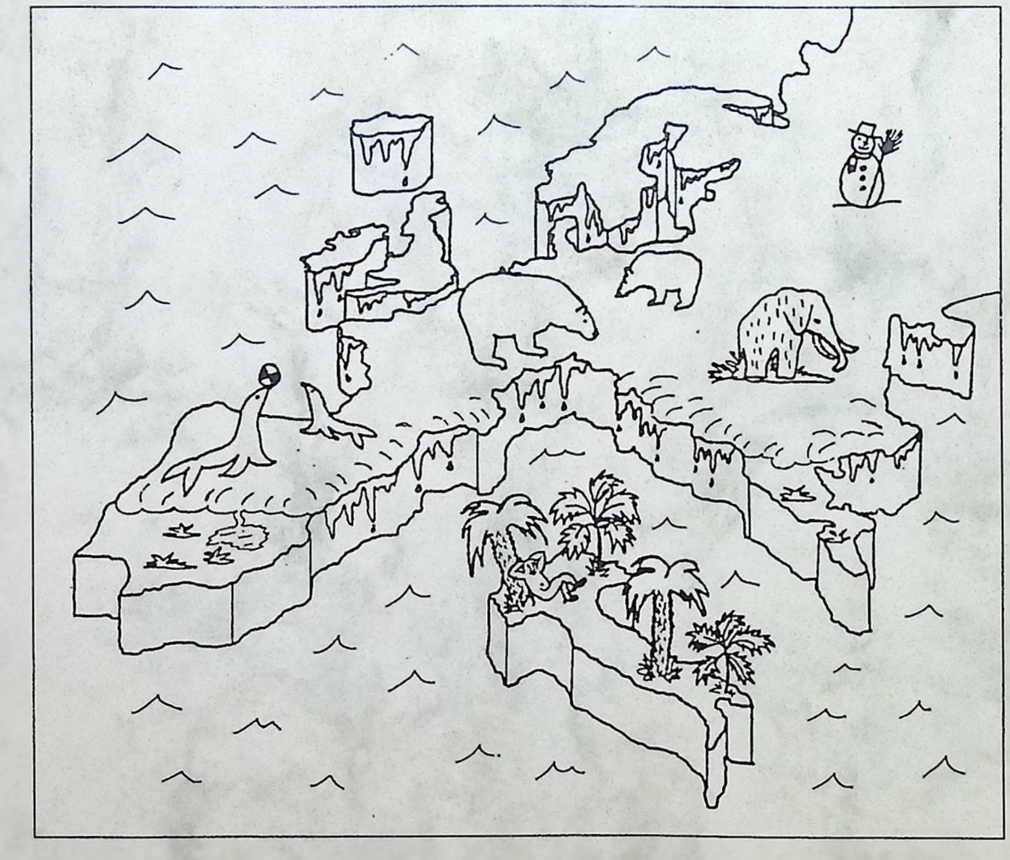
FLORA TERTIARIA MEDITERRANEA

Die
tertiären Floren des Mittelmeergebietes
Vegetationsgeschichte, Phytostratigraphie, Paläökologie, Paläoklimatologie, Paläogeographie

Herausgegeben von
Dr. Hans-Joachim Gregor

Pliocene plants, environment and climate of northwestern Italy

edited by E. MARTINETTO



Fünfter Band - achte Abteilung
München
Verlag Documenta naturae
2001

documenta naturae

Sonderbandreihe:

FLORA TERTIARIA MEDITERRANEA

Band V - Abteilung 8

Jahrgang 2001

ISSN 1433-1705

Herausgeber für diese Sonderbandreihe:
Dr. Hans-Joachim Gregor, Daxerstraße 21, D-82140 Olching
Priv.-Doz. Dr. Diethard H. Storch, Sägematte 2, D-19183 Waldkirch

Die Sonderbandreihe aus dem Verlag Documenta naturae erscheint in zwangloser Folge mit Themen aus den Gebieten Geologie, Paläontologie, Paläophytologie, Botanik, Stratigraphie, Paläökologie, Taphonomie, Paläoklimatologie usw., nur das Mediterrangebiet betreffend

Die Sonderbandreihe ist Mitteilungsorgan der
Paläobotanisch-Biostratigraphischen Arbeitsgruppe (PBA)
im Heimatmuseum Günzburg und im Naturmuseum Augsburg

Für die einzelnen Beiträge zeichnen die Autoren verantwortlich,
für die Gesamtgestaltung die Herausgeber.

Überweisung des Einzelpreises erbeten auf das Konto 1548460 bei der Sparkasse FFB
(BLZ 700 530 70) - Inh. H.-J. Gregor.

Bestellungen: bei Buchhandlungen und den Herausgebern.

Layout: Juliane Gregor und Hans-Joachim Gregor

Umschlagbild von S. Cavagna & E. Martinetto : Europe and Italy in the Neogene

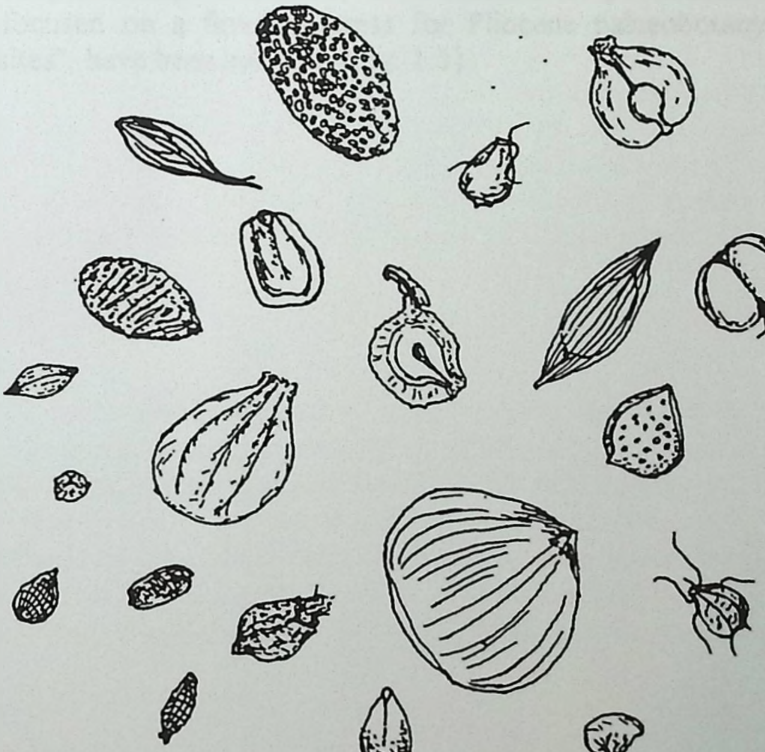
2001

FLORA TERTIARIA MEDITERRANEA V.8

Pliocene plants, environment and climate of northwestern Italy

edited by E. MARTINETTO

with contributions of G. BASILICI, R. BERTOLDI, F. CARRARO, M. GIARDINO,
E. MARTINETTO, G. PAVIA, C. RAVAZZI, D. VIOLANTI & M. ZANNI



Address of the authors:

Dr. Edoardo Martinetto, Prof. Giulio Pavia: Dipartimento Scienze della Terra, Via Accademia delle Scienze 5, I-10123 TORINO
Prof. Francesco Carraro, Dr. Marco Giardino, Prof. Donata Violanti: Dipartimento Scienze della Terra, Via Valperga Caluso 37, I-10125 TORINO
Prof. Remo Bertoldi: Sez. Biologia Vegetale dell'Università di Parma, Viale delle Scienze, 43100 PARMA
Prof. Giogio Basilici: Cidade Universitária - CP 6152, University of Campinas, 13083-970 CAMPINAS - SP (Brazil)
Dr. Casare Ravazzi, Dr. Mario Zanni: Centro Geodinamica Alpina e Quaternaria, Piazza Cittadella 4, I-24129 BERGAMO

Foreword

In April 1998 I organised a small «field conference» with the purpose to show to some European palaeobotanists the consistent record of terrestrial plant remains which was available in the Pliocene successions exposed in several districts of the Piedmont region, in northwestern Italy.

That seemed to be a good occasion to ask a few Italian colleagues, working in different fields of the Earth Sciences, to contribute some synthetic articles, suitable for an informative field-guide. In this way a volume of 85 pages was assembled, which was printed with 100 copies in 1998, as an internal report of my university department (Martinetto, 1998). Some parts of that work represented original contributions, e. g. all the data concerning the Cervo River section or the pollen diagram of the Stura site, but most of the work was merely a collection of formerly published articles or parts of them. However, a single synthetic volume containing an overview of Pliocene palaeofloral data from NW Italy may be certainly regarded as a useful tool, both for the presentation of the present knowledge and for the development of new research.

For this reason, after three years from its first publication, the volume has been updated, slightly extended, and adapted in order to be suitable for publication in an official review. Attention is focused on a few key-areas for Pliocene palaeobotany, where nine better studied "key-sites", have been selected (Fig. 1.1).

E. Martinetto

ACKNOWLEDGEMENTS

The following persons gave helpful contributions to this work: Simona Cavagna prepared the drawing for the cover page; Paola Cavallo studied plant material from the Castelletto Cervo outcrop; Valeria Venezia has drawn Plate 5.1 and carried out the climatic analysis of the Cossato leaf assemblage. Thanks are also due to Roberto Ecclesia for the discovery of several plant fossil sites of the Cervo River succession.

Flora Tertiaria Mediterranea	V.8	p. 1-88	28 figs.	12 tabs.	2 pls.	CD-Rom-pls.	München	2001

Pliocene plants, environment and climate of northwestern Italy.

edited by E. MARTINETTO

Summary

The work provides a synthetic overview of the Pliocene palaeobotanical record of the Piedmont region, in northwestern Italy. Attention is focused on a few key-areas for Pliocene palaeobotany: the "Biellese", the Ivrea district, the area north of Turin and the surroundings of Asti. The geomorphology and Plio-Quaternary geological evolution of such areas are briefly discussed. More detailed information is provided on the stratigraphy, sedimentology and palaeontology of nine "key-sites" with important fossil plant assemblages: Candelo, Cossato, Castelletto Cervo, Gifflenga, Val Chiusella, Ca' Viettone, Stura di Lanzo, R.D.B. Quarry of Villafranca d'Asti and Arboschio.

Riassunto

Viene presentata una breve sintesi sul record paleobotanico del Pliocene piemontese. Particolare attenzione è rivolta a quelle che sono ritenute aree chiave per la paleobotanica del Pliocene: il Biellese, il distretto di Ivrea, l'area a nord di Torino e i dintorni di Asti. Se ne discutono brevemente i lineamenti geomorfologici e l'evoluzione geologica plio-quaternaria. Vengono inoltre fornite informazioni più dettagliate sulla stratigrafia, sedimentologia e paleontologia di nove "siti chiave" con importanti associazioni fossili a resti di piante: Candelo, Cossato, Castelletto Cervo, Gifflenga, Val Chiusella, Ca' Viettone, Stura di Lanzo, Cava R.D.B. di Villafranca d'Asti e Arboschio.

Zusammenfassung

Das vorliegende Werk vermittelt einen paläophytologischen Überblick über das Pliozän der Piemonte Region in NW-Italien. Das besondere Augenmerk liegt auf einigen Schlüsselarealen der jungneogenen Paläophytologie: die Regionen Biella und Ivrea, das Gebiet nördlich von Turin und die Umgebung von Asti. Die geomorphologische Ausbildung und die geologische Entwicklung des Plio/Pleistozäns der genannten Gebiete werden kurz diskutiert. Nähere Informationen über Stratigraphie, Sedimentologie und Paläontologie von neun Schlüssellokalitäten mit wichtigen fossilen Pflanzenassoziationen werden zusammenfassend behandelt: Candelo, Cossato, Castelletto Cervo, Gifflenga, Val Chiusella, Ca' Viettone, Stura di Lanzo, R.D.B. Quarry von Villafranca d'Asti und Arboscio.

Index

PLIOCENE AND QUATERNARY IN THE BIELLESE AREA

THE IVREA DISTRICT

PLIOCENE DEPOSITS NORTH OF TORINO

PLIOCENE AND PLEISTOCENE DEPOSITS IN THE SURROUNDINGS OF ASTI

1. THE PLIOCENE OF PIEDMONT AND ITS PALAEOBOTANICAL RECORD -

by E. Martinetto

The western part of the Po Plain can be considered a Pliocene marine basin (Fig. 1.1) which has been completely filled by sediments. In facts Pliocene marine sediments are constantly present in the subsurface of this area, even if they are well exposed only in the territory to the south of the Turin-Monferrato Hills (Alessandria-Cuneo area), including the famous fossil-bearing sites near Asti. Minor outcrops are scattered at the foothills of the Western Alps, i. e. along the northern margin of the Plio-Quaternary basin of the western Po Plain. The westernmost outcrops of this second group lay in the neighbourhood of Ivrea (province of Turin), where the best exposed profiles are found in a limited area bordering the Chiusella river, a tributary of the Dora Baltea river (Basilici *et al.*, 1997). Further north-eastwards, the Pliocene marine sediments are discontinuously exposed from Biella to Lake Maggiore (Aimone & Ferrero Mortara, 1983).

