

CHRONOLOGICAL FRAMING OF PLIOCENE TO EARLY PLEISTOCENE PLANT MACROFOSSIL ASSEMBLAGES FROM NORTHERN ITALY

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ABSTRACT. The plant macrofossil documentation of northern Italy has been considerably increased by recent palaeocarpological studies. In this paper twenty rich local carpofloras of the Pliocene and Early Pleistocene are analysed. Some of them are well dated by means of non-palaeobotanical methods, and are exploited as reference points in defining the regional palaeofloristic features of different time intervals. The remaining ones are tentatively framed in a chronological sequence thanks to ecostratigraphic (palaeoclimatic) signals. Finally, the floristic data of both types of floras are used to detect the main floral changes: the Pliocene seems to be a crucial epoch for plant extinction, which occurred at least in two successive phases.

KEY WORDS: Pliocene, Early Pleistocene, northern Italy, plant macrofossils, biochronology, floristic change, extinction events

INTRODUCTION

The Pliocene to Early Pleistocene plant macrofossil documentation of northern Italy experienced a considerable increase in the last decade, both for the discovery of new sites and for the finding of more and more species. This is mainly due to studies on palaeocarpological assemblages (fruits, seeds and related structures), which are preferentially exploited for the purposes of the present work. On the other hand, the information deriving from fossil leaves and wood is very scarce in the studied time span, and sometimes in need of revision; therefore it is not treated here. The main purposes of this work are to discuss the geochronologic position of several fossil floras and to describe the contribution they can provide to the Plio-Pleistocene floral history of southern Europe, e. g. to establish the extinction time of several exotic plant taxa in this area.

THE PLANT MACROFOSSIL ASSEMBLAGES

We will analyze the elements useful to assess the chronologic position of 21 plant macrofossil assemblages, gathered both for marine and continental sediments, either from a single layer or from a set of layers in a given succession (which, of course, seem to indicate an homogeneous palaeofloral context). These assemblages have been selected because they allow to reconstruct local palaeofloras which contain a number species suitable for a comparative floristic analysis (20 or more, apart Lefte: 9 species). Most of them have been directly studied by the author, but additional information has

been obtained from papers by Ghiotto (1995), Gregor (1985, 1986, 1990), Mai (1994) and Ravazzi (1993, 1995). These local floras can be divided in two groups: some of them can be constrained in a more or less narrow chronological range by means of non-palaeobotanical dating elements (“dated” floras: Tab. 1); others have been gathered from sediments of uncertain age (“undated”: Tab. 2).

“DATED” LOCAL FLORAS

The possibility to define the geochronologic position of these local floras is undoubtedly fundamental for a correct tuning of the floral development in the study area, therefore the stratigraphic situation and the dating methods employed for each of them are discussed in detail. The geographic location of the fossil sites is shown in Fig. 1, and better explained in the cited papers specifically referred to each site, whose age is indicated in Fig. 2.

1) Breolungi. This local flora has been gathered from a single layer of gravely sand (layer 3) in a 100 m thick marine section. Foraminiferal assemblages have been studied (Pavia *et al.* 1989) both below and above the flora-bearing layer, and all of them include the benthic species *Uvigerina rutila* (see Rio *et al.* 1988), which disappears at the end of the Lower Pliocene, and *Bolivina leonardii*, which appears at the beginning of the Pliocene. The association of the two species allows to assign these sediments to the Zanclean (Lower Pliocene), a con-



Fig. 1. Location of the Pliocene and Early Pleistocene plant macrofossil sites of northern Italy cited in the present work

