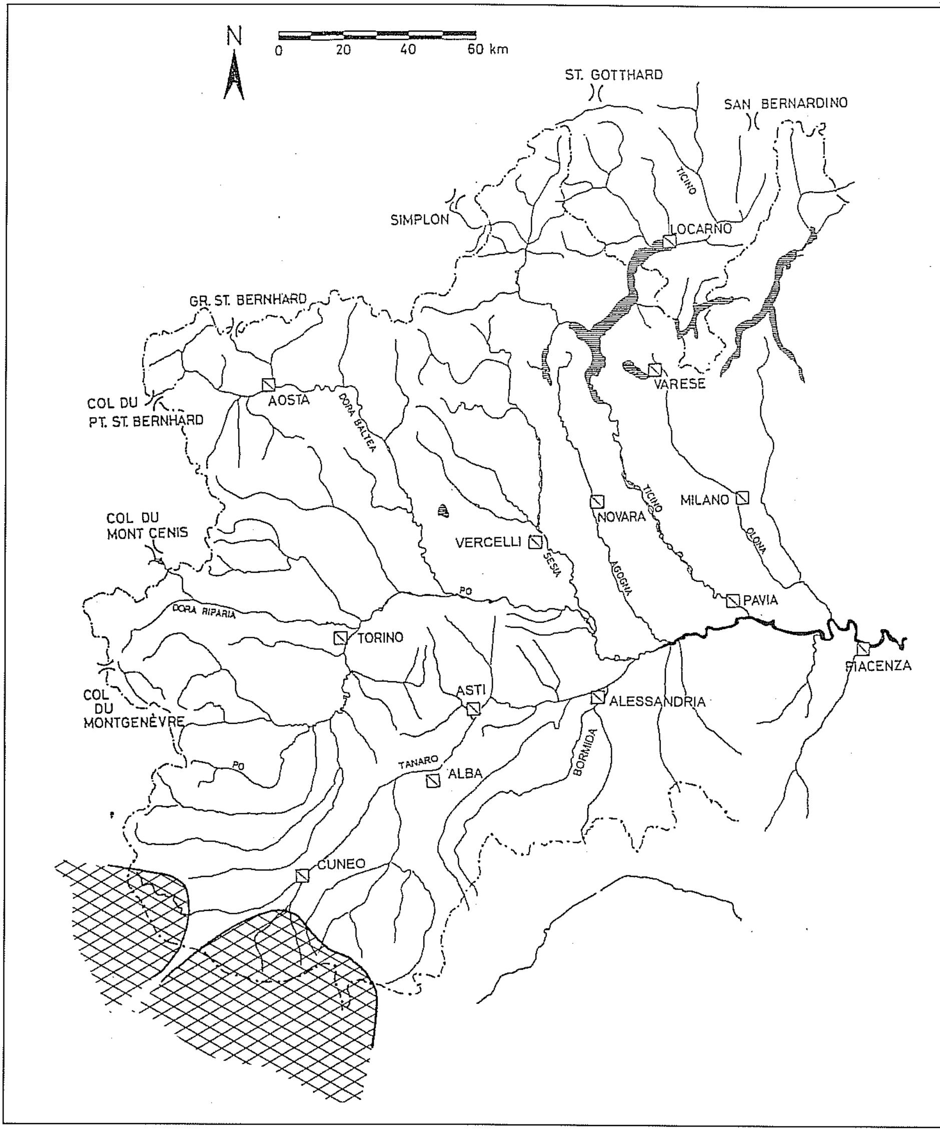

Fig. 2 - Distribution of *Saxifraga florulenta* in Piedmont.

as vegetationally, environmentally and stratigraphically significant by Bertoldi (1990) and Martinetto (1995). They have been assigned to later periods up to the Lower Pleistocene (Caramiello et al., 1996). The Plio-Pleistocene boundary (1,750,000 B.P.) is represented by the last palynological traces of Tertiary plants in the process of extinction, including Taxodiaceae (*Sciadopyitis, Sequoia*), *Myrica*, Celastraceae, *Actinidia*, Palmae, Magnoliaceae p.p., and Gingkoinae. Further indications stem from the palaeocarpological entities, such as *Nyssa disseminata, Sequoia abietina* and *Styrax maximus.*

Another floristic grouping with Tertiary elements became extinct during the first part of the Lower Pleistocene (more than 1,500,000 B.P.). It consisted of *Carya, Engelhardtia/Platycarya, Pinus aploxylon* s.s. type, *Juglans bergomensis, Podocarpus, Dacridium,* etc.

A set of common Pliocene-Lower Pleistocene elements (*Carya, Juglans, Cedrus, Tsuga* and *Pseudotsuga*) became extinct less than a million years ago.

This picture of the plant landscapes referable to the Lower Pleistocene precedes the start of the glacial period. In this long time span, there is an evident floristic impoverishment primarily brought about by the deterioration in the climate that culminated with the first true glaciation around 800,000 B.P. according to Orombelli, just prior to the end of the Matuyama epoch.

Floristic impoverishment is most evident in the Middle Pleistocene during the repeated glacial peaks that involved the whole of the Alps. In the Western Alps in particular, there was a discontinuous cover, probably during all the glaciations, with ice sheets decreasing in area from East to West and from North to South, with a minimum in the Maritime Alps. In the less glaciated geographical zones, there is current evidence of the refuge areas of Tertiary plants, which can be interpreted as both palaeo-endemisms (*Berardia subacaulis, Saxifraga florulenta* (Fig. 2), *Primula allionii, Campanula alpestris,* etc.) and neo-endemisms (*Brassica richeri,* etc.). The existence of refuge areas with particularly favourable microclimatic characteristics has enabled numerous stenomediterranean species to survive to this day in Piedmont and the Aosta Valley in stations regarded as "xerothermal oases", mainly found in the Susa Valley and the Aosta Valley (Fig. 3).