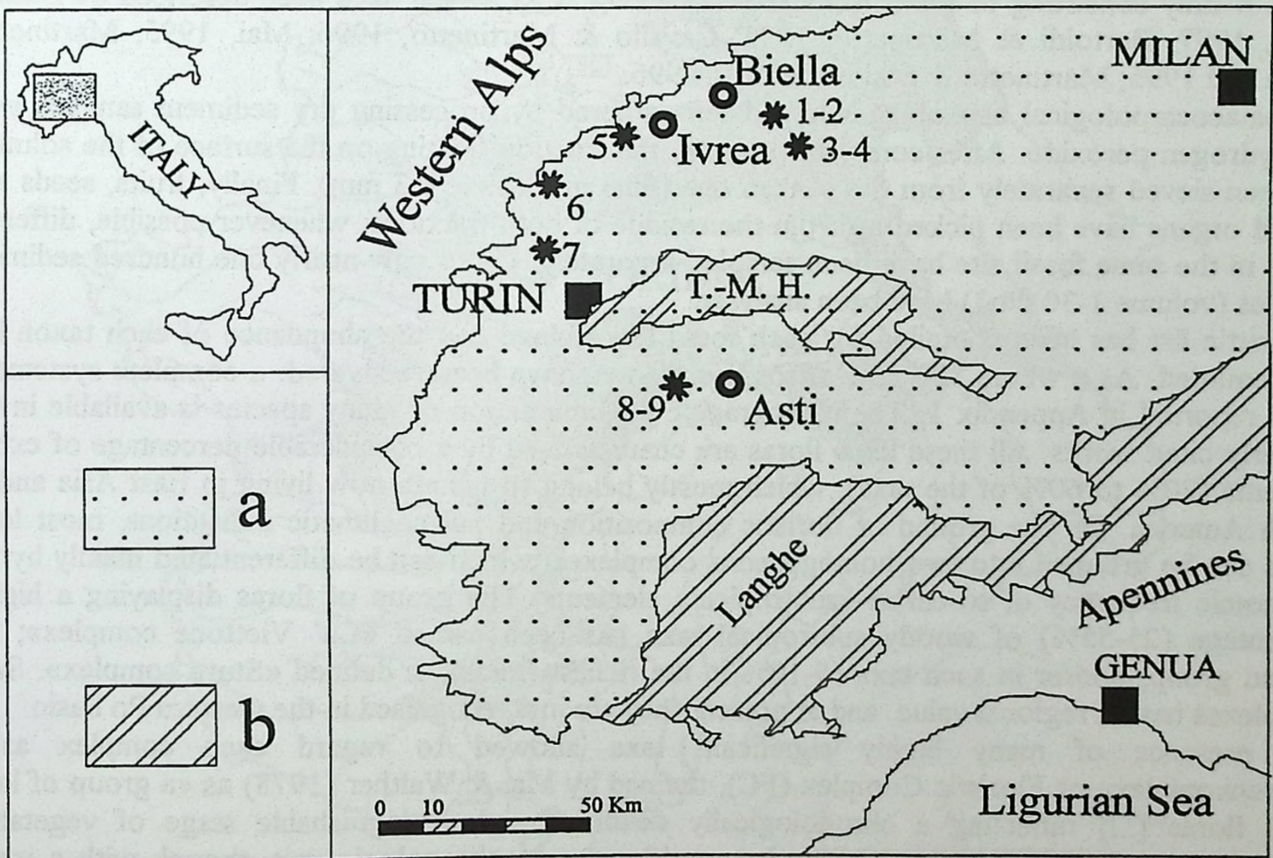


Fig. 1.1 - Sketch map of the Cenozoic and Quaternary basins of NW Italy. a: Plio-Quaternary basin of the western Po Plain. b: Pre-Pliocene Cenozoic sediments. T.-M. H.: Turin-Monferrato Hills. The numbers and related asterisks indicate the location of the key-sites treated in this volume.

The interfingering of continental and transitional sediments with shallow marine deposits of Pliocene age is well-known especially in the surroundings of Asti, but it has also been observed in other districts. Similar non-marine sediments are more commonly superposed to the marine ones, forming a lithostratigraphic unit locally known as "Villafranchiano" (Fig. 1.2). Actually, too many different deposits and facies associations have been included in this unit, and consequently its age has been largely disputed. According to Caramiello *et al.* (1996) the age of the «Villafranchiano» unit spans from Early Pliocene to Middle Pleistocene. However, most of its volume is given by Early to Middle Pliocene sediments deposited at the margin of the Po Plain basin, which testifies that the regression and consequent filling of the Pliocene gulf of the western Po Plain, started in the

Early Pliocene and possibly had been nearly completed yet in the Middle Pliocene. The geochronological scale adopted in this volume is shown in Fig. 1.3.

The record of the Pliocene terrestrial plants in the sedimentary successions of Piedmont is represented by several kinds of fossils. Unfortunately, the palaeobotanical documentation (e. g.: Charrier, 1953; Pavia, 1970; Peola, 1895, 1901; Sismonda, 1859, 1865) concerning fossil leaf and wood assemblages is still very scanty. In addition, many old identifications cannot be accepted without an updated revision. Palynological studies have been carried out just in a few stratigraphic sections (Francavilla & Tomadin, 1970; Francavilla *et al.*, 1971; Lona & Bertoldi, 1973; Allason *et al.*, 1981; Cerchio *et al.*, 1990; Bertoldi in Carraro, 1996; Bertoldi & Martinetto, 1996).

Fruit and seed floras studied in the last decade

In the last decade several Pliocene freshwater and marine sections have been sampled for plant macrofossils in different districts of Piedmont. These investigations provided twenty-five local floras, mainly consisting of fossil fruits and seeds (Fig. 1.2), which have been described by Basilici *et al.*, 1997; Bertoldi & Martinetto, 1995; Cavallo & Martinetto, 1996; Mai, 1995; Martinetto, 1994a and 1995; Martinetto & Mai in Carraro, 1996.

The palaeocarpological assemblages have been gathered by processing dry sediment samples with 5% hydrogen peroxide. After complete reaction, the fraction floating on the surface of the solution has been sieved separately from the sunken one (final mesh size: 0.3 mm). Finally, fruits, seeds and related organs have been picked up from the residue of both fractions; whenever possible, different layers in the same fossil site have been sampled separately. Up to now nearly one hundred sediment samples (volume 1-30 dm3) have been analysed.

A floristic list has been compiled for each fossil assemblage and the abundance of each taxon has been counted. As a whole 320 taxa of fossil diaspores have been recovered: a complete systematic list is reported in Appendix 1. The iconographic documentation of many species is available in the formerly cited works. All these local floras are characterised by a considerable percentage of exotic elements (20% to 60% of the taxa), which mostly belong to genera now living in East Asia and/or North America. On the ground of floristic composition and palaeoclimatic indications, most local floras can be grouped into two homogeneous complexes, which can be differentiated mainly by the taxonomic frequency of so-called «subtropical» elements. The group of floras displaying a higher percentage (25-55%) of woody subtropical taxa has been named «Ca' Viettone complex»; the second group, poorer in such taxa (5-10% in the richest floras), is defined «Stura complex». Such complexes have a regional value, and at present they are just recognised in the western Po basin.

The presence of many highly significant taxa allowed to regard each complex as a «Florenkomplex» or Floristic Complex (FC), defined by Mai & Walther (1978) as «a group of local fossil floras [...] reflecting a chronologically delimited and distinguishable stage of vegetation development». In this sense a FC may be considered a biochronologic unit, though with a rough time resolution (see also Martinetto *et al.*, 1997). Therefore, the construction of floral complexes comprising both dated and undated floras can be useful to suggest the age of the last ones, and this is precisely what has been done for many undated floras of Piedmont - often the richest ones - coming from the «Villafranchiano» unit (see above).

The typical representatives of the «subtropical» elements in the carpofloras of the «Ca' Viettone Floristic Complex» are: *Cyclea, Ficus, Cinnamomum, «Litsea»*, *Mallotus, Meliosma canavesana*, several Rutaceae, *Symplocos* spp., three species of Theaceae and *Trigonobalanopsis*. The percentage of species belonging to exotic genera ranges from 40% to 60% in different local floras of the «Ca' Viettone FC». These have been detected in continental and marine deposits in the provinces of Turin (6 sites), Biella (3) and Cuneo (3). Their floristic lists include 20 to 130 species.

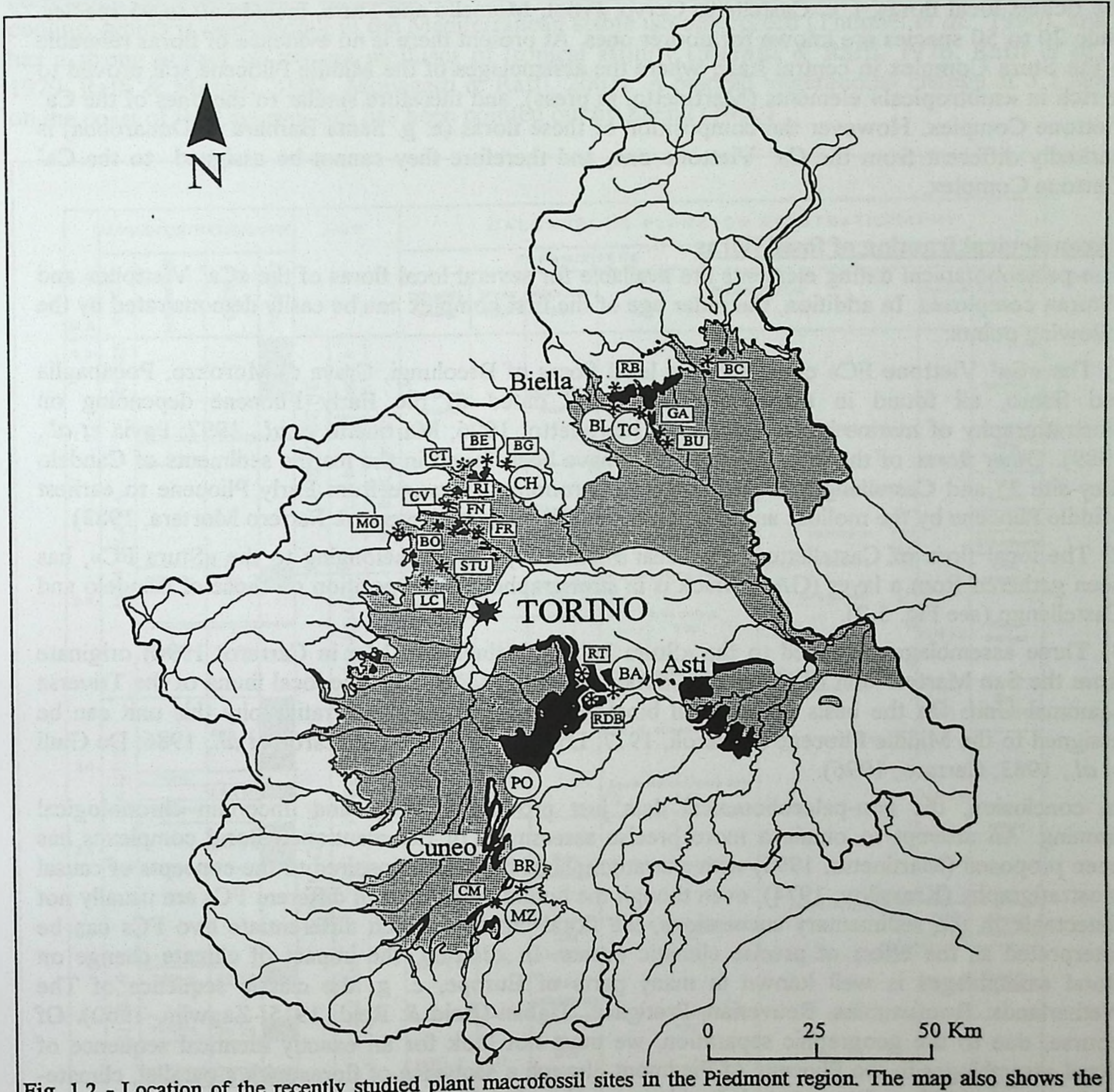


Fig. 1.2 - Location of the recently studied plant macrofossil sites in the Piedmont region. The map also shows the approximate distribution, after Caramiello *et al.* (1996), of continental deposits of the «Villafranchiano» unit in the outcrop (black) and underground (pointed). Symbols referred to freshwater fossil sites are enclosed in boxes, those referred to marine ones in circles. **BA**: Baldichieri d'Asti; **BE**: Benasso near Castellamonte; **BC**: Boca near Maggiora; **BG**: Sento, Val Chiusella, freshwater succession; **BL**: Candelo-Bocca del Lupo; **BO**: Boschi di Barbania; **BR**: Breolungi; **BU**: Buronzo; **CH**: Sento, Val Chiusella, marine succession; **CM**: Crava di Morozzo, freshwater succession; **CT**: Canton Talentino near Castellamonte; **CV**: Ca' Viettone near Levone Canavese; **FN**: Barbania; **FR**: Front; **GA**: Castelletto Cervo; **LC**: La Cassa; **MO**: Momello near Lanzo; **MZ**: Crava di Morozzo, marine succession; **PO**: Pocapaglia; **RI**: Rivara; **RB**: Ronco Biellese; **RDB**: R.D.B. pit of Villafranca d'Asti; **RT**: Cascina Melona near Roatto; **STU**: Stura near Nole Canavese; **TC**: Castellengo (from Martinetto, 1996).