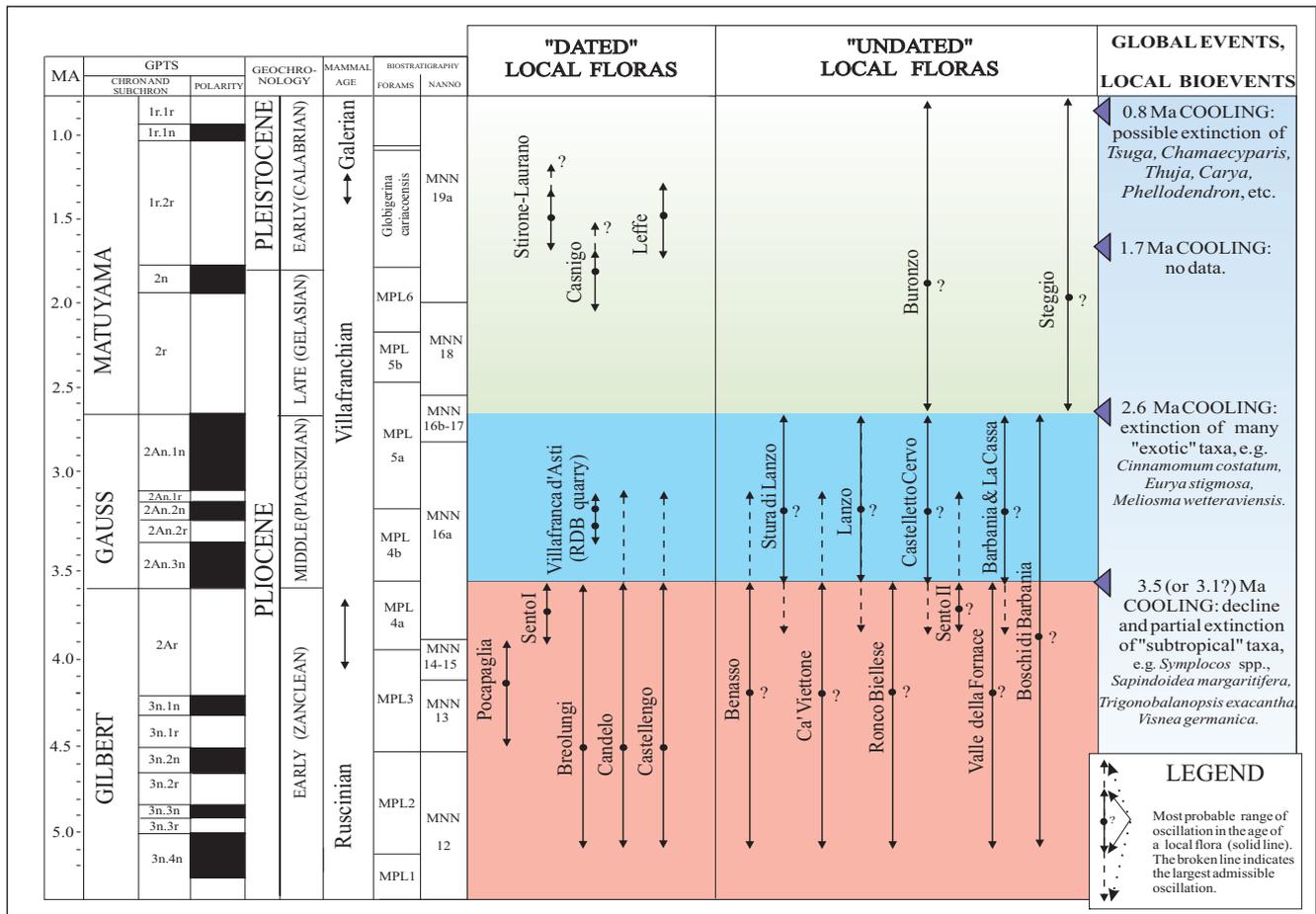


Fig. 2. Integrated stratigraphic scheme for the Pliocene-Early Pleistocene (from Rio *et al.* 1994, drawn by Adele Beritni) with the possible age range of "dated" and "undated" floras. The age range of Sento I, Candelo and Castellengo relies on the "*Bufonaria marginata* hypothesis" (see text). In the left column are indicated a few global climatic events, deduced from the literature, and the local floral changes they may have caused.

clusion also corroborated by the composition of molluscan assemblages (Pavia *et al.* 1989).

2–3) The local floras of **Candelo** and **Castellengo** originate from two layers of the same shallow marine succession, which also contains molluscs and foraminifers. The ones of Candelo, studied by Aimone & Ferrero Mortara (1983), in a first time seemed to point to a Middle Pliocene age; however Ferrero Mortara is now carrying out a revision of the fossil fauna, which seems to give more indications for an Early Pliocene age. Even if a definite statement about the age cannot be provided before the conclusion of such investigation, the occurrence of a few important mollusc species both in the **Candelo** and **Castellengo** deposit (author's collection) provides some good indications: *Lissochlamys excisa* and *Pelecypora gigas* are characteristic of the molluscan unit MPMU 1 of Raffi & Monegatti (1993), spanning from the beginning of the Pliocene to about 3.1 Ma. Furthermore, *Bufofonia marginata* would restrict the possible age range to the Early Pliocene (i.e. prior to 3.5 Ma) according to the “*B. marginata* hypothesis” of Monegatti & Raffi (in SPI 1996).