A paper published by Montacchini and Caramiello (1969) listed 52 steno-mediterranean entities in the Susa Valley on the orographic south-facing slope in the area of Chianocco, Foresto and Susa. There are also small, non-valley areas (Musiné, Monte San Giorgio di Piossasco) with Mediterranean elements (*Quercus ilex, Cistus salvifolius, Notholaena maranthae, Serapias vomeracea,* etc.) in a zone geographically definable as pre-alpine.

These isolated stations cannot be attributed to post-glacial recolonisation, since they are too far distant from the present distribution of the species. They are very probably a record of the Middle Pleistocene plant landscape marked by discontinuities heavily influenced by both morphological and microclimatic factors.

The literature is virtually silent with regard to the Middle Pleistocene in Piedmont. There is solely a paper by Charrier (1990) describing the apparent survival of some Tertiary elements (*Tsuga, Cedrus, Carya, Pterocarya, Zelkova,* etc.) until the end of the Gunz-Mindel interglacial (lower part of the Middle

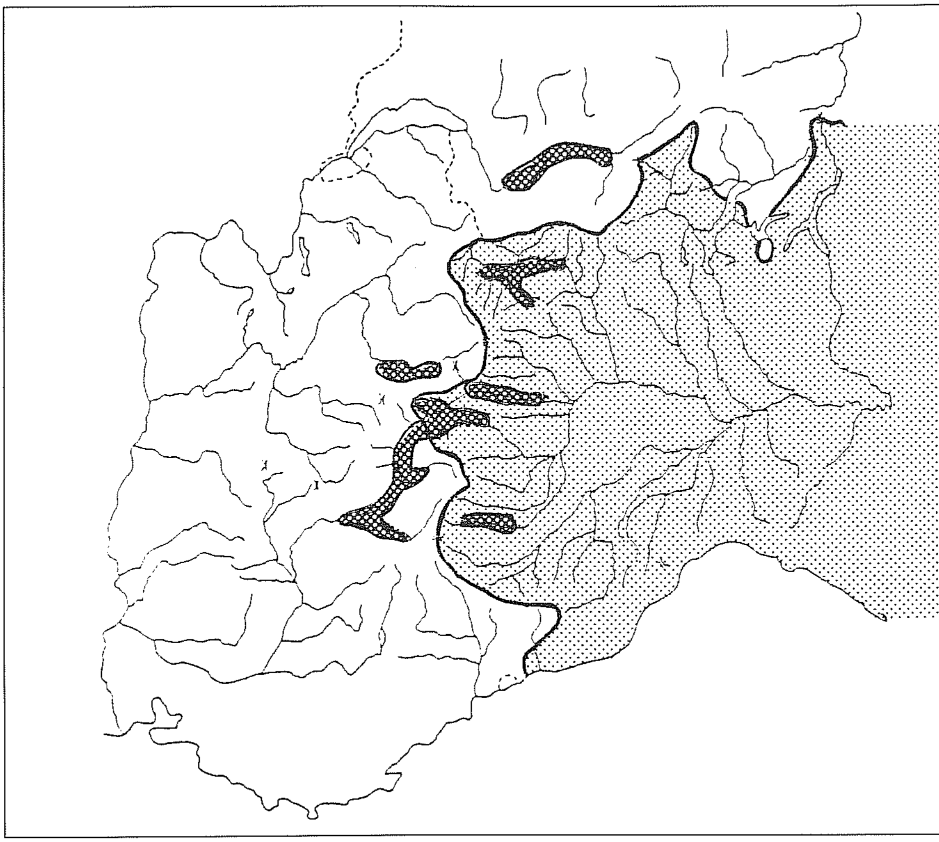

Fig. 3 - Xerothermal oases (dark points) in the Western Alps (from Montacchini, 1992) (light points: Italy).

Pleistocene: 800-600,000 yr B.P.) in the Susa Valley. This ancient landscape is thought to have alternated with a cold-temperate forest vegetation composed of *Quercus* t. *caducifolia, Abies, Tilia, Ulmus* and *Salix.*

The same paper suggests that during the lower and middle periods of the Middle Pleistocene (600-135,000 B.P.) there were several glacial peaks that would explain the disappearance of these Tertiary elements and the diffusion of cold-temperate vegetational types.

A study of the Rio Garosso district near Rivalta conducted by Charrier and Peretti (1972), in fact, identified a forest landscape with dominant mesophilous deciduous species (*Alnus, Corylus, Capinus* t. *orientalis, Ulmus, Fraxinus*) and an absence of archaic entities. This is attributed to the Riss-Würm interglacial on account of its similarity with the coaeval Austrian loess area vegetation described by Frenzel (1964), and called the "*Carpinus* vegetation".

Another landscape referred to the Riss-Würm interglacial is that of Re in Val Vigezzo, whose macrofossils and pollen have been described by many workers, such as Sordelli (1883, 1886), Benassi (1896), Corti (1895), Craveri (1912), Novarese (1927), Gianotti (1950), Lona (1952) and Betolani-Marchetti (1955), and again by Sidler and Hantke (1993).