The «Stura Floristic Complex» is characterized by a conspicuous representation of "Tertiary" deciduous plants (40-50% of the woody taxa); subtropical taxa seem to be relics. The local floras assigned to such complex (Fig. 1.2) were found in five outcrops of the "Villafranchiano" unit north of Turin (Barbania, Front, La Cassa, Momello, Stura), in the brackish sediments of Castelletto Cervo near Biella (key-site 3) and in the "type-Villafranchian" of Villafranca d'Asti (key-site 8).

The richest local floras, i. e. Castelletto Cervo, Front, Momello and Stura, include 50 to 95 species, while 20 to 50 species are known for poorer ones. At present there is no evidence of floras referable to the Stura Complex in central Italy, where the assemblages of the Middle Pliocene still proved to be rich in «subtropical» elements (Martinetto, in press), and therefore similar to the ones of the Ca' Viettone Complex. However the composition of these floras (e. g. Santa Barbara or Dunarobba) is markedly different from the Ca' Viettone one, and therefore they cannot be assigned to the Ca' Viettone Complex.

Chronological framing of fossil floras

Non-palaeobotanical dating elements are available for several local floras of the «Ca' Viettone» and «Stura» complexes. In addition, the older age of the first complex can be easily demonstrated by the following points:

1) The «Ca' Viettone FC» comprises the local floras of Breolungi, Crava di Morozzo, Pocapaglia and Sento, all found in marine sediments and dated to the Early Pliocene depending on biostratigraphy of marine biota (Cavallo & Martinetto, 1996; Martinetto *et al.*, 1997; Pavia *et al.*, 1989). Other floras of the «Ca' Viettone FC» have been found in the marine sediments of Candelo (key-site 1) and Castellengo, constrained in a chronological range from Early Pliocene to earliest Middle Pliocene by the mollusc and foraminiferal assemblages (Aimone & Ferrero Mortara, 1983).

2) The local flora of Castelletto Cervo near Biella (key-site 3), belonging to the «Stura FC», has been gathered from a layer (GA1) which is in stratigraphical superposition on those of Candelo and Castellengo (see Fig. 5.2).

3) Three assemblages assigned to the «Stura FC» (Martinetto & Mai in Carraro, 1996) originate from the San Martino unit of Villafranca d'Asti, which provided the type local fauna of the Triversa Mammal Unit. On the basis of Mammal biochronology and magnetostratigraphy this unit can be assigned to the Middle Pliocene (Azzaroli, 1977; Linsay *et al.*, 1980; Azzaroli *et al.*, 1986; De Giuli *et al.*, 1983; Carraro, 1996).

In conclusion, the non-palaeobotanical data just provide a rough and uncertain chronological framing. An attempt to obtain a more precise assessment of the mentioned floral complexes has been proposed (Martinetto, 1995) with a stratigraphical procedure inspired to the concepts of causal biostratigraphy (Krassilov, 1974): even though the boundaries between different FCs are usually not detectable in the sedimentary successions, the floral changes which differentiate two FCs can be interpreted as the effect of precise climatic events. In addition, the impact of climate change on floral assemblages is well known in many parts of Europe, e. g. the classic sequence of The Netherlands: Brunssumian, Reuverian, Pretiglian, Tiglian (Reid & Reid, 1915; Zagwijn, 1960). Of course, due to the geographic separation, we must not look for an exactly identical sequence of floral assemblages in the Pliocene of Piedmont, though a sequence of floras with a parallel, climate-driven, evolution is to be expected. In this sense, the «Ca' Viettone FC» is certainly time equivalent of the Brunssumian, and also from the floristic point of view it does not differ so much (e. g. *Turpinia ettingshausenii*, *Trigonobalanopsis exacantha* both in Brunssum and Ca' Viettone: Zagwijn, 1990).

If the «Ca' Viettone FC», from the climatostratigraphic point of view, is Brunssumian, the floral change separating the «Ca' Viettone FC» and the «Stura FC» may be correlated with the Brunssumian-Reuverian transition: in both cases a retreat of thermophilous elements - more precisely of hygro-megatherm taxa (Mai, 1964) - has been detected. This event might have been caused by a climatic deterioration occurred around 3.5 Ma, whose impact on pollen assemblages of the NW-Mediterranean has been described for example by Bertoldi (1990), Bertoldi *et al.* (1994) and Suc *et al.* (1995). If this first hypothesis is not correct, the «Ca' Viettone FC» to »Stura FC» transition should be correlated to one of the well-known Early or Middle Pliocene episodes of climatic deterioration (Berggren & Van Couvering, 1974; Zubakov & Borzenkova, 1990). The second best hypothesis, depending on the biostratigraphic constraints cited above, consists in correlating the event which separates the «Ca' Viettone FC» from the «Stura FC» with the 3.1 Ma cooling, which is outstanding in the Mediterranean stable isotope record (Thunnel *et al.*, 1990), and has a strong impact on marine molluscs of tropical affinity (Marasti & Raffi, 1976; Raffi *et al.*, 1979; Raffi & Marasti, 1982; Monegatti & Raffi, 2001). A marked vegetational change at 3.1 Ma on the coast of the Ligurian Sea has been pointed out by Zheng (1990).

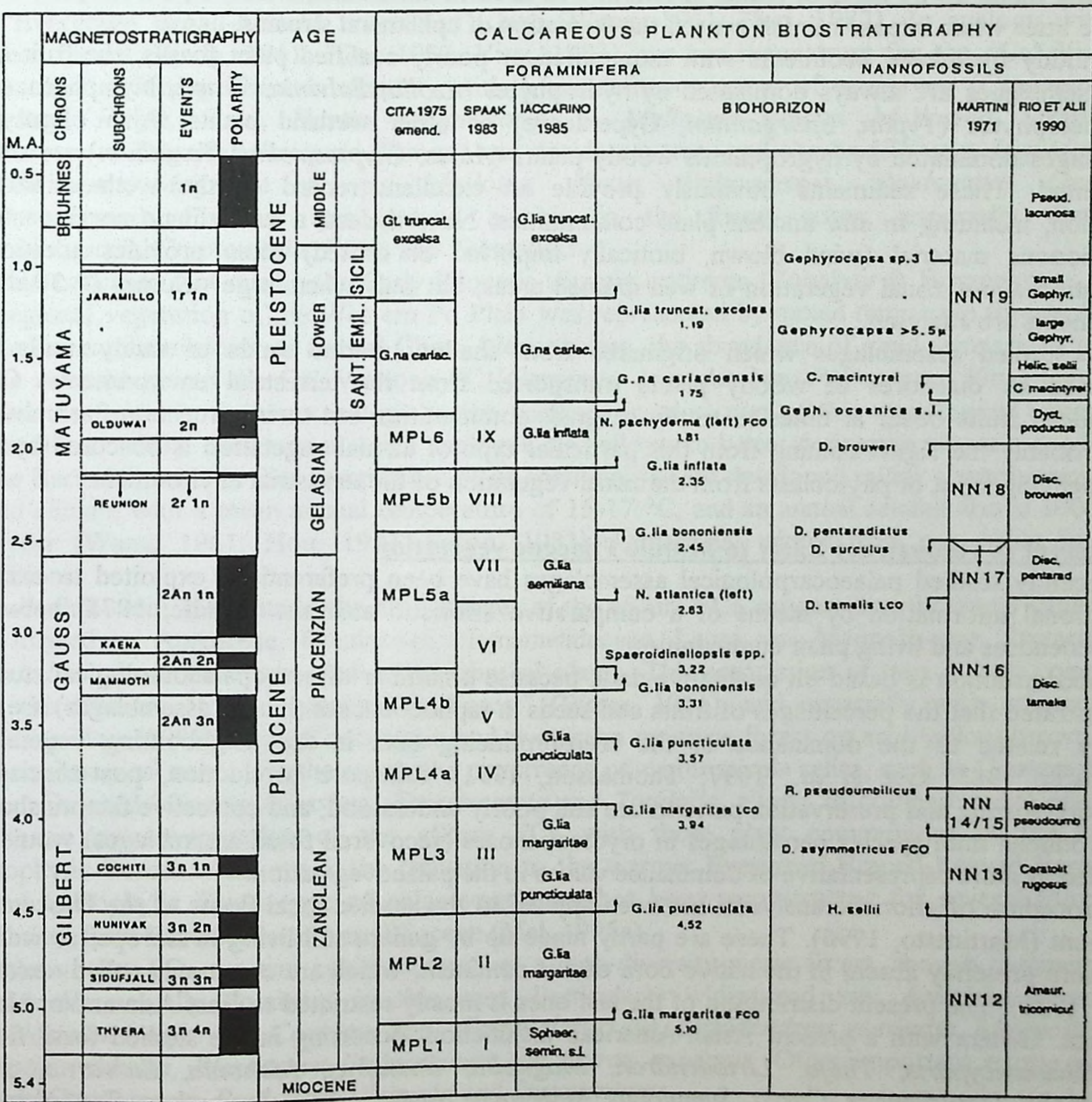


Fig. 1.3 - Integrated stratigraphic scheme for the Plio-Pleistocene (from SPI, 1996).

Fossil assemblages and sediment type

The lithostratigraphic unit locally known as «Villafranchiano», made up by continental and transitional sediments, provided the most diverse fruit and seed assemblages (Fig. 1.2), though sufficiently rich ones have been studied in shallow marine Pliocene sediments too (Martinetto, 1995). The interpretation of the environmental signals provided by fossil assemblages requires to take in consideration the taphonomical biases and the sedimentary features of every fossiliferous layer. Actually, the studied plant macrofossil assemblages have been found in layers with different grain size and sedimentary structures. Even though each assemblage is a case on its own, a few general features deduced from sample analysis and from the literature can be listed:

1) Plant macrofossil assemblages in sandy or sandy-gravely freshwater sediments show high specific diversity and contain a large number of diaspores of mesic woody taxa. Hydrophytes are almost absent and wetland herbs are never dominant. These features, as well as actuopalaeontological data (Gee *et al.*, 1997; Spicer & Wolfe, 1987), suggest that such assemblages are mostly made up by parts of plants grown in well-drained conditions, which have been picked up from the litter when intense rainfall caused the formation of ephemeral streams.

2) In muddy freshwater sediments with mummified or poorly coalified plant fossils, the fruit and seed assemblages are always dominated by hydrophytes (*Azolla*, *Salvinia*, *Trapa*, Nymphaeaceae, etc.), helophytes (*Typha*, *Sparganium*, Cyperaceae) or other wetland plants. Also oligotypic assemblages dominated by hygrophilous woody plants (*Alnus*, *Glyptostrobus*, *Taxodium*) are often represented. These sediments obviously provide an excellent record of the wetland azonal vegetation, including *in situ* ancient plant communities. Nevertheless, a subordinate contingent of allochthonous material (wind blown, biotically imported or drifted) often provides additional information about zonal vegetation of well drained areas, but only when large volumes (> 30 dm^3) of sediments are analysed.

3) The studied assemblages which originated from shallow marine sands or sandy muds are dominated by diaspores of woody plants transported from the terrestrial environments. Only *Cymodocea* fruits occur at times to testify seagrass communities, but their percentages are always low. Probably the signal coming from this particular type of azonal vegetation is obscured by the overwhelming input of phytoclasts from the zonal vegetation of the terrestrial environment.

An attempt to reconstruct Early to Middle Pliocene vegetation

The recently studied palaeocarpological assemblages have been preferentially exploited to extract vegetational information by means of a comparative «floristic analysis» (Wolfe, 1971) between oryctocoenoses and living plant communities.

The reconstruction is based on qualitative data, because a number of actuopalaeontological studies demonstrated that the percentages of fruits and seeds in taphocoenoses (buried assemblages) are not directly related to the dominance of the seed-producing taxa in the neighbouring vegetation (Collinson, 1983; Gee *et al.*, 1997; Thomasson, 1991). Diaspore production, post-abscission transport, sorting and preservation patterns are still poorly understood, and corrective factors should be introduced until species percentages in oryctocoenoses (recovered fossil assemblages) would be regarded as more representative of dominance values in the palaeovegetation.

The procedure of «floristic analysis» has been applied to the studied local floras of the Pliocene of Piedmont (Martinetto, 1996). These are partly made up by genera still living in Europe, as well as by genera presently absent in the native flora of our continent, which are commonly called «exotic» (Reid, 1920). The present distribution of the last ones is mostly restricted to East Asia and/or North America. Genera with a present Asian-American disjunction, occurring in the studied fossil floras are: *Chamaecyparis*, *Thuja*, *Liriodendron*, *Magnolia*, *Sassafras*, *Mahonia*, *Stewartia*, *Itea*, *Hamamelis*, *Liquidambar*, *Carya*, *Symplocos*, *Meliosma*, *Nyssa*, *Aralia*, *Leucothoe*, *Cephalanthus* and *Ampelopsis*. Additionally, just a few recovered genera are confined to North America (*Sequoia*, *Taxodium*, *Proserpinaca*, *Decodon*, *Dulichium*).