4) The fossil flora of **Pocapaglia**, first cited by Martinetto (1995) and preliminarily described by Cavallo & Martinetto (1996), has been collected from a single sandy layer in a succession prevalently made up by offshore muddy sediments, whose age is indicated by the coccolith assemblage of the silty layer directly above the plant-bearing one, studied by A. d'Atri. The concomitant occurrence of *Helicosphaera sellii* and *Reticulofenestra pseudoumbilica*, in the absence of *Pseudoemiliania lacunosa*, indicates the interval between the nannoplankton zones NN13 and the lower part of zone NN14–NN15, i.e. a time interval between 4.5 and 3.8 Ma in the younger part of the Early Pliocene (d'Atri, pers. com. 1998)

5) The **Sento** succession is made up by 80 m of shallow marine to coastal sediments, which provided about ten layers with fossil carpofloras (Basilici *et al.* 1997). The assemblages from the basal marine layers (PT1, S1, S2) are named “Sento I flora” in this paper, while those (S4–S9) originating from the coastal, mostly tidal, sediments in the upper part are called “Sento II”. The age of the Sento I flora is given by the co-occurrence of the benthic foraminiferal index forms *Ellipsopolymorphina fornasinii* and *Buccella granulata* which suggests MPL4 foraminiferal biozone of Cita (1975). In addition, the occurrence of the gastropod *Bufofonia marginata* (see above) would restrict the possible age range within subzone MPL4a (latest Zanclean). Sento II, at this point of the discussion, is to be considered an “undated” flora.

6) **Villafranca d'Asti**. The 40 m thick succession exposed at the R.D.B. quarry is made up by sandy and muddy layers, which are bluish-grey in the basal 10 m and ochre-coloured (oxidized) above. It belongs to the San Martino Unit deposited in a coastal swamp environ-

ment on a deltaic plain (Basilici in Carraro 1996). A variety of fossils have been found in the last two centuries: vertebrates of the Triversa Mammal Unit, i.e. earliest Villafranchian (Azzaroli 1977, De Giuli *et al.* 1983), molluscs and plant macrofossils. The last ones have been studied by Günther & Gregor (1989), Mai (1995) and Martinetto & Mai (in Carraro 1996). The age of the section is problematic because magnetostratigraphic studies gave different results. According to Bormioli and Lanza (in Carraro 1996) the section can be placed within the 2A (Gauss) chron, thereby confirming what was already proposed by Lindsay *et al.* (1980). Recently Lindsay *et al.* (1997) have re-interpreted the magnetostratigraphic data of the R.D.B. quarry succession, suggesting a late Early Pliocene age, however their arguments do not seem to be convincing, so in this paper I still accept the assignment of the Villafranca d'Asti flora to the Middle Pliocene. An age across the Plio-Pleistocene boundary, as supposed by former authors (e.g. Lona & Bertoldi 1973, Krutzsch 1988), is totally unlikely.

7–8) The only plant macrofossil assemblage possibly referable to the Late Pliocene (Gelasian) is the still unpublished **Casnigo** local flora (material in the author's collection). It has been washed out from continental muddy sands of the marginal part of the Lefte Basin (Lombardy). The overlying “main brown coal seam” (Ravazzi 1993) of this basin also provided a few plant macrofossil species (“**Lefte flora**”) both in the past century (Sordelli 1896) and in recent times, thanks to the sampling carried out by the “Caffi” Museum of Bergamo. This material has been preliminarily identified by Gregor (1990) or Ravazzi (1995). Additionally, *Phellodendron elegans* and *Tsuga* sp. are listed in table 1 as a result of recent findings. The lithostratigraphy of the Lefte Basin is well known, and magnetostratigraphy has been carried out in a 190 m deep continuous core (Ravazzi 1993, Cremaschi & Ravazzi 1995). These data, together with the occurrence of large mammals, allow to date the Casnigo and Lefte floras with a good approximation: the first one should fall within the Olduvai subchron, but it may also be slightly younger; the second one falls within the reversed magnetic interval at the base of the Early Pleistocene (most probably 1.8 to 1.5 Ma).

9) Finally, a group of fairly well dated Early Pleistocene macrofloras (S7–8) has been described by Gregor (1985, 1986, 1990) and partly by Mai (1994: *Picea florschuetzii*) from a short portion of the Miocene-Pleistocene succession of the **Stirone** River, in outcrop near the village of **Laurano** (province of Parma). Furthermore, I have listed in table 1 a few species which I collected in the same layers (*Ajuga* cf. *iva*, *Corylus avellana*, *Eupatorium cannabinum*, *Phellodendron elegans*, *Pterocarya limburgensis*, *Schisandra* sp., *Taxus baccata*) and *Juglans bergomensis*, which has been found in layer S3,

about 30 m below S7–8 (Gregor 1985). Several stratigraphical and palaeontological studies have been carried out in this succession (see SPI 1996), whose chronological tuning is presently well established for the Early to Late Pliocene deep marine portion (Mary *et al.* 1993; Channel *et al.* 1994). The Early Pleistocene portion is dated by marine fossils (e. g. Pelosio & Raffi 1977, Bertolani Marchetti *et al.* 1979), however it has not yet been precisely calibrated, due to its shallow marine to lacustrine facies. Anyway, the available data allow to date the Stirone-Laurano flora between 1.8 and 1.0 Ma.