The sum of the studies made of an approximately 12-metre profile resting on a "Rissian" moraine has revealed a landscape that changed upwards from a closed wood of conifers to a mixed oak forest with dominant *Pinus, Quercus* and *Ulmus,* later enriched with *Abies, Picea* and *Corylus.* At the upper limit of the sequence, these entities are joined by *Abies alba, A. nordmanniana* and *Tilia.*

This assemblage is a significant fragment from the Riss-Würm interglacial. Despite the absence of its initial and final stages, there is an evident trend from a colder, dry period to one that was humid enough to allow the expansion of *Tilia.*

Sporadic macrofossil and palynological surveys have been made of *Hedera, Buxus sempervirens, Ilex aquifolium,* whose sequence at Les Echet in France has indicated them as typical of the warm Middle Eemian (de Beaulieu and Reille, 1984). It is thought that the last two archaic relicts, *Abies nordmanniana* and *Castanea latifolia,* did not disappear until the Würm Glaciation (about 125-18,000 B.P.) (Paganelli, 1961).

The presence of these two species and *Rhododendron ponticum* (=*R. sordellii*) is evidence of the Southern Pontic (Colchic) nature of Val Vigezzo's Eemian flora.

During the Würm interstadials, the flora became progressively more similar to that found in Piedmont today. The data reported for these periods can be used in the tentative reconstruction of certain plant landscapes at various altitudes.

Both Charrier and Peretti (1977) and Tropeano and Cerchio (1984) examined some peat deposits discovered during the working of a quarry at about 200 m a.s.l. in the Moncalieri-Carignano area of the Po flatlands to the south of Turin. These peats are from 8 to 10 metres thick and date to about 30,000 B.P. They would thus be assignable to the Würm 3 glaciation peak. This was the period of the large mammals *Elephas primigenius* and *Megaceros giganteus.* The dominant tree species are *Pinus sylvestris, P. montana, P. cembra, Betula* t. *nana* and *Alnus* t. *viridis.* The herbaceous plants are represented by Gramineae, *Artemisia,* other Compositae, *Polygonum* t. *bistorta* and *Selaginella selaginoides.*

The pollen data indicate a subarctic vegetation similar to that of present-day Alpine peatbogs about 1,800-2,000 m a.s.l. The surrounding vegetation was mostly composed of cold steppe with occasional pine and birch woods.

Pollen sampling at Alice Superiore (about 600 m a.s.l.) in the Ivrea morainic amphitheatre by Arobba et al. (1996) has revealed a forest vegetation with dominant *Quercus,* plus *Fagus, Betula, Picea, Carpinus, Abies* and *Tilia.* Radiocarbon dating has given a conventional age of more than 43,000 years, which places the deposit in a Last-Würm interstadial (according to the scheme of Dansgaard et al., 1993), but does not provide more precise information.

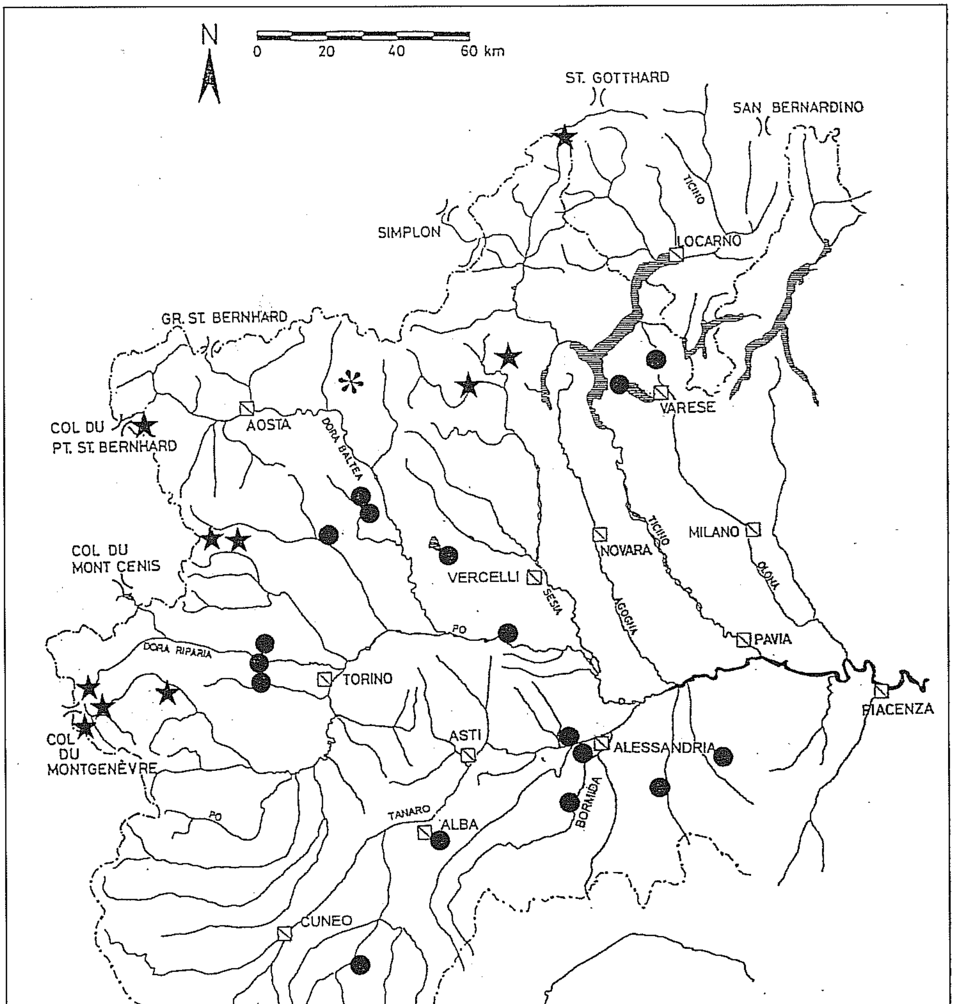

Fig. 4 - Sites in Piedmont and the Aosta Valley that have formed the subject of Post-glacial palynological studies (from Caramiello et al., 1996). The site investigated by Brugiapaglia (1996) is marked with an *; points refer to plain or pre-alpine areas. Stars refer to alpine areas.