The exclusively East Asian component is represented by many genera: *Cathaya*, *Pseudolarix*, *Cryptomeria*, *Glyptostrobus*, *Taiwania*, *Cephalotaxus*, *Cinnamomum*, *Euryale (Pseudoeuryale)*, *Sinomenium*, *Distylium*, *Cyclocarya*, *Pterocarya*, *Eurya* s. s., *Hartia*, *Trichosanthes*, *Actinidia*, *Rehderodendron*, *Mallotus*, *Phellodendron*, *Toddalia*, *Turpinia*, *Sargentodoxa*, *Schizophragma*, *Sabia*, *Alangium* and *Paulownia*. This observation suggests that Recent plant communities of East Asia, and particularly of China, can act as a model for the reconstruction of the Pliocene zonal vegetation and climate in the Po Basin.

Zonal palaeovegetation

The sandy or sandy-gravelly freshwater sediments, as reported above, contain allochthonous plant macrofossil assemblages with fruit and seeds of mesic woody taxa. Such assemblages can provide a good record of the plants growing on wide areas of well-drained soil, i. e. the zonal flora and vegetation. In the allochthonous assemblages of the «Ca' Viettone FC», the occurrence of *Cinnamomum, Eurya, Fagus, Hartia, Magnolia* and *Ternstroemia* allows to trace a parallelism between the zonal palaeovegetation of this «Florenkomplex» and some living plant communities of the "Evergreen Broad-Leaved Forest" of China (Wang, 1961; Hou, 1983). In analogy with the Chinese model (Wang, 1961; Hou, 1983; Ying, 1983), we can reconstruct for the «Ca' Viettone FC» a high-diversity forest community with a simultaneous cover of evergreen (*Cinnamomum, Distylium, Eurya, Ficus, Hartia, Magnolia* p. p., *Meliosma* subgen. *Meliosma, Symplocos, Ternstroemia, Trigonobalanopsis, Visnea*) and deciduous trees and shrubs (*Ehretia, Liquidambar, Liriodendron, Magnolia* p. p., *Mallotus, Nyssa, Palaeocarya, Paulownia, Quercus, Rehderodenron*). Conifers also played a role in the forest cover, especially *Cathaya, Chamaecyparis, Cryptomeria, Pinus* and *Tetraclinis*.

We can conclude that during the Early Pliocene climatic optimum (Zubakov & Borzenkova, 1990) the regional vegetation of the Western Po Plain was represented by mixed temperate forests similar to the Recent *Laurisilvae* of central China. Nevertheless, the abundance of «mid-temperate» genera in the assemblages of the Ca' Viettone FC (*Carpinus, Liquidambar, Pterocarya, Vitis*) allows to restrict the field of maximum analogy to the northern (cooler) part of this «subtropical vegetation zone» (Hou, 1983). This recent Asian analogue also allows to better define the climatic conditions of the Early Pliocene, in fact comparable plant communities are developed under a warm-temperate humid climate with a mean annual temperature of 15-17 °C, and an annual rainfall above 1000 mm per year (Wang, 1961; Hou, 1983; Satoo, 1983). Occasional winter frost can occur in such conditions.

The allochthonous elements in the assemblages of the «Stura FC» suggest that the zonal vegetation was formed by Aceraceae, Betulaceae, Hamamelidaceae, Lauraceae, Magnoliaceae, Styracaceae, *Fagus, Liriodendron, Nyssa,* and other arboreal plants. This association of taxa is best compared with the Chinese "Mixed Mesophytic Forest" (Wang, 1961), and especially with communities called by Hou (1983) "mixed deciduous and evergreen montane forest on acid yellow-brown soils of the subtropical zone". Furthermore, the occurrence of «subtropical» relics, such as *Cinnamomum, Ficus, Eurya, Meliosma miessleri, Ternstroemia* and *Toddalia*, allows to compare more precisely the mesic palaeovegetation of the «Stura FC» with those plant communities of the Mixed Mesophytic Forest which mark the transition to the warmer Evergreen Braoad-Leaved Forest. A Mixed Mesophytic Forest-type of palaeovegetation has been reconstructed for several European fossil sites from Palaeocene to Late Pliocene (Mai, 1995a).

For the «Stura FC» we can again reconstruct a high-diversity mesic forest, though summergreen species are actually dominant in this case. Particularly widespread are: *Actinidia faveolata, Ampelosis malvaeformis, Carpinus* spp., *Fagus decurrens, Liriodendron geminata, Magnolia cor, Parrotia reidiana, Pterocarya limburgensis* and *Styrax maximus*. Other important exotic genera include *Cryptomeria, Paulownia, Sequoia* and *Sinomenium*.

From the climatic point of view, the «Stura» step of vegetational evolution is characterised by warm-temperate and humid conditions, similar to the ones of the preceding Ca' Viettone FC, yet a decrease in temperature occurred, bringing the annual mean towards 13-14 °C (Wang, 1961; Wolfe, 1971; Numata; 1974). The «Stura FC» can be considered the macrofloral expression of the «pre-Tiberian» palynological phase of Bertoldi (1990), as confirmed by the associated pollen and fruit/seed floras in the same layers of the R.D.B. succession of Villafranca d'Asti (Bertoldi in Carraro, 1996; Martinrtetto & Mai in Carraro, 1996).

Azonal palaeovegetation

Among several types of azonal vegetation, only the ones which are linked to depositional environments can be recorded quite reliably in the fossil state. Obviously, wetland vegetation is very well recorded, and this is also the case in the Pliocene successions of Piedmont, where assemblages dominated by diaspores of freshwater macrophytes have been found in several muddy and coaly layers of different localities. In contrast with the mesic plants, the Pliocene wetland plants do not show a distinct Asian affinity, because they mostly belong to genera which are almost cosmopolitan at present.

In two local floras of the «Ca' Viettone FC» (Benasso and Canton Talentino) hydrophytic communities are testified by abundant macrospores of *Azolla* cf. *pyrenaica* and *Salvinia miocenica*. Angiosperms include *Brasenia*, *Ceratophyllum*, *Nymphaea* and *Proserpinaca*. Additionally, *Nuphar* and *Potamogeton* have been found in Ca' Viettone.

The hydrophytic assemblages of the «Stura FC» are distinguished by the occurrence of different water fern species: *Azolla tegelensis* and *Salvinia tuberculata*, found in Castelletto Cervo, Front, Stura and Villafranca d'Asti (R.D.B. pit). Diaspores of freshwater macrophytes are scattered in several local floras of the «Stura FC», including: *Brasenia*, *Ceratophyllum*, *Luronium*, *Nuphar*, *Najas*, *Potamogeton*, *Proserpinaca*, *Pseudoeuryale*, *Ranunculus* ex gr. *aquatilis*, *Trapa* and *Zannichellia*.

Hygrophylous palaeocommunities are very well represented both in the «Ca' Viettone FC» and «Stura FC», though no marked distinction is apparent between the two Floristic Complexes. Cyperaceae are often dominant (*Carex*, *Cladium*, *Eleocharis*, *Scirpus*) together with a few other herbs (*Lycopus*, *Oenanthe*, *Potentilla*, *Ranunculus*, *Sparganium*, *Typha*). Reed-like Poaceae are testified by rhizomes and stems in the Stura di Lanzo fossil site. It is also remarkable the occurrence of extinct species (e. g.: *Carex flagellata* C. & E.M. Reid, *Lobelia pliocenica* (Dorofeev) Mai) and exotic genera, such as *Decodon* and *Dulichium*.

In the Middle Pliocene the taxodiaceous *Glyptostrobus*, associated with *Alnus* and several hygrophylous herbs (*Ranunculus*, Lamiaceae, Cyperaceae, etc.), formed extensive swamp forests, that have been wonderfully recorded *in situ* in the "Villafranchiano" unit (Martinetto, 1994a, 1994b). A palaeocarpological assemblage indicating a *Taxodium-Nyssa* swamp forest is exclusively represented in the Middle(?) Pliocene deposits of the R.D.B. Pit of Villafranca d'Asti (Martinetto & Mai in Carraro, 1996).

MARTINETTO E. - An introduction to the Pliocene sediments of Piedmont and their palaeobotanical record. *In* MARTINETTO E. (ed.): Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.4 (2001): 3-10.

The Biellese area

2. AN INTRODUCTION TO GEOMORPHOLOGY AND RECENT GEODYNAMIC OF THE BIELLESE AREA - by M. GIARDINO

The key-sites 1 to 4 are located in the newly formed administrative district (Provincia) of Biella; this district is geographically known as the «Biellese», an area extending from the internal side of the North-Western Alps to the higher part of the Piemontese Plain.

From the geomorphological point of view the «Biellese» shows some sections with different major features:

- a section of alpine mountains and valleys on the north-western side (A in Fig. 2.1), whose maximum elevation reaches 2600 m a.s.l. at Mt. Mars;
- an ENE-WSW-elongated hilly area (section B in Fig. 2.1) of milder relief and lower elevation than the alpine side;
- a wide section of high plain and river terraces (C in Fig. 2.1) whose north-western part is more deeply cut into by streams than the south-eastern one;
- an area of elongated and concentric ridges and small valleys (section D in Fig. 2.1) which correspond to the north-eastern part of the Ivrea morainic amphitheatre, a complex of terminal moraines related to the Balteo glacier of Aosta Valley.

The morphology of «Biellese» area has a general stepped WNW-ESE profile (Fig. 2.2), due to exogenic and endogenic processes.

The higher and steeper part is on the NW side, along the alpine mountain slope (A in Figs. 2.1 and 2.2); here different lithological features of the bedrock contribute to differentiate resistance to erosion (e.g.: strength in gabbro > micashist > altered granite), thus determining local differences in morphological setting. However, in a broad outline, it is still possible to separate the mountainous and hilly parts of the «Biellese» in some zones of similar general morphology (Bortolami *et al*., 1967): this is mainly due to the structural setting of the area. So, the NW end of the profile is part of the Sesia-Lanzo Zone (basement rocks of the Europe-verging Australpine nappe system), the adjacent sector (at an intermediate elevation) is made of intrusive basic rocks of Ivrea-Verbano Zone (Southern Alps; Africa-verging lower continental crust and upper mantle), the hilly area at the lower elevation (B in Figs. 2.1 and 2.2) is mainly composed of volcanics and altered granite of late and post-Hercinian Southern Alpine Units, plus the local occurrence of Pliocene terrigenous post-orogenic deposits.

Morphological steps between these different structural units correspond to the surface occurrence of some important tectonics discontinuities:

- the Canavese Line strikes NNE-SSW and separates Sesia-Lanzo from Ivrea-Verbano units; it is the western part of the Insubric Line (also called Periadriatic Line), a main crustal fracture zone along which African and European plates collided, indented and sutured during Alpine orogenesis;
- the Cremosina Line is a system of ENE-WSW-trending faults; North-East of Biella it separates intrusive basic rocks of Ivrea-Verbano Zone from late and post-Hercinian Southern Alpine Units.

The above mentioned structural discontinuities have been analysed from the geological and geomorphological point of view in order to detect possible recent tectonic activity (ENEL, 1981). The Canavese Line cuts through Pre-Pliocene formations; a 30-km long lineament was drawn in the Biellese area according to remote-sensing analysis (both satellite imagery and aerial photographs): it correspond to the field evidence of several morphological features (saddle points, elongated depressions, counterslopes, drainage network anomalies). The Neotectonic Map of Italy (CNR, 1983) indicates Canavese Line as a Pliocene and Quaternary normal fault.

A more complex situation is that of Cremosina Line: in the Biellese area, this is a 1 to 10 km-wide, ENE-WSW system of discontinuities. It is composed of several different faults (detected by analysis of landforms and stratigraphic evidences), only some of them displacing Pliocene sediments (Sessera and Sesia valleys). Recent activity of Cremosina Line was studied by Gabert (1962), Bortolami *et al.* (1967) and Boriani *et al.* (1973; 1974). Neotectonic Map of Italy (CNR, 1983) indicates some faults of the Cremosina system as Pliocene and Quaternary normal faults; some others faults are shown as of undefined type, characterized by Middle Pleistocene to Holocene activity.