“UNDATED” LOCAL FLORAS

Several rich and diverse assemblages of fruits and seeds have been found during the author’s investigations in NW Italy (Martinetto 1995) in sediments where dating elements independent from palaeobotany do not exist, even if the geological context constrains their age in the Early Pliocene–Early Pleistocene range. The floras of Barbania, Benasso, Boschi, Buronzo (assemblages of the downthrown block of the Cervo River succession, see Martinetto 1998), Ca’ Viettone, Castelletto Cervo, La Cassa, Ronco Biellese, Sento II (see above) and Stura di Lanzo originate from the transitional or continental sediments of the “Villafranchiano” lithostratigraphic unit of the western Po Plain (Caramiello *et al.* 1997). The location and stratigraphy of the successions which provided the foregoing floras are reported by Martinetto (1995).

Another rich macroflora is known from the Steggio succession (Veneto). It has been preliminarily described by Ghiotto (1995), who is preparing a taxonomical overview of the fruit and seed assemblages, which comprise several tens of species. This fossil flora is actually not absolutely “undated”, since Mammal biochronology and magnetostratigraphic data constrain the chronological range to the Late Pliocene–Early Pleistocene (Paronuzzi & Tonon 1992).

The foregoing floras are so species-rich to represent a paramount source of floristic and palaeoenvironmental information, which cannot be neglected for the simple reason that independent dating elements are lacking. On the contrary, it’s worth trying to assess the age of such floras on the ground of palaeobotanical data.

APPROACH TO THE CHRONOLOGICAL FRAMING OF “UNDATED” LOCAL FLORAS

Several attempts of chronological framing of “undated” local floras on the ground of floristic characters or climatic indications have been discussed in past works (Martinetto 1994, Bertoldi & Martinetto 1995, Martinetto 1995, Cavallo & Martinetto 1996, Basilici *et al.*

1997, Martinetto & Ravazzi 1997, Martinetto (ed.) 1998). In this paper I try to solve the problem from the starting point, by neglecting former interpretations. Presently, the only possible solution for the chronological framing of “undated” floras seems to be the development of a local biochronology based on time-dependent floristic changes. This implies, first of all, to analyse the distribution patterns of each species in the “dated” local floras (Tab. 1), and to use it for the determination of the most likely chronologic position of specific bioevents (appearance, disappearance, decrease). For example, the existing record of *Trigonobalanopsis exacantha* (Tab. 1) shows that it was well distributed in the Early Pliocene, but there is no prove for a later occurrence in northern Italy. This situation suggests that it disappeared from this area around the end of the Early Pliocene. Of course, not all the individual bioevents are useful for time correlations: a lot of them are surely the result ecological or casual factors. Therefore I try to select those floristic changes (bioevents) which seem to be time-dependent, irreversible and synchronized to other similar bioevents (Tab. 3, right column). Several collective bioevents of this type have been detected by analysing the floral changes from the older to the younger studied floras. They mostly correspond to the local decrease, extinction or migration of thermophilous taxa, which are likely to be due to climate change. In particular, such local bioevents can tentatively be correlated with global cooling phases, evidenced by palynology, stable isotopes and other palaeoclimate indicators (Fig. 2).

At this point, the floristic composition of “undated” fossil floras can easily suggest the chronological range in which they fall, provided that they include species affected by those climate-related bioevents cited above.

MAIN “DATED” BIOEVENTS USEFUL FOR THE CHRONOLOGIC FRAMING OF “UNDATED” FLORAS

All the “dated” floras of the Early Pliocene (Brelung, Pocapaglia, Sento I, etc.) are very rich in so called “subtropical” elements which are never found in the Middle Pliocene to Early Pleistocene ones (Tab. 1), such as: *Arctostaphyloides cf. menzelii*, *Cyclea palatinati-bavariae*, *Litsea sonntagii*, *Magnolia lignita*, *Meliosma aff. reticulata*, *Rehderodendron ehrenbergii*, *Sapindoidea margaritifera*, *Symplocos gothanii*, *Symplocos salzhausemensis*, *Tetraclinis salicornioides*, *Toddalia latisiliquata*, *Trigonobalanopsis exacantha*, *Visnea germanica*. This fact does not seem to be due to changes of sedimentary facies or by a different biostratigraphic history of plant remains: both Early Pliocene and post-Early Pliocene assemblages contain autochthonous, parauto-

Table 1. Distribution of selected species in "dated" local floras. As a whole, more than 300 taxa have been submitted to this analysis. The species are ordered in five groups according to their disappearance/appearance; the ordination of some species, e.g. *Alangium* sp., is based on information derived by table 2