The third landscape which can be broadly reconstructed is that of the highland level at Entracque (894 m a.s.l.) in Val Gesso. The very uniform sediment core taken by Charrier (1970) contained very little pollen. *Pinus* (probably *P. sylvestris*) was dominant, accompanied by Gramineae, Cyperacaeae and Chenopodiaceae. This formation is dated to about 50,000 B.P. and illustrates the extreme floristic and vegetational poverty of the area.

The thermal minimum of the Last Würm glaciation, which culminated about 20,000 B.P., may be supposed to have resulted in the maximum floristic impoverishment of many parts of the Alps. This landscape formed the starting point for the recolonisation typical of the Post-Glacial period (13,000 B.P.). The sites studied with regard to this period in Piedmont, and the Aosta Valley are shown in the map in Fig. 4.

The few numerical datings determined so far allow only a partial reconstruction of the chronology. Further information concerning the Aosta Valley can be found in the paper by Brugiapaglia in this volume.

Schneider's review (1985) of the palynological literature relating to the history of the Alpine vegetation from Turin to Trieste in the last 15,000 years showed that fewer data had been collected for the western as opposed to the eastern sector, especially for the 800-1,700 m altitude belt.

Subsequent studies have not remedied this shortage of data. For the areas in which surveys have been conducted, reconstruction of the post-glacial environment is easier than that of the previous interglacials and interstadials, not only because the landscapes become increasingly similar to those of today, but also because the numerous pollen diagrams drawn for many zones throughout the whole of Europe illustrate the migration pathways of many arboreal and herbaceous entities. Furthermore, a fairly complete knowledge of the changes in the climate that have taken place since the last glaciation has been built up from protohistorical and historical as well as palynological data.

The Older Dryas (to 13,300 yr B.P.) and the Bölling (13,300 to 12,400 B.P.)

In the western Po Valley, as in parts of Central Europe, the late-glacial phase was marked by tundra and the dominance of non-arboreal species, such as *Artemisia, Rumex* and Chenopodiaceae. This was followed by a period with thin birch woods, together with *Larix* and *Pinus* (the Bölling phase). Schneider's data do not allow differentiation of the cool Older Dryas oscillation from the subsequent Bölling in the Western Alps. Between 1,000 and 1,500 m, *Juniperus, Pinus* (*P. sylvestris* and *P. mugo*) and *Betula* species were dominant, accompanied by *Salix* and *Ephedra. Larix* was present between Ivrea and Turin in the Bölling (Schneider, 1978) and it has thus been supposed that refuge areas were preserved, as reported for the period 15-14,000 B.P. near Lake Garda.

In relation to *Artemisia* "cold steppe", which was present in this and in other moments, determination of the species of this genus would be interesting in the light of detailed morphometric data (Caramiello et al., 1980). Unpublished data obtained by Caramiello et al. from the sphagnum moss layer of an Alpine peatbog has shown a great abundance of recently deposited *Artemisia* grains (30-40%), whereas the area itself and its immediate vicinity carry only a few *Artemisia campestris* and *A. glacialis* plants.

Middle Dryas (12,400-11,900) and Alleröd phase (11,900-10,800)

Schneider's data also show that plant landscapes composed of *Pinus* and *Betula* woods can be reconstructed for low altitudes, and that mixed oak and other broad-leaved (*Tilia, Ulmus, Corylus*) woods appeared in the Alleröd. This mixed oak or oak-hornbeam complex points to a better environment and wide diffusion of numerous forest species. It was to dominate the plant landscape at low and medium altitudes in Piedmont from this period onwards. The pollen data are unable to provide a precise reconstruction of the types of mixed woods in different places and at different times, one reason being the present absence of undisturbed woods which could serve as a reference.

At higher levels, the situation is the same as in the previous phase. The few data available indicate the presence of conifer woods with dominant *Larix* and *Pinus*.

Recent Dryas (10,800-10,300 B.P.)

This very short period is marked by the last evident post-glacial deterioration in the climate capable of appreciably thinning out the woods, coupled with an increase in non-arboreal pollen granules, such as those of *Artemisia* and Chenopodiaceae, which provide evidence of a cold, dry climate. At the end of this period, the complete pollen curve for the mixed oak forest rises and remains constant until the Sub-Boreal and Sub-Atlantic phases, in other words until the woods began to be altered by human activities. At altitudes of more than 700-800 metres, *Abies alba* appears in the company of other conifers, though with very low and discontinuous values. Its migration from the Central Alps and their forelands to the Western Alps is well documented (Schneider, 1978), though its appearance as early as the Alleröd in the Viverone pollen diagram and from the Younger Dryas in those for Alice, Avigliana and Trana suggests that it may not have migrated, but remained in refuge oases in the pre-Alpine foothills of NW Piedmont.

Pre-Boreal (10,300-8,900 B.P.)