As a summary of geodynamic characteristics of the "Biellese" it is possible to differentiate two zones of recent activity, which follow two of the main geomorphological characters of the area; according to the Neotectonic Map of Italy (CNR, 1983), they are:

- the mountainous area, at the internal side of the Pre-Pliocene Alpine chain, affected by strong and nearly continuous uplift in Pliocene and Quaternary;
- the high plain area, which has to be considered an outer sector of the Po plain trough, affected by

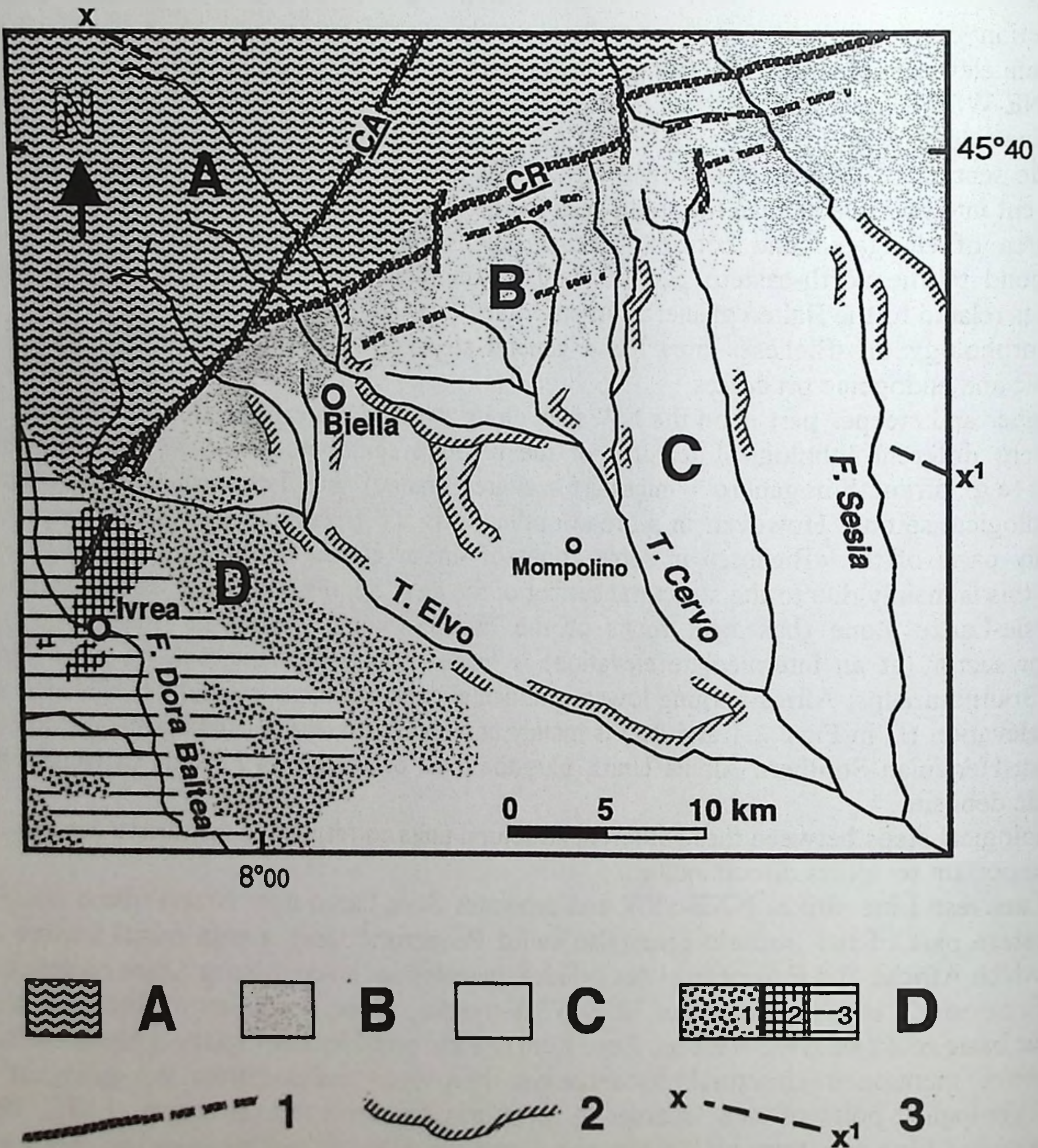


Fig. 2.1 - Sketch-map of geomorphological and geological features of the «Biellese» and surrounding areas. A: section of alpine mountains and valleys. B: hilly area of milder relief and lower elevation than the alpine side. C: wide section of high plain and river terraces whose north-western part is more deeply cut into by streams than the south-eastern one. D1: north-eastern part of the Ivrea morainic amphitheatre (D1: terminal moraines; D2: bedrock hill modelled by glacier; D3: internal plain of the morainic complex). 1: major tectonic lines (CA: Canavese Line; CR: Cremosina Line). 2: main scarps of alluvial terraces. 3: cross-section tips and traces (see also Fig. 2.2).

moderate lowering in Early Pliocene; weak to moderate uplift in Middle to Late Pliocene and Quaternary.

The flatter and lower part of the «Biellese» NW-SE profile (C in Fig 2.2) is related to the occurrence of more erodible formations than the crystalline basement of the mountain side and to constructional landforms of fluvial origin. We will try to delineate a possible morphological evolution of this area.

Pliocene marine deposits (sands, gravels, sandy clays and marls: Bortolami *et al.* 1966) and Plio-Pleistocene deposits of the «Villafranchiano» unit (sands, gravels, silts and clays: Caramiello *et al.* 1996) outcrop both in the plain and at the mouth of the valleys. Data from outcrops and boreholes distributed along main alpine valleys indicate that these valleys also were filled up by the above-mentioned deposits: this demonstrates that the main alpine valleys had already been modelled before Pliocene times. They were later submerged by the sea, thus originating a highly indented coastline (*«rias»*: Gabert, 1962).

The end of marine Cenozoic sedimentation in the area corresponded to the progressive migration of the coastline from the mountain side (Carraro, 1992), as shown by sedimentological characters and distribution of «Villafranchiano» unit deposits. This regressive succession also shows a typical aggradational character: no internal occurrence of widespread terracing phenomena has been found.

After the deposition of «Villafranchiano» unit sediments, an erosional phase took place in the «Biellese» area: it started the typical terraced succession of pleni-Pleistocenic age, whose geomorphological evidences are still the dominant character of the piedmont part of the area. A series of coalescent alluvial fans developed at the mouth of the valleys: the major ones are those related to the Cervo and Elvo stream channels. Further changes in base level and channel gradient and/or alteration of sediment yield and flow discharge caused incision of previously-formed constructional landforms and bedrock relieves.

The oldest terraces in the area are now preserved only as remnants at the mountain front: they

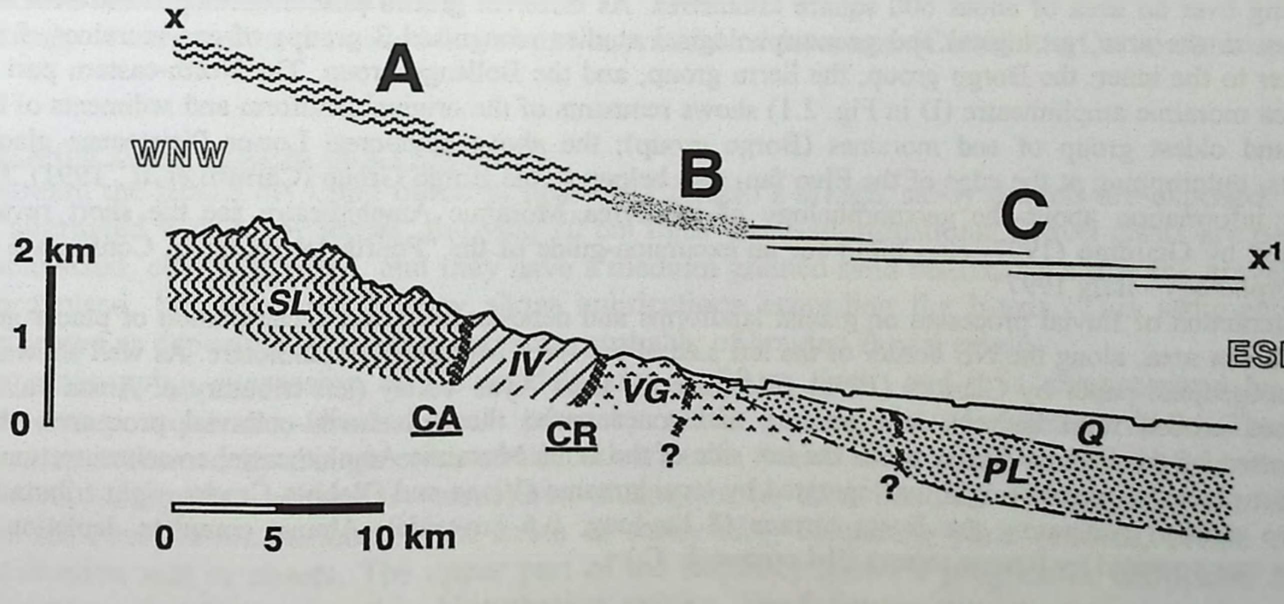


Fig.2.2 - Schematic cross-section of geomorphological and geological features of the «Biellese» area. A: section of alpine mountains and valleys. B: hilly area of milder relief and lower elevation than the alpine side. C: wide section of high plain and river terraces. SL =Sesia-Lanzo Zone (basement rocks of the Europe-verging Australpine nappe system). IV: intrusive basic rocks of Ivrea-Verbano Zone (Southern Alps; Africa-verging lower continental crust and upper mantle). VG: volcanics and altered granite of late and post-Hercinian Southern Alpine Units. PL: Pliocene terrigenous post-orogenic deposits. Q: alluvial terraced Quaternary deposits. CA: Canavese Line. CR: Cremosina Line. ?: Other tectonic discontinuities (Cremosina system?).

correspond to strongly-dissected sedimentary bodies mainly made by highly-altered coarse deposits («Upper Villafranchian» deposits; Bortolami *et al.*, 1967). Rare relieves modelled into bedrock «emerge» from coarse deposits of these terraces: they are the *inselberg*-like hills of Burcina, M. Cucchello, M. Rotondo (Gabert, 1962; Carraro *et al.*, 1991).

From the piedmont to the plain, the Biellese area shows a sequence of terraced alluvial deposits younger than the "Upper Villafranchian" ones; on the basis of relative location and elevation of their topographic expression and pedostratigraphic evidences, Bortolami *et al.* (1967) recognised four groups of terraces in this sequence. The oldest ones, whose local name is "Baragge", cut into "post-Villafranchiano" deposits: they are at higher elevation than the others and possess well-developed soils of reddish-brown colours. Intermediate terraces are less dissected than those of the highest group: they show a well-developed soil of yellowish-brown colour. The major one is the wide terrace south-eastward Biella. Last groups of terraces are those whose geomorphic expression has the lowest topographic relief with respect to the present-day floodplain; they also show a decreasing degree of soil development.

Several phases of clay illuviation during pedogenesis caused most of surface deposits of the Biellese highplain to be almost impervious to water; this is a common character of the highest terraces cut into deeply-altered coarse deposits as well as of intermediate terraces mantled by loess. The soil properties and the relatively warm climate fostered the development of extensive cultivation of rice in the area.

In the western part of Biellese, the alluvial-fluvioglacial terrace system developed in interaction with the deposition of the terminal moraines of the Balteo Glacier (D in Fig. 2.1). Carraro *et al.* (1991) studied the geomorphological evolution of the contact area between the Elvo alluvial fan and the Ivrea Morainic Amphitheatre: they stated that this evolution started with the formation of a morainic dam-lake along the Elvo stream. Local drainage network was then greatly modified by the development of new streams constrained by the glacial landforms: a complex terrace system developed in the contact area between former Elvo alluvial fan and Ivrea Morainic Amphitheatre. Pedostratigraphic studies in the area and paleomagnetic analysis on interbedded fine deposits of the terrace system indicate Early Pleistocene ages for some stratigraphic units constituting the older terraces, the drainage network thus being modified between Lower and Middle Pleistocene, after the deposition of Lower Pleistocene glacial deposits of the Ivrea Morainic Amphitheatre (Carraro *et al.*, 1991).

The Ivrea Morainic Amphitheatre is the third largest end-morainic complex of the internal side of the Alps, stretching over an area of about 600 square kilometres. As different glacial phases developed different end moraines in the area, geological and geomorphological studies recognised 3 groups of end-moraines, from the outer to the inner: the Borgo group, the Serra group, and the Bollengo group. The North-eastern part of the Ivrea morainic amphitheatre (D in Fig. 2.1) shows remnants of the original landform and sediments of the outer and oldest group of end moraines (Borgo group); the above mentioned Lower Pleistocene glacial deposits, outcropping at the edge of the Elvo fan, also belong to the Borgo Group (Carraro *et al.*, 1991). For further information about the geomorphology of the Ivrea Morainic Amphitheatre see the short review presented by Giardino (1997; cum bibl.) for an excursion-guide of the "Fourth International Conference on Geomorphology - Italy 1997".

The interaction of fluvial processes on glacial landforms and deposits produced accumulation of placer gold in the Bessa area, along the NE border of the left side of the Ivrea Morainic Amphitheatre. As well shown in the monographic paper by Gianotti (1996) gold minerals from Ayas Valley (left tributary of Aosta valley) had been eroded from bedrock lode sources and concentrated through eluvial-colluvial processes, then transported by the Balteo Glacier up to the left side of the Ivrea Morainic Amphitheatre; re-concentration of the older placer of glacial origin was operated by local streams (Viona and Olobbia Creeks, right tributaries of Elvo stream) generating the Bessa terrace (8 km-long; 0,6 km-wide). Almost complete depletion of placers was operated by Roman miners (II-I century b. C.).

GIARDINO M. - An introduction to geomorphology and recent geodynamic of the Biellese area. *In* MARTINETTO E. (ed.) MARTINETTO E. (ed.): Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.4 (2001): 11-14.

3. THE SEDIMENTARY SUCCESSION OF THE CERVO RIVER - by G. BASILICI

Introduction

Along the course of the Cervo River, between Candelo and Castelletto Cervo, sandy, secondarily gravely, sediments of Pliocene age outcrop (Aimone & Ferrero Mortatra, 1983). The strata constantly dip of 2-3° towards N160 (Fig. 5.1). These deposits make up a succession that geological mapping methods have estimated to be ca. 300 m thick. However the sedimentary succession outcrops for about 120 m only, exclusively along the banks of the Cervo river and its neighbouring tributaries. The study area is flat and the outcrop conditions are linked to the linear erosion activity, which the Cervo river and its tributaries exert on their own stream beds as consequence of the anthropic quarrying of inert material (sands and gravels) from the stream bed.