Distribution of selected taxa in "dated" local floras						
Age (Ma)	PLIOCENE			PLEIST.		
	5.3 to 3.5 (?or 3.1)	3.5 to 2.6	< 1.8	1.8 to 0.8		
Floristic complexes	Ca' Viettone		Stura			
Fossil floras	C		V			
	a	P	i			
	s	o B	l			
	t	c r	l			
	e	C S a e	a	C	L	
	l	a e p o	f	a	a	
	n	n n a l	r	s	L	u
	e	d t g u	a	n	e	r
	n	e o l n	n	i	f	a
	g	l i g	c	g	f	n
o	o I a i	a	o	e	o	
Total number of species	20	26	56	63	38	63
<i>Alangium</i> sp.						
<i>Arctostaphyloides</i> cf. <i>menzelii</i>						
<i>Cyclea palatinati-bavariae</i>						
<i>Ehretia</i> sp.						
<i>Litsea sonntagii</i>						
<i>Ilex saxonica</i>						
<i>Magnolia allasoniae</i>						
<i>Magnolia lignita</i>						
<i>Meliosma</i> aff. <i>reticulata</i>						
<i>Rehderodendron ehrenbergii</i>						
<i>Sapindoidea margaritifera</i>						
<i>Spirella</i> sp.						
<i>Symplocos gothanii</i>						
<i>Symplocos salzhausenensis</i>						
<i>Symplocos schereri</i>						
<i>Tetraclimis salicornioides</i>						
<i>Toddalia latisiliquata</i>						
<i>Trigonobalanopsis exacantha</i>						
<i>Visnea germanica</i>						
<i>Actinidia faveolata</i>						
<i>Ampelopsis malvaeformis</i>						
<i>Boehmeria lithuanica</i>						
<i>Carex flagellata</i>						
<i>Cinnamomum costatum</i>						
<i>Cryptomeria rhenana</i>						
<i>Eurya stigmosa</i>						
<i>Fagus decurrens</i>						
<i>Ficus potentilloides</i>						
<i>Itea europaea</i>						
<i>Meliosma wetteraviensis</i>						
<i>Parrotia reidiana</i>						
<i>Prunus (Padus) aff. padus</i>						
<i>Sinomenium cantalense</i>						
<i>Styrax maximus</i>						
<i>Toddalia rhenana</i>						
<i>Azolla tegelensis</i>						
<i>Carex</i> aff. <i>atrofusca</i>						
<i>Carya</i>						
<i>Corylus avellana</i>						
<i>Eupatorium cannabinum</i>						
<i>Frangula alnus</i>						
<i>Juglans bergomensis</i>						
<i>Liriodendron geminata</i>						
<i>Magnolia cor</i>						
<i>Phellodendron elegans</i>						
<i>Potentilla supina</i>						
<i>Pterocarya limburgensis</i>						
<i>Ajuga</i> cf. <i>iva</i>						
<i>Hippuris vulgaris</i>						
<i>Schisandra</i> sp.						
<i>Taxus baccata</i>						
<i>Tsuga</i> (cones)						
<i>Eucommia europaea</i>						
<i>Picea florschuetzii</i>						

chthonous, and allochthonous elements, including representatives of freshwater vegetation, mires, swamp and well-drained forest. Instead, the seemingly synchronous

disappearance of the foregoing species suggests a phase of marked retreat of thermophilous elements which must be correlated to one of the Early or Middle Pliocene episodes of climatic deterioration (Rio *et al.* 1994; Zubakov & Borzenkova 1990). In previous works (Martinetto 1995, 1996) it has been proposed the correlation with an analogous event detected in NW-Mediterranean and Dutch pollen records, and dated around 3.5 Ma (Bertoldi *et al.* 1994; Suc *et al.* 1995; Zagwijn 1960, 1990). However, due to the scarce Middle Pliocene plant macrofossil record in Italy, the foregoing event may also be correlated to the cooling phase around 3.1 Ma (Martinetto & Ravazzi 1997) which has several evidences in the Mediterranean palaeontological and stable isotope proxies (Raffi & Monegatti 1993; Thunell *et al.* 1990; Zheng 1990).

This analysis allows to conclude that the age of the "undated" floras which contain abundant "subtropical" species (Benasso, Ca' Viettone, Sento II, Ronco Biellese, Valle della Fornace: "Ca' Viettone Floristic Complex" of Martinetto 1993, 1995) cannot be younger than 3.5 Ma or, less probably, 3.1 Ma (Fig. 2). The Boschi flora represents a separate case, because it contains *Symplocos salzhausenensis* and *S. schereri*, which seem to be restricted to the Early Pliocene, but also *Azolla tegelensis*, *Potentilla supina* and *Magnolia cor*, which are found in the study area only later than Early Pliocene. Therefore the Boschi flora may be regarded as a transitional assemblage, whose age may be Early Pliocene as well as Middle Pliocene.