The flatlands and hills up to 500-600 m were occupied by a mixed-oak forest with *Quercus, Ulmus, Tilia, Acer* and *Fraxinus*. Higher up, there were *Pinus* and then *Abies alba* woods. *Abies alba* became dominant in many areas between 1,000 and 1,500 m from about 9,500 B.P. (Schneider, 1985). At the end of the Pre-Boreal, *Picea excelsa* arrived from the East and established itself in the foothills of Eastern Piedmont, at low altitudes at first, and then in the higher belts with *Larix* (Charrier, 1970).

This period has provided the first data for the vegetation at high altitudes following the recent disappearance of the ice sheets. The pollen record for the Rutor peatbog (Burga, 1991), shows a periglacial landscape composed of *Artemisia, Rumex, Alnus, Betula* and Gramineae.

The Pre-Boreal was also marked by the Piottino cold oscillation, which lowered the timberline.

The Pre-Boreal-Boreal boundary cannot be readily identified owing to the constant *Corylus* pollen values. The increase recorded in some other areas, however, is regarded as a yardstick.

Boreal (8,900-7,500 B.P.)

Woods now occupy more extensive areas. Mixed oak forests in the lowlands are followed by conifer woods with *Pinus sylvestris, Pinus cembra, Abies alba* and *Picea excelsa* at higher altitudes. Both *Abies alba* and *Picea excelsa* increase compared with the previous period. The paucity of data for the 1,000-1,800 m belt makes it impossible to reconstruct the plant landscapes. One can only suppose from the high-altitude pollen diagrams relating to the present alpine belt that there were woods composed of the forest species just mentioned. Above the timberline, in the Rutor peatbog, for example, there is evidence of Ericaceae formations in the company of *Abies, Betula* and *Pinus* (Burga, 1991). *Abies* expanded earlier than *Picea* in this bog and also in the Ghighel bog (Braggio Morucchio et al., 1993), as asserted by Keller (1935) and Charrier and Peretti (1972) for the Western Alps in general, whereas in the Valtellina *Picea* seems to have spread earlier (Bertolani Marchetti, 1975). In some Western Piedmont valleys, the expansion of *Picea* was very limited. One example is the Gimont Valley, where *Pinus cembra* was dominant at high altitudes up to the timberline (Charrier and Peretti, 1978-79).

Older Atlantic (7,500-6,000 B.P.)

This period is marked at all levels by a rise in temperature and attainment of the post-glacial climate optimum. The main evidence is provided by an upward shift of all the arboreal formations, and an advance of the timberline to as high as 2,500-2,600 m on the more favourable slopes according to some authors (Burga, 1991) with *Larix, Pinus cembra* and *Picea excelsa*. The Rutor peatbog (2,500 m) records the appearance of high percentages of *Abies alba* and *Tilia* grains, though it may be assumed that they grew lower down, but still high enough for their pollen to be transported to the bog. At present, however, there are no *Tilia* nor *Abies* species in the valley below the bog. The rise in the timberline is estimated at about 500 metres above the present level by Armando and Charrier (1985), though the 300-400 m proposed by Burga (1991) seems more likely. This increase would correspond to a mean annual temperature 2-3 °C higher than today. According to Porter and Orombelli (1985), this warm phase lasted about 2,400 years (8,400 to 6,000 B.P.) and coincided with the first clear and general evidence of human felling. The mixed oak forest continued to occupy the flatlands and hills, whereas the uplands were occupied by conifer woods with an increased presence of *Alnus* and of *Picea excelsa* at higher levels. Throughout the Atlantic, extensive, compact fir and spruce woods, sometimes mixed with *Tilia, Acer, Quercus* or other conifers, such as *Larix, Pinus montana* and *P. cembra,* depending on the altitude, must have covered most of Piedmont. It was in the Older Atlantic, indeed, that *Fagus sylvatica* appeared. This species migrated towards SE Europe during the glaciations and eventually became an increasingly substantial component of upland woods. Above the tree line alpine pastures and shrubs were dominant with xerophilous species indicative of dry episodes (Charrier and Peretti, 1975).

Younger Atlantic (6,000-4,700 B.P.)

From the end of the Older Atlantic to about 5,000 B.P., there was a sharp fall in temperature and a probable retreat of the timberline. The pollen spectra for the lower levels disclose an increase in the percentage of *Alnus,* which becomes abundant everywhere alongside the mixed oak forest. In the uplands, *Taxus, Carpinus* and *Ostrya* increased, as is plainly shown near Lake Ganna (Schneider and Tobolski, 1983, 1985).

Fagus sylvatica becomes dominant in the Atlantic belt and pollen grains are also present in high-altitude sediments (e.g. in Val Formazza: Braggio Morucchio et al., 1993). At still higher levels, the vegetation was the same as in the Older Atlantic, though there were probably downward shifts caused by the drop in temperature. Clear and widespread traces of human activity appear in the pollen diagrams for the Younger Atlantic (Caramiello et al., 1996). Cereal pollen grains are found on 60% of the sites and there is an increase in the number of clearings due to pasture.

True farming began to spread in Piedmont between 6,000 and 5,000 B.P., probably in favourable conditions such as those presented by the mouths of the Alpine valleys, where substantial settlements and evidence of the square-mouthed pot (vasi a bocca quadrata) and the Lagozza cultures have been found. The beginning of cropping and the spread of agriculture had such a pronounced influence on the vegetation from now onwards that it becomes more difficult to say whether its changes were the result of differences in the climate or not. The establishment of new cultivation practices can presumably be attributed to the migration of peoples from South to East. The newcomers altered the land use by substituting their practices for those of the previous inhabitants, who were gradually relegated to less favourable areas, as has been shown in numerous studies of the genetics of human populations (Cavalli Sforza, 1986; Fedele, 1981, 1985, 1990).