The sedimentary succession is prevalently made up by well sorted, fine to coarse grained sands. Locally, in the lower and central part of the succession, sandy gravels up to 15 m of thickness are exposed. Near Castelletto Cervo, in the upper part of the measured succession, sandy and clayey silts are the main lithological constituents.

The depositional evolution is very complicated, and the controlling factors of sedimentary episodes are not very clear yet. Generally the succession from Candelo to Castelletto Cervo is characterised from the lower to the upper part by (Fig. 3.1):

a) Sandy gravels, secondarily sands, deposited within a high energy, probably braided, fluvial system (Candelo's bridge outcrop).

b) Sands, deposited within subtidal channels in a macrotidal environment (Bocca del Lupo outcrop).

c) Sandy gravels and sands, overlying, through an erosional surface, bioturbated sands with marine molluscs; this succession could be interpreted as effect of fluvial sedimentation (Castellengo outcrop).

d) Medium sands with compound trough cross-stratifications, deposited in macrotidal environment (Strona stream confluence outcrop).

e) Sandy or clayey silts, deposited in an inter-supratidal environment (Castelletto Cervo outcrop).

Bocca del Lupo outcrop (KEY-SITE 1)

Upstream the Bocca del Lupo outcrop, near the Candelo's bridge, sandy gravels are exposed. They are alternated with sandy lenses, showing 10 cm thick cross-stratifications. Gravel clasts are pebble-cobble sized, clast supported, and they have a medium grained sand matrix. As a rule the gravels are disorganised, but occasionally they show imbrications according the b-axis. This sediments are interpreted as deposited by tractive currents, probably of braided-fluvial origin.

The outcropping succession of Bocca del Lupo is 30 m thick, and it is characterized by four sedimentary sequences, divided each other by sandy gravels, few decimetres thick. The first sequence is formed by trough cross-stratification sands, which show cyclic sandy silt foresets, and allow to recognise sedimentary structures analogous to tidal bundles. Occasionally it may be observed reactivation surfaces. Thin strata of sandy silts, containing plant remains, divide cross-stratification sets or cosets. The upper part of the sequence shows a progressive disruption of the sedimentary structures, caused by bioturbation activity. The following two sequences are formed by very fine - fine sands, with a rich plenty of ichnofacies; sedimentary structures lack. The last sequence is made up by medium-coarse sands with trough cross-stratifications.

The sequences with sedimentary structures could be attributed to the building up of composite tidal bars within subtidal channels. Pelitic foresets, re-activation surfaces, tidal bundles, compound cross-stratifications are features of depositional bodies formed in tidal energetic conditions. The dimensions of the structures suggests a macrotidal environment.

The highly bioturbated sequences are interpreted as environments with not very strong tidal currents, lower sedimentation rate and an intense substratum colonisation of organisms which destroyed the sedimentary structures.

Along the Cervo river at the confluence of the Strona Stream (KEY-SITE 2)

Upstream the Strona Stream confluence, about 2 km NW of Castellengo (Castellengo outcrop), the sandy succession is interlayered with a sandy gravel body. This sedimentary body is 15 m thick. Its bottom is a weakly inclined erosion surface, overlying bioturbated sands with marine molluscs; its top gradually passes to bioturbated sands. The sandy gravel succession represents a fluvial deposition episode following the formation of an erosional surface, probably an incised valley. The outcropping succession from the Strona Stream confluence downstream is 30 m thick. The main lithofacies consists of medium - coarse grained sands organised in trough cross-bedding, from few decimetres to more than 1 m thick. Different orders of cross-beddings are superimposed: they are

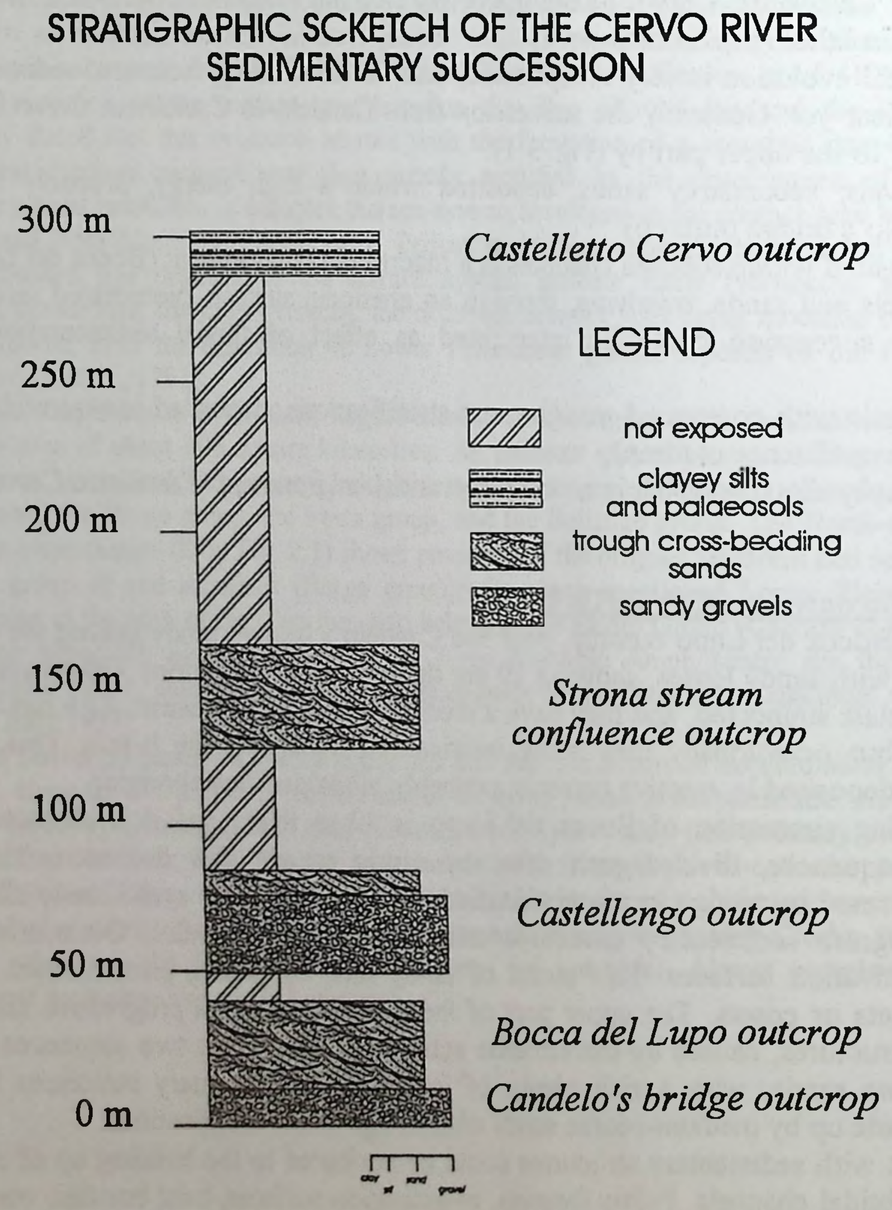


Fig. 3.1.

the depositional effect of fields of dunes or composite bars. Trough cross-bedding cosets are divided by thin sandy silt strata. Sandy gravel strata, less than 20 cm thick and with erosive bottom, allow to identify 5 sedimentary sequences. They are alternated with sands and they are organised in strata which are laterally continuous for more than 100 m. Each sequence is from 2.5 to 8 m thick, and it is weakly fining-upward. Above a thin layer of sandy gravel, the sequence consists of medium grained sandy trough cross-beddings, organised in composite cosets. In the upper part of the sequence, or occasionally in the upper part of through cross-bedding cosets, fine-medium grained sands are bioturbated.

A preliminary facies analysis study allows to interpret this succession as formed in a subtidal part of a macrotidal channel system. Each sedimentary sequence could represent the progressive abandonment and filling of the tidal channel. The sandy gravels testify lag deposits on the bottom of the channel. The trough cross-stratification sets and cosets are part of great three-dimensional tidal bars or dune fields. Bi- or polymodal palaeocurrents, pelitic foresets, tidal bundles, opposite current ripples on cross bedding foresets, reactivation surfaces are arguments which testify tidal energetic conditions. When the tidal bar building slowed down or stopped, owing to tidal current switching, benthic organisms colonised the top of the bar, and by means their activity they bioturbated the sandy bottom.

Castelletto Cervo outcrop (KEY-SITE 3)

The outcropping sedimentary succession is divided by a strike-slip fault zone with dip toward N160 and an unknown throw (see Giardino, this vol.). The deposits on the footwall consist of a 5 m thick succession. It is made up by fine grained bioturbated sands and sandy silts, covered by laminated clayey silts and organic clay or lignite. The clayey silts contain root traces, desiccation mud cracks, and pedogenic slickensides.

On the hangingwall analogous facies with lignites, sandy silts and clayey silts outcrop for 2 m about. A composite profile of palaeosols overlies these deposits. The palaeosol profile is at least 2 m thick, it shows clear horizons, yellowish brown and reddish brown coloured, prismatic structures, and drab-haloed root traces. The palaeosol profile is covered again by clayey silts and sandy clayey silts with common lignite strata.

This succession represents the inter- and supratidal environment of an estuary or bay system. Intertidal signs are recognisable in the rhythmic laminated clayey silts. Subaerial and supratidal conditions are testified by mud cracks and thin hydromorphic palaeosols. Laminated clayey silts, organic rooted clay and lignite recorded an environment near or just below the sea level. On the contrary the yellowish brown and reddish brown coloured, composite palaeosol profile testifies drained conditions and a very long pedogenetic period. This last extended pedogenesis could be caused by a rapid lowering of the base level; as consequence of this lowering the depositional processes have been stopped, and an evolved and well-drained soil developed. A new raising of the base level brought again supratidal-palustrine depositional conditions.

Synthesis

In this first research phase the sedimentary succession of the Cervo River could represent a coastal environment, dominated by tidal currents (probably an estuary), which underwent, during a general seaward progradation, at least three important base level oscillations. The first two yielded an erosional (probably regional) surface on which fluvial sediments deposited. The third oscillation is recorded within the studied succession by an intense and long pedogenesis of previous deposits in a drained environment.

BASILICI G. - The sedimentary succession of the Cervo River. *In* MARTINETTO E. (ed.): Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.4 (2001): 15-17.

4. STRUCTURAL AND MORPHOLOGICAL EVIDENCES OF THE CASTELLETTO CERVO FAULT - by M. GIARDINO

Some deformational structures (either fractures and faults) are exposed along the Castelletto Cervo cross-section and in the surrounding area. Their geometrical setting and kinematics indicators have been measured and analysed according to the brittle microtectonic principles (Hancock, 1985) in order to recognise meso-structural associations possibly related to the evolution of major tectonic structures. To detect any possible geomorphic expression of the fault, present-day local topographic features have been studied by field observations and aerial photography interpretation; sedimentological characters have been preliminarly analysed to infer past surface expression of the fault.

The deformational features will be described following the order of their occurrence on the exposed cross-section from the NNE side to the SSW side (Fig. 5.3); deformational features outcropping in the vicinity of the Castelletto Cervo cross-section will be presented later.

In the Northern part of the Castelletto Cervo cross-section, between m 135 and 145 of the reference coordinate system, some structural discontinuities can be found into medium to coarse sands; they are mainly subvertical metric fractures whose strikes range from N60E to N110E (Fig. 3.1a); the most frequent system (N70E) is spaced 20 to 80 cm.

A complex set of faults and fractures outcrops on the exposed wall of the cross-section and in the lower step of the river bank between m 160 and 165 of the reference coordinate system. The main fault is visible in the lower part of the outcrop. It is a N70E-trending plane with a dip direction of 78-160; from the observations of the fault plane it is possible to recognise thin grooves and mechanical striae: the pitch of lineations is 87S, sense of movement is normal, according to steps on fault plane. The vicinity of the main fault plane shows a zone of intense shearing; a mm to cm-spaced anastomosing cleavage (dm-thick; Fig. 4.2 a) is developed on both sides of the slip surface; microlithons are 1-3 cm long, flattened according to the fault plane. Other minor subvertical faults cut through massive fine sands on both sides of the main fault plane: strikes range from N60E to N80E (Fig. 4.1b).

The lower part of the outcrop and the river bank (between m 165 and 170 of the reference coordinate system) show a set of subvertical, N70E trending, faults. They define a few lithons (metric in size) of massive silty sands; their occurrence was best shown after 1993 flood which deeply eroded along the left side of the Cervo River; after that flood a set of anastomosing fault planes was exposed through the most part of the river channel (Fig. 4.2). This set defines the shear zone possibly connected to the main fault; successive flooding covered up most of the previously-exposed outcrops with present-day alluvial deposits. A few evidences of the shear zone are still visible only in a limited area of the river bed when it is dry. Measurements in this area are shown in the stereographic projection of Fig. 4.1d.