In the Middle Pliocene a single (though diverse) dated flora is available: Villafranca d'Asti. However, also in this case we can list a number of elements (mostly thermophilous ones) which are not found in the younger floras: *Actinidia faveolata*, *Boehmeria lithuanica*, *Carex flagellata*, *Fagus decurrens*, *Ficus potentilloides*, *Itea europaea*, *Meliosma wetteraviensis*, *Nyssa disseminata*, *Parrotia reidiana*, *Proserpinaca europaea*, *Styrax maximus*, *Toddalia naviculaeformis* and *Toddalia rhenana*. So, the dated flora of Villafranca d'Asti seems to be the last assemblage of its type before a huge floral change which can be tentatively correlated with the marked cooling at 2.6 Ma, i.e. the onset of the "glacial" Pliocene (Rio *et al.* 1994).

As the "undated" floras of Barbania, Castelletto Cervo I, Front, La Cassa, Stura and Lanzo (the "Stura Floristic Complex" of Martinetto 1993, 1995) contain many of the species cited above, they must be older than 2.6 Ma, and probably younger than 3.5 Ma, because they do not contain species restricted to the Early Pliocene.

The Late Pliocene lacks a sure reference flora till now: the one of Casnigo (see above) is just a possible exception. In the case that its age is really latest Pliocene, it shows that the floristic composition is yet much different from the Middle Pliocene. The exotic genera

are reduced to a few, while the native European ones dominate.

The decrease of "exotic" elements is still confirmed by the dated floras of the Early Pleistocene (Leffe and Stirone-Laurano), however *Carya*, *Chamaecyparis*, *Liriodendron geminata*, *Magnolia cor*, *Eucommia europaea*, *Juglans bergomensis* and *Phellodendron elegans* are still common. These exotic taxa do not pass in the Middle Pleistocene in Central Europe, so their extinction event might be placed in the late Early Pleistocene, and it could correspond to the cooling phase registered around 0.8 Ma (Fig. 2). Therefore, the "undated" floras of Buronzo and Steggio (Tab. 2), which contain most of the taxa cited above, can be tentatively considered older than 0.8 Ma, and younger than 2.6 Ma (because they lack typical Middle Pliocene elements). However this hypothesis is in strong need of confirmation, because

the Middle Pleistocene plant macrofossil documentation in Italy is presently so scarce that there is no robust evidence to exclude that *Carya*, *Chamaecyparis* etc. may have got extinct later than 0.8 Ma in this area.

PLIO-PLEISTOCENE FLORISTIC CHANGE

A detailed description of the floristic composition of the fossil assemblages cited above is beyond the scope of the present work, and it has been dealt with by Martinetto (1994, 1995, 1998), Cavallo & Martinetto (1996), Basilici *et al.* (1997), Martinetto & Ravazzi (1997). In this paper I try to give an impression of the contribution of palaeocarpology to the understanding of the floristic change in northern Italy. In order to avoid a long list of taxa the reader is referred to table 3, which shows the present knowledge on the chronologic distribution of a few taxa occurring in the studied floras, which are considered more significant from the stratigraphic and palaeoclimatic point of view.

These new Italian findings, together with palaeocarpological data from middle Europe (C. & E. M. Reid 1915, Szafer 1947, Mai & Walther 1988, 1991, Van den Burgh 1978, 1983), prove that especially the Pliocene has been a crucial epoch for plant extinction, which occurred at least in two successive phases: Early to Middle Pliocene and Middle to Late Pliocene. Those species which seem to disappear in the first phase are mostly thermophilous elements indicating a "subtropical" vegetation of East Asian affinity (Martinetto 1996). Notice that the "undated" floras give a fundamental contribution by adding a good number of species (*Alangium* sp., *Ilex saxonica*, *Phytolacca salsoloides*, etc.) to such a group (Tab. 3). These floras are also responsible for the Middle Pliocene record of several species which provide outstanding palaeoenvironmental information (*Itea europaea*, *Phellodendron elegans*, etc.).

Table 2. Distribution of selected species in "undated" local floras, whose probable age is proposed on the ground of palaeobotanical features. Notice the similarity of the distribution patterns of the same species in table 1. The floras of Barbania and La Cassa have not been listed because they contain a scarce number of species (24 and 21)