Sub-Boreal (5,000-2,500 B.P.)

The main feature of this period is quicker and more intense climate oscillations. It begins, in fact, with a warm oscillation followed by a hot-arid oscillation that moved the conifers upwards and expanded the *Larix, Pinus cembra* and *Pinus uncinata* woods. This in turn gave way to a cooler, damp period during which *Fagus* expanded (3,000-2,500 B.P.: Charrier, 1975). Charrier (1990) is of the opinion that there was a dry period from 3,600 to 3,000 B.P. (maximum between 3,300 and 3,200), followed by rapid cooling, as shown by an increase in *Abies* and *Fagus* even in the lowlands.

Human impact on vegetation became more and more evident. Shrinkage of the mixed oak forest grains due to felling in the same lowlands is accompanied by increases in the percentages of cereal, ruderal and weed pollen grains, together with those of *Vitis, Juglans* and *Castanea.*

The increase in *Juglans* is earlier than that of *Castanea,* which begins towards the end of the Sub-Boreal and proceeds through Roman and Medieval times in most of the pre-alpine uplands and the hills, and partly at higher altitudes.

Sub-Atlantic (since 2,500 B.P.)

The cold period at the start of this phase lasted until about 2,100 B.P. It was followed by a warmer climate recorded in the Roman period, reported by various Roman historians and by a wealth of vegetational evidence.

In the lowlands, there was a widespread replacement of mixed oak forests by chestnut plantations, especially in the pre-alpine foothills. *Juglans* and *Castanea* pollen grains were also transported to alpine peatbogs (Arobba and Imperiale, 1981; Braggio Morucchio et al., 1993).

Detailed evidence of the works of Roman farmers and the species they cultivated is everywhere available up to about the 1,000 m level, especially from palynological and carpological studies of archaeological sites (Arobba and Caramiello, 1998; Caramiello and Potenza, 1998).

The oscillations during the Roman epoch, the Middle Ages and the so-called "Little Ice Age" are also recorded in many Piedmontese sites by pollen data agreeing with the historical evidence.

CONCLUSIONS

As mentioned at the outset, there is a lack of palaeobotanical data for the Western Alps, and especially for their uplands, during the Middle Pleistocene. This suggests the need for closer cooperation with geologists to allow more stratigraphic sequences reconstructed by coring to be used in reconstructions of palaeo-environments.

Completion of the temporal panorama and quantitative and qualitative correlation of the vegetational data with the changes in the climate will allow the formulation of hypotheses concerning its variations in the decades ahead. Since the presence of some species in pollen sediments is indicative of particular environmental conditions, reconstruction of the climate enables the physiognomy of future vegetation to be predicted with a certain degree of accuracy. This is particularly true when data for the Post-Glacial are used, since this is a recent period during which the plant species have maintained the genetic conditions responsible for their remarkable autoecological stability.

Relatively small temperature swings of the order of 1-1.5 °C repeated during the course of one or two human generations have themselves been the cause of detactable altitudinal oscillations, especially of the timberline (Mercalli, 1996).

On the basis of these observations, the concept of stability of vegetational types may be modified by considering the extensive potential of their rapid dynamism.

REFERENCES

AMBROSETTI P., AZZAROLI P., FICCARELLI G., MASINI F., SALA B., TORRE D. 1996 - Vertebrati. In: F. Carraro (ed.), Revisione del Villafranchiano nell'area-tipo di Villafranca d'Asti. Il Quaternario, 9: 5-120.

ARMANDO E., CHARRIER G. 1985 - La torbiera del Rutor (Valle d'Aosta). Relazioni sui risultati conseguiti dallo studio palinostratigrafico di nuovi affioramenti torbosi segnalati alla fronte attuale del ghiacciaio. Geografia Fisica e Dinamica Quaternaria, 8: 144-149.

AROBBA D., CALDERONI G., CARAMIELLO R., CARRARO F., GIARDINO M., QUAGLIOLO P. 1996 - First report of interstadial deposits in the Ivrea morainic amphitheatre (Alice Superiore, Torino, Italy). Allionia, 34: 337-342.

AROBBA D., CARAMIELLO R. 1998 - Agricoltura e ambiente dal VI al I millenio a.C.: ricostruzione su base palinologica. In: L. Mercando, E. Micheletto (eds.), Archeologia in Piemonte. Vol. 3, Allemandi, Torino.

AROBBA D., IMPERIALE G. 1981 - Indagini sedimentologiche e palinologiche del deposito torbo-lacustre de l'Arpiat (Ceresole Reale, Piemonte). Rev. Valdotaine d'Hist. Naturelle 35: 27-49.

BEAULIEU J.L. DE, REILLE M. 1984 - A long upper Pleistocene pollen record from Les Echets, near Lion, France. Boreas, 13: 111-132.

BENASSI P. 1896 - Piante e insetti fossili di Re in Val Vigezzo. Riv. Ital. Paleont., 2/6: 315-320.

BERTOLANI MARCHETTI D. 1955 - Contributi alla storia della vegetazione e del clima della Val Padana. Lineamenti paleobotanici dei depositi quaternari della Val Vigezzo. Reperti di *Abies* di tipo orientale. N. Giorn. Bot. Ital., 62: 388-394.

BERTOLANI MARCHETTI D. 1975 - Cenni sulla vegetazione del postglaciale in Valtellina. In V. Credaro, A. Pirola (eds.), La vegetazione della Provincia di Sondrio. 28-33.