At m 165 of the reference coordinate system, the upper part of the outcrop shows displaced sand layers and laminae (Fig. 4.2 b). A normal fault cuts through all the visible thickness of the outcrop: it is a N85E-trending plane with a dip direction of 85-175. Maximum displacement is 40 cm marked by a set of displaced carbon-rich oblique laminae and lag deposits. Other minor faults offset Fe-oxide rich laminae of medium to fine sands: their strikes range from N80E to N110E (Fig. 4.1c).

In 1998 the main fault plane was exposed on the left bank of the Cervo River. Here laminated silty clay were gently dipping towards South; they were affected by faults and fractures (Fig. 4.1e). Dip direction of the main fault plane was 80-160. Subvertical sand-filled fissures (maximum thickness: 1.5 cm) were approximately normal to the main fault plane.

A channelled body of gravels with rounded pebbles outcropped in the south-east side of the fault zone; the matrix was poorly sorted and Fe-oxide rich.

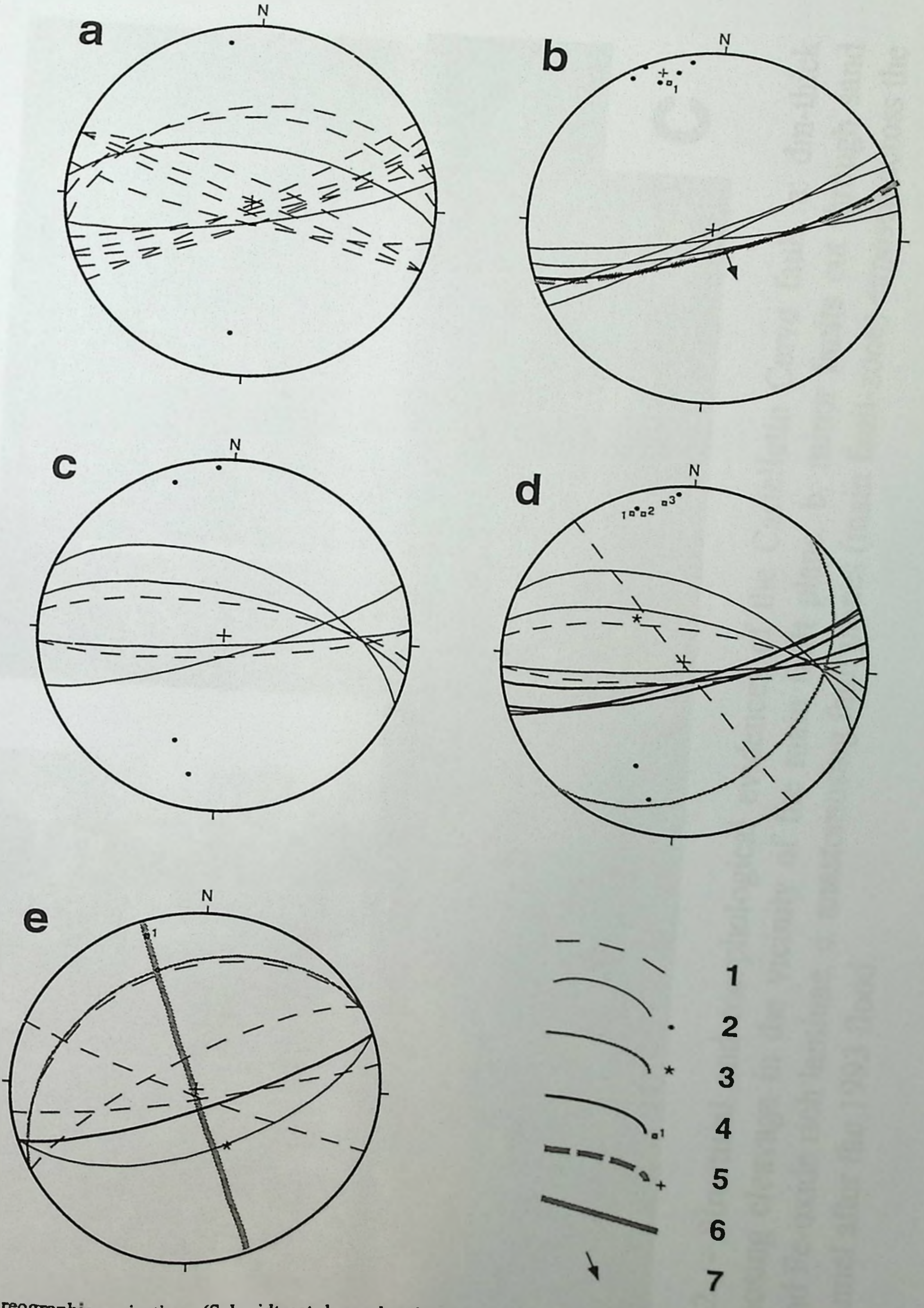


Fig. 4.1 - Stereographic projections (Schmidt net, lower hemisphere) of deformational features from different location (a, b; c, d, e; see text) along the Castelletto Cervo cross-section. 1: fractures. 2: normal fault. 3: reverse fault. 4: main fault plane. 5: anastomosing cleavage. 6: filled fissure. 7: pitch of grooves and mechanical striae.

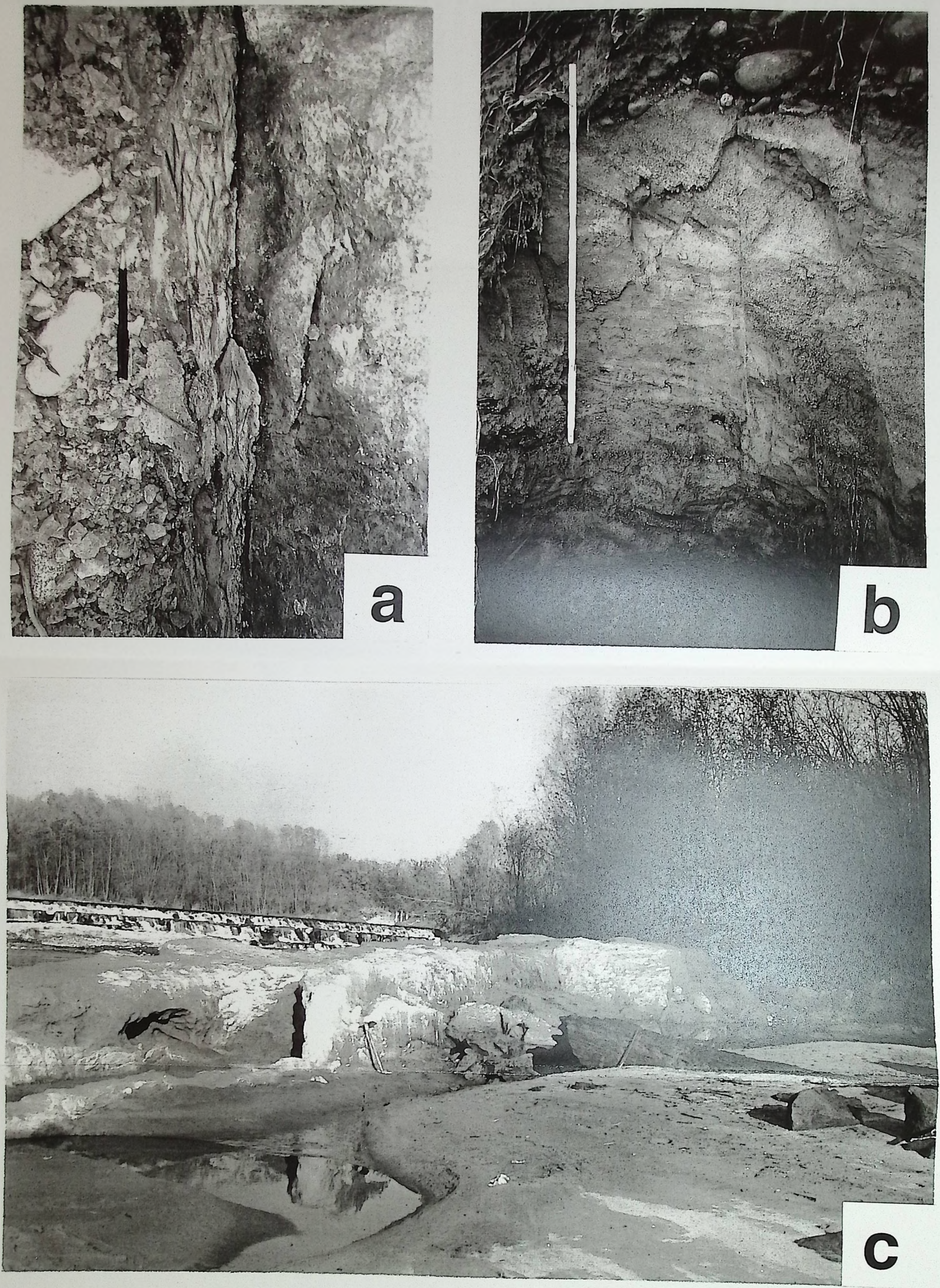


Fig. 4.2 - Structural and morphological evidences of the Castelletto Cervo fault. a: dm-thick anastomosing cleavage in the vicinity of the main fault plane. b: minor faults cut through sand layers and Fe-oxide rich laminae. c: anastomosing fault planes (main fault-zone) exposed across the river channel after the 1993 flood.

Analysis of the above described structures are at a preliminary stage. At present, data have been collected from simple observation of existing outcrops and landforms and analysis of remote-sensing imagery, with no other field techniques, either trenching or geophysical methods.

In the "work-in-progress map" of geomorphological features of the Castelletto Cervo area (Fig. 4.4), local drainage pattern (A), main scarps of fluvial terraces (B), elongated depressions (C), deeply eroded surfaces of the highest terraces (D) and distribution of rice-fields along the intermediate terraces (E) are shown. None of the surveyed local topographic features can be interpreted as a morphotectonic element (*sensu* Ollier, 1981) with respect to the present-day geomorphological setting. Most certainly the Castelletto Cervo fault and deformational features has to be considered morphostructural elements exhumed by present-day fluvial processes.

Analysis of the historical evolution of the channel form of Cervo River showed impressive morphological modifications during last decades; according to the Brice's (1983) classification of channel forms in meandering rivers, the Cervo River changed from a sinuous braided to a sinuous point bar channel, locally to a sinuous canaliform channel. Ramasco & Rossanigo (1988b) interpreted the channel pattern changes as a response to the following, strictly related, controlling factors:

- increasing of erosional processes related to quarrying along the Cervo River;
- decreasing amount of alluvial deposit at former bars of Cervo channel;
- changes in resistance to erosion due to incision of the river bed into cohesive fine-grained deposits lower than coarse alluvial deposits.

In the Castelletto Cervo area (Fig. 4.4) these factors caused a progressively higher sinuosity of the river channel; moreover, the incision of fine-grained sediments of the «Villafranchiano» unit is well-shown on the exposed wall of the river bank, below a m-thick cover of coarse alluvial deposit.

Differential structural and lithological characteristics of the recently exposed fine-grained sediments could have controlled the development of some anomalies in channel long profile and plan form. After the 1993 flood, a knickpoint formed where highly cohesive clayey silts were exhumed (Fig. 4.2 c). Increase in flow velocity rapidly adjusted the discontinuity of the longitudinal profile: differential erosion then revealed the structural pattern of the Castelletto Cervo fault zone, at present partially buried by later sediment accumulation. A sharp bend of the river channel is located at the south-western edge of the fault zone: trend of upstream channel progressively approximated the fault zone while river eroded highly deformed fine-grained sediments.

Other minor anomalies are shown in the local hydrographic network. As the above-mentioned features, the elongated depressions (C in Fig. 4.4) located SW of the "Key-site 3" (F in Fig. 4.4) also could be possibly interpreted as the effect of passive tectonic controls (*sensu* Summerfiel, 1991), i.e. a local differential erosion along a highly-deformed zone characterized by a lower degree of resistance than surrounding lithologies.

The above mentioned field data cannot exclude a past superficial expression of the Castelletto Cervo fault. Indeed, later erosion and deposition may have removed or buried much of the geomorphic evidences of surface faulting. In this case data have to be collected from the stratigraphic record in the area. Along the Castelletto Cervo cross-section and in the nearby outcrops, the geometrical setting and the deformational characteristics of faults and fractures are in agreement with a superficial extensional shear zone driven by N70E-trending subvertical normal faults. The *en-echelon* pattern of the main fault segments, with associated Riedel sets of fracture and faults, suggests a possible right-lateral component of the general displacement.

As presented in the introduction to geomorphology and geodynamics of the "Biellese" (par. 2.1, this volume), landforms and stratigraphic evidences indicate for the area a neotectonic activity of the Cremosina Line: the deformational structures of the Castelletto Cervo cross-section could be related to this ENE-WSW system of structural discontinuities.

Further studies should be focused on the possible seismogenic behaviour of the Cremosina Line: a precise mapping and dating of geomorphic and stratigraphic evidences of deformations along the Castelletto Cervo cross-section and surrounding areas could lead to identify paleoseismic evidences.

Fig. 4.3 - "Work-in-progress map" of geomorphological features of the Castelletto Cervo area. A: local drainage pattern. B: main scarps of fluvial terraces. C: elongated depressions. D: deeply eroded surfaces of the highest terraces. E: distribution of rice-field along the intermediate terraces. F: "Key-site 3".