"Undated" local floras															
Age (Ma)	PLIOCENE									PLEIS.					
	5.3 to 3.5 (for 3.1)					3.5 to 2.6				2.6 to 0.8					
Floristic complexes	Ca' Viettone						Stura								
Fossil floras	R										C				
	o	V										a			
	n	a										s			
	c	C	l										t		
	o	à	l										e		
		e										l			
	B	V	F	B	S						B	S			
	i	i	F	B	e						e	u	t		
	e	e	o	e	n	B						e	r		
	l	t	r	n	t	o	L	S	F	t	o	g			
l	t	n	a	o	s	a	t	r	t	o	g				
e	o	a	s	c	n	u	o	o	n	g					
s	n	e	c	s	I	h	z	r	n	z					
e	e	e	o	I	i	o	a	t	I	o					
Total n° of species	27	130	36	49	108	47	98	96	61	91	52	106			
<i>Alangium</i> sp.															
<i>Arclostaphyloides</i> cf. <i>menzelii</i>															
<i>Cyclea palatinati-bavariae</i>															
<i>Ehretia</i> sp.															
<i>Ilex saxonica</i>															
<i>Litsea sonntagii</i>															
<i>Magnolia allasoniae</i>															
<i>Magnolia lignita</i>															
<i>Meliosma</i> aff. <i>reticulata</i>															
<i>Rehderodendron ehrenbergii</i>															
<i>Sapindoidea margaritifera</i>															
<i>Spirella</i> sp.															
<i>Symplocos gothanii</i>															
<i>Symplocos salzhausensis</i>															
<i>Symplocos schereri</i>															
<i>Tetraclinis salicornioides</i>															
<i>Toddalia latisiliquata</i>															
<i>Trigonobalanopsis exacantha</i>															
<i>Visnea germanica</i>															
<i>Actinidia faveolata</i>															
<i>Ampelopsis malvaeformis</i>															
<i>Boehmeria lithuanica</i>															
<i>Carex flagellata</i>															
<i>Cinnamomum costatum</i>															
<i>Cryptomeria rhenana</i>															
<i>Eurya stigmosa</i>															
<i>Fagus decurrens</i>															
<i>Ficus potentilloides</i>															
<i>Itea europaea</i>															
<i>Meliosma wetteraviensis</i>															
<i>Parrotia reidiana</i>															
<i>Prunus</i> (<i>Padus</i>) aff. <i>padus</i>															
<i>Sinomenium cantalense</i>															
<i>Styrax maximus</i>															
<i>Toddalia rhenana</i>															
<i>Azolla tegelensis</i>															
<i>Carex</i> aff. <i>atrofusca</i>															
<i>Carya</i>															
<i>Corylus avellana</i>															
<i>Eupatorium cannabinum</i>															
<i>Frangula alnus</i>															
<i>Juglans bergomensis</i>															
<i>Liriodendron geminata</i>															
<i>Magnolia cor</i>															
<i>Phellodendron elegans</i>															
<i>Potentilla supina</i>															
<i>Pterocarya limburgensis</i>															
<i>Ajuga</i> cf. <i>iva</i>															
<i>Hippuris vulgaris</i>															
<i>Schisandra</i> sp.															
<i>Taxus baccata</i>															
<i>Tsuga</i> (cones)															
<i>Eucommia europaea</i>															
<i>Picea florschuetzii</i>															

The Middle to Late Pliocene phase of extinction seems to affect a larger number of species whose recent

Table 3. Chronological distribution of selected plant macrofossil species in northern Italy, compiled on the ground of the analytic data shown in tables 1 and 2. The bars related to each species indicate the possible age range of the fossil floras in which they occur, as shown in Fig. 2. The black portions indicate that the species occurs at least in one “dated” flora, whose age falls within such time range; where the bars are hatched, the species occurs only in “undated” floras (see text). The broken line indicates time intervals where the occurrence of the species is possible (due to the uncertainty in estimating the age of “undated” floras) but not demonstrated by the present evidence. Finally, *Azolla tegelensis* and *Liriodendron geminata* surely occur in a not defined point of the Late Pliocene-Early Pleistocene interval, as shown by the two lines with arrows