BERTOLDI R. 1990 - Apporto della palinologia alla conoscenza dei giacimenti continentali pliocenici e pleistocenici inferiori dell'Italia centro-settentrionale. St. Trent. Sc. Nat., 66: 9-18.

BERTOLDI R. 1996 - Complesso inferiore. In: F. Carraro (ed.) - Revisione del Villafranchiano nell'area-tipo di Villafranca d'Asti. Il Quaternario, 9: 79-85.

BILLARD A., OROMBELLI G. 1986 - Quaternary glaciations in the french and italian piedmonts of the Alps. In: V. Sibrava, D.Q. Bowen, G.M. Richmond (eds.), Quaternary glaciations in northern hemisphere. Report of the I.G.C.P., 24, Quat. Sc. Rew., 5: 407-428.
BRAGGIO MORUCCHIO G., CORNARA L., CAVALIERE S., PLACEARANI S. 1993 - Analisi polliniche nella torbiera del Ghighel (Val Formazza-Alpi Occidentali) e ricostruzione della paleovegetazione. Candollea 48: 475-484.
BRUGIAPAGLIA E. 1996 - Dynamique de la végétation tardiglaciaire et Holocene dans les Alpes italiennes nord-occidentales. Thèse, Faculté des Sciences et Techniques de Saint Jerôme.
BURGA C.A. 1991 - Vegetation history and palaeoclimatology of the Middle Holocene: pollen analisys of alpine peat bog sediments, covered formerly by the Rutor Glacier, 2510 m (Aosta Valley, Italy). Global Ecology and Biogeography Letters 1: 143-150.
CARAMIELLO R., FOSSA V., SINISCALCO C., POTENZA A. 1990 - Schede palinologiche di *Artemisia glacialis* L., *Artemisia genipi* Weber e *Artemisia umbelliformis* Lam. su campioni freschi e acetolizzati (schede n°. S 175, S 176, S 177). Aerobiologia, 6: 221-238.
CARAMIELLO R., CARRARO F., COLLO F., GIANOTTI F., GIARDINO M., MARTINETTO E., PEROTTO A., SINISCALCO C. 1996 - Revisione del significato dei depositi "Villafranchiani in Piemonte". Il Quaternario, 9: 187-194.
CARAMIELLO R., POTENZA A. 1998 - Ricerche palinologiche in insediamenti tardoromani e altomedievali del Piemonte. In: L. Mercando, E. Micheletto (eds.), Archeologia in Piemonte. Vol. 3, Allemandi, Torino.
CARAMIELLO R., SINISCALCO C. 1996 - Complesso Superiore. In: F. Carraro (ed.) - Revisione del Villafranchiano nell'area-tipo di Villafranca d'Asti. Il Quaternario, 9: 90.
CARRARO F. (ed.) 1996 - Revisione del Villafranchiano nell'area-tipo di Villafranca d'Asti. Il Quaternario, 9: 5-120.
CAVALLI SFORZA L. 1986 - The impact of farming on expansion of human populations. In: C. Barigozzi, The origin and domestication of cultivated plants. Elsevier, Amsterdam.
CHARRIER G. 1970 - Studio palinologico del sondaggio geognostico G2 in Rio Colletta presso Entracque (Valle Gesso, Alpi Marittime). Allionia 16:133-154.
CHARRIER G. 1990 - Documenti di paleoclimi e paleoambienti del Pliocene terminale, Pleistocene ed Olocene nel territorio della Valle di Susa e sue adiacenze. Bull. Associazione Mineraria Subalpina, 27: 1-55.
CHARRIER G., PERETTI L. 1972 - Ricerche sull'evoluzione del clima e dell'ambiente durante il Quaternario nel settore delle Alpi occidentali Italiane. III Primo reperto di polline fossile entro formazioni würmiane e prewürmiane dell'anfiteatro morenico di Rivoli-Avigliana (Provincia di Torino). Allionia 18: 179-194.
CHARRIER G., PERETTI L. 1975 - Analisi palinologica e datazione radiometrica di depositi torbosi intermorenici della regione alpina piemontese, applicate allo studio del clima e dell'ambiente durante il Quaternario superiore. Boll. Comit. Glac. Ital., 23: 51-66.
CHARRIER G., PERETTI L. 1977 - Ricerche sull'evoluzione del clima e dell'ambiente durante il Quaternario nel settore delle Alpi Occidentali Italiane. VII. Allionia 22: 157-192.
CHARRIER G., PERETTI L. 1978-79 - Ricerche sull'evoluzione del clima e dell'ambiente durante il Quaternario nel settore delle Alpi Occidentali Italiane. VIII Documenti del Neoglaciale nella Valle del Gimont (Cesana Torinese). Allionia 23: 119-152.
CORTI B. 1895 - Ricerche micropaleontologiche sul deposito glaciale di Re in Val Vigezzo. Rend. Ist. Lomb., 27: 498-504.
CRAVERI M. 1912 - Comparazione fra la flora fossile e la flora vivente della Val Vigezzo nell'Ossola in relazione al mutato ambiente. Malpighia, 18: 346-355.
DANSGAARD W., JOHNSEN S.J., CLAUSEN H.B., DAHL-JENSEN D., GUNDESTRUP N.S., HAMMER C.U., HVIDBERG C.S., STEFFENSEN J.P., SVEINBJIORNSDOTTIR A.E., JOUZEL J., BOND G. 1993 - Evidence for general instability of past climate from 250 -kyr ice-core record. Nature, 364: 218-220.
FEDELE F. 1981- Il popolamento delle Alpi nel Paleolotico. Le Scienze 27: 22-39.
FEDELE F. 1985 - Il Paleolitico in Piemonte: le Alpi Occidentali. Ad Quintum. Archeologia del Nord-Ovest 7: 23-44.
FEDELE F. 1990 - Boira Fusca e Rupe di Salto. Ad Quintum 8: 1-77.
FRENZEL B. 1964 - Zur Pollenanalyse von Lössen. Eiszeitalter Gegenwart, 15: 5-64.
GIANOTTI A. 1950 - Osservazioni sulla flora fossile quaternaria di Re in Val Vigezzo (Novara). Riv. Ital. di Paleont. e Statigr., 56: 13-23.
JOHNSEN S.J., DAHL-JENSEN D., DANSGAARD W., GUNDERSTRUP N. 1995 - Greenland paleotemperatures derived from GRIP bore hole temperature and ice core isotope profiles. Tellus, 47 B: 624-629.
KELLER P. 1935 -Pollenanalytische Untersuchungen an Mooren del Südostalpen. Z. Bot. 24: 186-197.
LONA F. 1952 - Revisione della flora fossile insubrica attraverso i resti microscopici. N. Giorn. Bot. Ital., 59: 506-509.
LONA F., BERTOLDI R. 1972 - La storia del Plio-Pleistocene italiano in alcune sequenze vegetazionali lacustri e marine. Acc. Naz. Lincei Mem., CL Sc. ff. mm. nn. S. VII, Sez. III: 1-45.
MARTINETTO E. 1995 - Significato cronologico e paleoambientale dei macrofossili vegetali nell'inquadramento stratigrafico del "Villafranchiano" di alcuni settori del Piemonte (Italia NW). Tesi di Dottorato, Dipartimento di Scienze della Terra, Università di Torino.