Geochronology	PLIOCENE			PLEISTOCENE
	Early	Middle	Late	Early
Age (Ma)	5.3 to 3.5	3.5 to 2.6	2.6 to 1.8	1.8 to 0.8
Floristic complexes	Ca' Viettone	Stura		
<i>Alangium</i> sp.	hatched			
<i>Litsea sonntagii</i> Gregor	black			
<i>Arctostaphyloides</i> cf. <i>menzelii</i> Kirchheimer	black			
<i>Cyclea palatinati-bavariae</i> Gregor	black			
<i>Ehretia</i> sp.	hatched			
<i>Hartia quinqueangularis</i> Mai	hatched			
<i>Ilex saxonica</i> Mai	hatched			
<i>Magnolia allasoniae</i> Martinetto	black			
<i>Magnolia lignita</i> (Unger) Mai	black			
<i>Meliosma</i> aff. <i>reticulata</i> (Reid) Chandler	black			
<i>Ocotea</i> sp. A	hatched			
<i>Phytolacca salsoloides</i> Martinetto	hatched			
<i>Rehderodendron ehrenbergii</i> (Kirchheimer) Mai	black			
<i>Sapindoidea margaritifera</i> (Ludwig) Kirch.	black			
<i>Symplocos gothanii</i> Kirchheimer	black			
<i>Symplocos minutula</i> (Sternberg) Kirchheimer	hatched			
<i>Symplocos salzhausenensis</i> (Ludwig) Kirchheimer	black			
<i>Symplocos schereri</i> Kirchheimer	black			
<i>Tetraclinis salicornioides</i> (Unger) Kvacek	black			
<i>Toddalia latisiliquata</i> (Ludwig) Gregor	black			
<i>Trigonobalanopsis exacantha</i> (Mai) Kv. & Walth.	black			
<i>Visnea germanica</i> Menzel	black			
<i>Zanthoxylum ailanthiforme</i> (Gregor) Gregor	hatched			
<i>Zanthoxylum mueller-stollii</i> Gregor	hatched			
<i>Actinidia faveolata</i> C. & E.M. Reid	hatched	black		
<i>Ampelopsis malvaeformis</i> (Schlotheim) Mai	black	black		
<i>Boehmeria lithuanica</i> Dorofeev		black		
<i>Carex flagellata</i> C. & E.M. Reid	hatched	black		
<i>Cinnamomum costatum</i> (Mai) Pinget <i>et al.</i>	hatched	black		
<i>Cryptomeria rhenana</i> Kilpper	black	hatched		
<i>Eurya stigmosa</i> (Ludwig) Mai	black	hatched		
<i>Fagus decurrens</i> C. & E.M. Reid		black		
<i>Ficus potentilloides</i> Mai	hatched	black		
<i>Itea europaea</i> Mai		hatched		
<i>Meliosma wetteraviensis</i> (Ludwig) Mai	hatched	black		
<i>Parrotia reidiana</i> Kirchheimer		black		
<i>Sinomenium cantalense</i> E.M. Reid	hatched	black		
<i>Spirella</i> sp.	black	hatched		
<i>Styrax maximus</i> (Weber) Kirchheimer	black	black		
<i>Symplocos casparyi</i> Ludwig	black	hatched		
<i>Toddalia rhenana</i> Gregor	hatched	black		
<i>Phellodendron elegans</i> (Reid & Reid) Reid & Reid		hatched	black	black
<i>Liriodendron geminata</i> Kirchheimer	black	black	black	black
<i>Magnolia cor</i> Ludwig		black	black	black
<i>Carya</i>		hatched	black	black
<i>Azolla tegelensis</i> Florschuetz		hatched	black	black
<i>Pterocarya limburgensis</i> C. & E.M. Reid	black	black	black	black
<i>Juglans bergomensis</i> (Balsamo-Criv.) Massal.	hatched	black	black	black
<i>Eupatorium cannabinum</i> L.		hatched	black	black
<i>Eucommia europaea</i> Mädlar			black	black
<i>Hippuris vulgaris</i> L.			black	black
<i>Picea florschuetzii</i> Van der Hammen			black	black
<i>Schisandra</i> sp.			black	black
<i>Ajuga</i> cf. <i>iva</i> L.			black	black
<i>Taxus baccata</i> L.			black	black
<i>Tsuga</i> sp. (cones)			black	black

relatives tolerate a cool temperate climate (*Cryptomeria rhenana*, *Fagus decurrens*, etc.), however also the last "subtropical" relics disappear: *Cinnamomum costatum*, *Eurya stigmosa*, *Symplocos casparyi*, *Toddalia rhenana*. As discussed above, for the moment there is no definite Late Pliocene macrofossil record, because the flora of Casnigo may yet date to the earliest Pleistocene. However, all the macrofloras younger than Middle Pliocene are very similar: they always include some relic exotic elements (Tab. 3), but no "subtropical" species.

Despite the basic analogy to middle Europe, the record of northern Italy differs for the later disappearance of *Cinnamomum costatum*, *Cyclea palatinati-bavariae*, *Eurya stigmosa*, *Ficus potentilloides*, *Magnolia lignita*, *Sapindoidea margaritifera*, *Toddalia latisiliquata*, *Zanthoxylum ailanthiforme* and *Zanthoxylum mueller-stollii*. These species are known only until the Late Miocene in middle Europe (Gregor 1978, 1979, 1980, Mai 1964, 1975, Pingen *et al.* 1994), while in northern Italy they are documented until the Early and sometimes Middle Pliocene (*C. costatum*, *E. stigmosa* and *F. potentilloides*). A few species known until the Tiglian (Late Pliocene according to the geochronology adopted here) pass into the Early Pleistocene in northern Italy: *Juglans bergomensis*, *Magnolia cor*, *Phellodenron elegans*.

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