MERCALLI L. 1996 - Quantitative evidence of abrupt climatic changes in the last 100,000 years and their implications for the world's ecosystems. Allionia, 34: 95-106.
MONTACCHINI F., CARAMIELLO R. 1969 - La componente mediterranea della flora del Piemonte. Arch. Bot. e Biogeogr. Ital., 45 (4 serie, XIV): 259-283.
MONTACCHINI F. 1992 - Aspetti fitogeografici delle Alpi Occidentali. Allionia, 31: 121-131.
NOVARESE V. 1927 - L'età delle filliti in Val Vigezzo. Atti R. Accad. Sci. Torino, 62: 638-642.
PENCK A., BRUCKNER E. 1909 - Die Alpen im Eiszeitalter. 3. Die Eiszeiten in den Südalpen und im Bereich der Ostabdachung der Alpen. Tauchnitz, Leipzig.
PAGANELLI A. 1961 - Il graduale impoverimento della flora forestale nel quaternario della Pianura Padana. N. Giorn. Bot. Ital., 68: 109-117.
PERETTI L., CHARRIER G. 1967 - Segnalazione e analisi pollinica di torba deposta alla fronte attuale del Ghiacciaio del Rutor (Valle d'Aosta). Considerazioni di paleogeografia e paleoclimatologia locale. Boll. Com. Glac. It. 14: 1-19.
PORTER S.C., OROMBELLI G. 1985 - Glacier contraction during the middle Holocene in the western Italian Alps: evidence and implications. Geology, 13: 296-298.
RAVAZZI C., ROSSIGNOL STRICK M. 1995 - Vegetation change in a climatic cycle of Early Pleistocene age in the Leffe Basin (Northern Italy). Palaeogeogr. Palaeoclimatol. Palaeoecol., 117: 105-122.
RICHMOND G.M., FULLERTON D.S. 1986 - Introduction to Quaternary glaciations in the United States of America. In: V. Sibrava, D.Q. Bowen, G.M. Richmond (eds.), Quaternary glaciations in northern hemisphere. Report of the I.G.C.P., 24, Quat. Sc. Rew., 5.
RIO D., SPROVIERI R., DI STEFANO E. 1993 - The Gelian Stage: a proposal of a new chronostratigraphic unit of the Pliocene series. Riv. It. Paleont. Strat., 100: 103-124.
SCHNEIDER R.E. 1978 - Pollenanalytische Untersuchungen zur Kenntnis der spät- und postglazialen vegetationsgeschichte am Südrand der Alpen zwischen Turin und Varese (Italien). Bot. Jahrb. Syst. 100: 26-109.
SCHNEIDER R. 1985 - Palynological research in the Southern and Southeastern Alps between Torino and Trieste. Diss. Bot., 87: 83-103.
SCHNEIDER R., TOBOLSKI K. 1983 - Palynologische und stratigraphische Untersuchungen im Lago di Ganna (Varese, Italien). Bot. Helv. 93: 115-122.
SCHNEIDER R. and TOBOLSKI K. 1985 - Lago di Ganna. Late-glacial and holocene environments of a lake in the Southern Alps. Diss. Bot. 87: 229-271.
SIDLER C., HANDTKE R. 1993 - La flora del Lago interglaciale Riss/Würm di Re (Val Vigezzo). Boll. Soc. Tic. Natur., 81: 11-20.
SORDELLI F. 1883 - Sulle filliti quaternarie di Re, in Val Vigezzo. Rend. R. Lomb. Sci. Lett., 16: 843-851.
SORDELLI F. 1886 - Flora Fossilis Insubrica. Studi della vegetazione di Lombardia durante i tempi geologici. Milano.
TROPEANO D., CERCHIO E. 1984 - L'orizzonte torboso würmiano nel sottosuolo della Pianura piemontese meridionale. Osservazioni preliminari. Boll. Associazione Mineraria Subalpina, 3: 199-221.