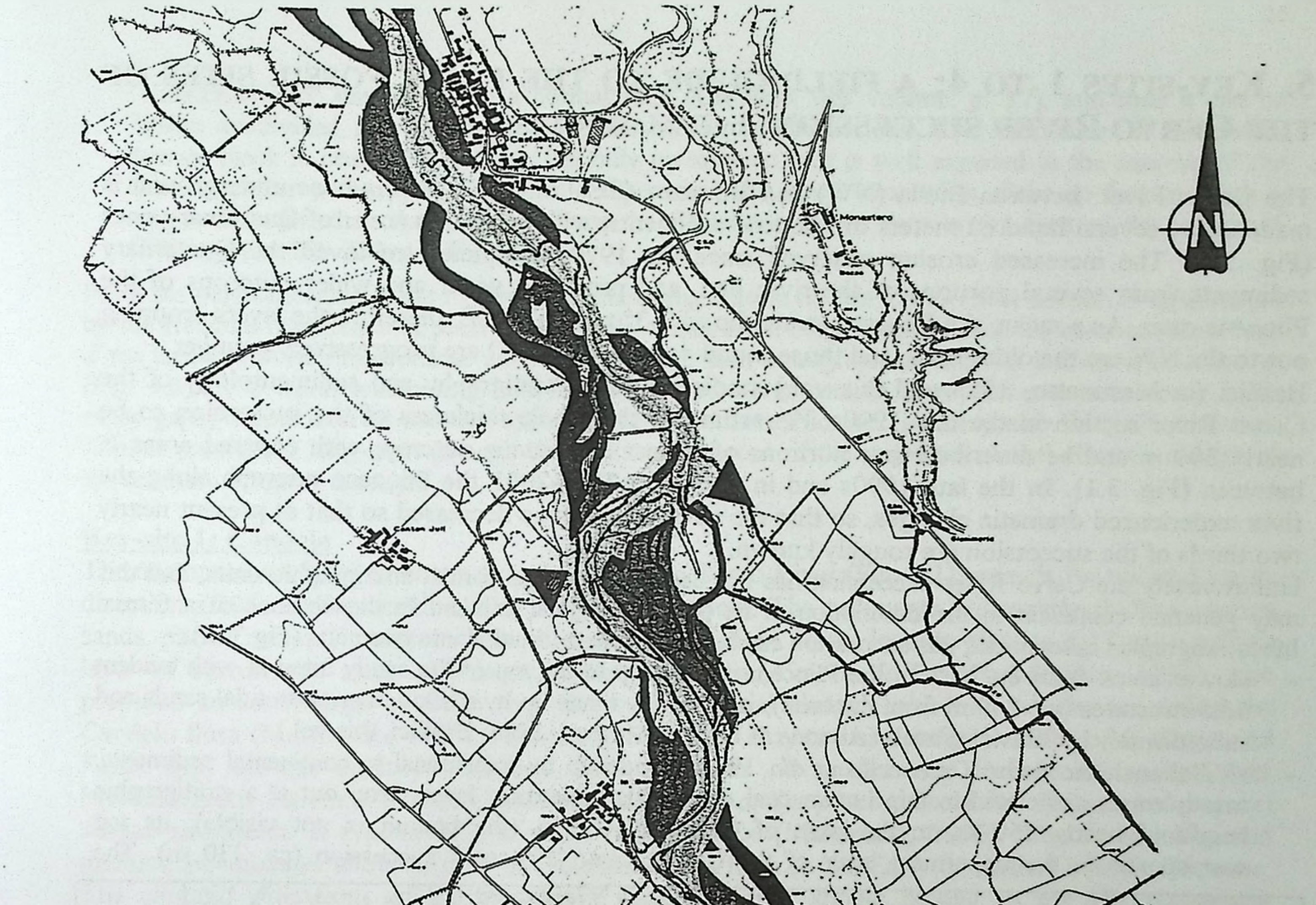


Fig. 4.4 - Historical evolution of Cervo River channel (modified from Ramasco & Rossanigo, 1988). A: 1979 river channel. B: 1954 river channel. C: 1882 river channel. D: "Key-site 3".

GIARDINO M. - Structural and morphological evidences of the Castelletto Cervo fault. *In* MARTINETTO E. (ed.): Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.4 (2001): 18-23.

5. KEY-SITES 1 TO 4: A FIELD GUIDE TO THE PLANT FOSSIL SITES OF THE CERVO RIVER SUCCESSION - by E. MARTINETTO

The Cervo River, between Biella (NW) and Buronzo (SE), runs in a plain whose underground is made up by several hundred meters of Pliocene sediments, with just a thin cover of Quaternary ones (Fig. 5.1). The increased erosion observed since the 1970s completely removed the Quaternary sediments from several portions of the river bed, and produced wider and wider outcrops of the Pliocene ones. As a mean, the Pliocene strata dip of 2-3° towards SSE, therefore the layers cropping out to the NW are the older ones, and those found downstream (SE) are progressively younger.

Basilici (in Martinetto, 1998 and this vol.) studied the lithostratigraphy and sedimentology of the Cervo River section in the mid-1990s. He estimated the whole thickness of the succession to be nearly 300 m and he described four portions of almost continuous outcrop, with covered areas in between (Fig. 3.1). In the late 1990s and in the years 2000-2001 the Pliocene oucrops along the river experienced dramatic changes, so that the covered portions decreased so that at present nearly two thirds of the succession are roughly known.

Unfortunately the Cervo River succession has not been divided into formal stratigraphic units, and this may generate confusion in the description of its palaeontological content. In the absence of a formal lithostratigraphic assessment, this succession can be provisionally divided into two units (Fig. 5.2):

- «lower unit»: from the base of the Pliocene section up to the top of the sandy interval with evident tidal structures (ca. 240 m from the base); it is mainly made up by shallow marine to tidal sands and subordiantely by ?fluvial gravels (Aimone & Ferrero Mortara, 1983; Basilici, this vol.)
- «Villafranchiano unit» (Caramiello *et al.*, 1996), made up by transitional to continental sediments, mostly muds associated to thin brown coal seams. Its lowermost layers crop out at a stratigraphic height of nearly 260 m, to the west of Castelletto Cervo (the bottom is not visible); its top corresponds to the uppermost layer of the Cervo River "Pliocene" succession (ca. 330 m). The

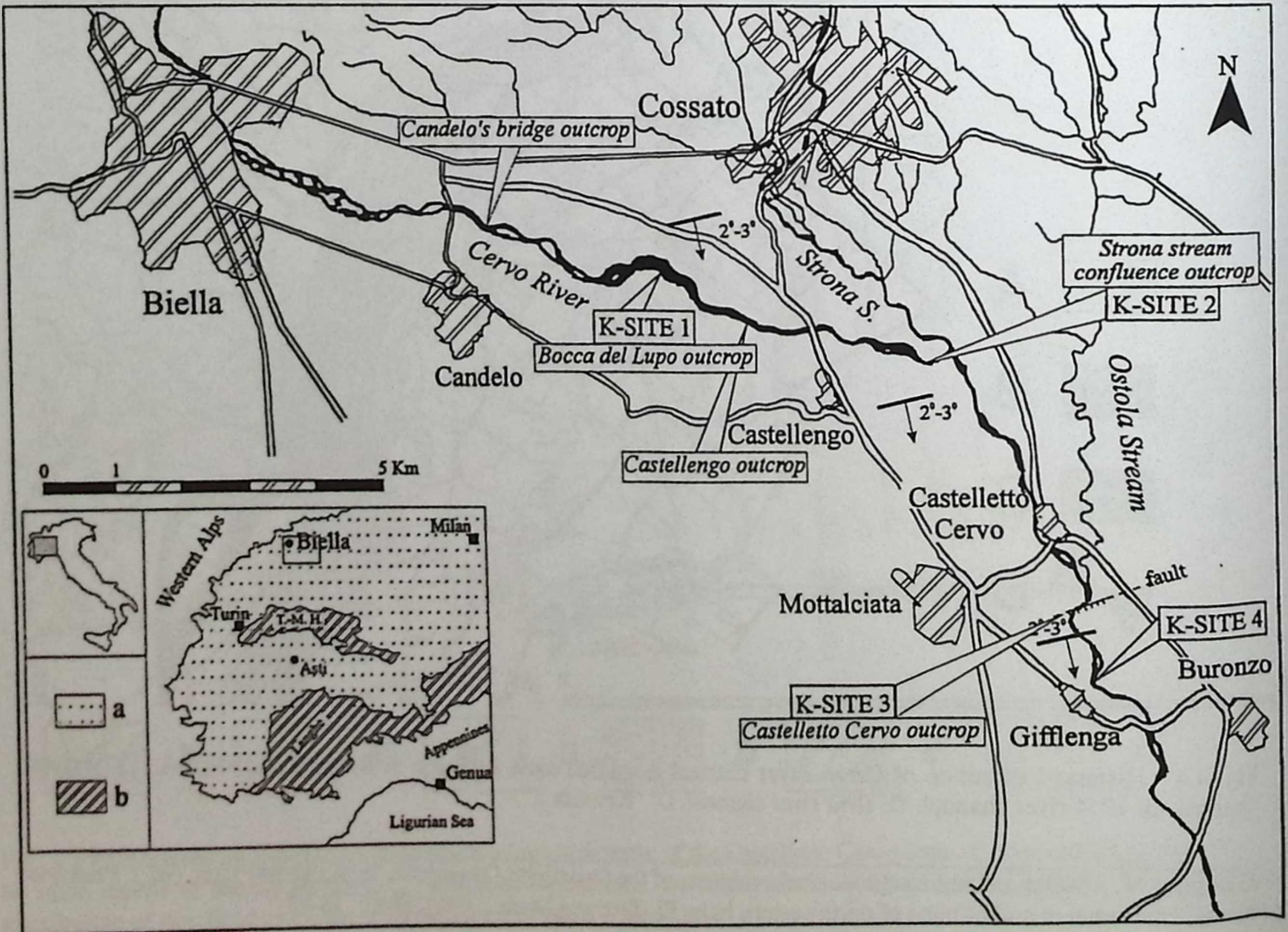


Fig. 5.1 - Map of the Cervo River course from Biella to Buronzo with location of the key-sites cited in the text.

"Villafranchiano" unit is cut by a normal fault (Giardino, this volume, p. 17), and thus it can be further subdivided in a down-thrown block and an up-thrown one. The succession of the down-thrown block is nearly 30 m thick, but only its topmost part is well exposed in the outcrop of the Castelletto Cervo dam (Fig. 5.3). On the other hand, the whole succession of the up-thrown block is very well exposed in the river bed from the Castelletto Cervo dam to the East of the village of Gifflenga (ca. 290-330 m in Fig. 5.2).

From the palaeobotanical point of view, the interesting feature of The Cervo River section is represented by the frequent occurrence of plant macrofossils, which have been found in each exposed portion. Even if the layers with rich macrofloras are widely spaced, their stratigraphical order is known with certainty (Fig. 5.2). It is worth anticipating here that the Cervo River composite section seems to cover (with many gaps) a time interval between Early Pliocene and Late Pliocene (possibly also Early Pleistocene). Thus it provides a long-term (though discontinuous) record of the vegetational and climatic change at the southern fringe of the Alps.

Key-site 1: Candelo

The northernmost large Pliocene outcrop along the Cervo River (Fig. 5.1) extends for about 4 km in direction E30S, to the North of the village of Candelo. The sediments are mostly shallow marine sands, part of which show tractive structures of tidal origin. In the locality «Bocca del Lupo» a thick layer of bioturbated sand, rich in marine shell fossils (Aimone & Ferrero Mortara, 1983), also provided an assemblage of fruits and seeds of terrestrial plants (Tab. 5.1), which was called the Candelo flora (Martinetto, 1995). After each flood it is easy to observe fossil cones of *Cathaya* and *Pinus* spp. on the outcrop's surface. The diaspores of smaller size include many «younger Mastixioidean» elements (*Rehderodendron, Sapindoidea, Symplocos, Toddalia, Trigonobalanopsis*) whose abundance is typical of the «Ca' Viettone FC» (Martinetto, 1995). The foraminifer and mollusc assemblages allow to date this allochthonous flora to the Early or earliest Middle Pliocene. The climatic indications of the carpoflora suggest that it should belong to the «Brunssumian» optimum, i. e. to the Early Pliocene.

The outcrop of Candelo terminates 1 km downstream from Bocca del Lupo (key-site 1). A second limited outcrop of Pliocene sediments extends 1 km upstream from the bridge of the main road Mottalciata-Cossato near Castellengo. Here, another thick layer of bioturbated shallow marine sands rich in mollusc shells (*Donax, Ostrea, Nucula, Pecten, Tellina, Turritella*, etc.) provided a younger assemblage of fruits and seeds whose composition is very similar to the Candelo one (Castellengo flora: Martinetto, 1995).

TAXA	Candelo	Castellengo	TAXA	Candelo	Castellengo
Acer (sect. Platanoidea) sp. C	1		*Pinus* cf. *salinarum*	5	1
Carpinus betulus		1	*Pinus hampeana*	2	1
Cathaya van-der-burghii	8c	1	*Pinus peuce*	1	
Crategus sp.	1		*Pterocarya limburgensis*	1	
Cryptomeria rhenana	1c		*Quercus* spp.	2	4
Cymodocea sp.	9		***Rehderodendron ehrenbergii***	7	2
Eurya stigmosa	1		***Sapindoidea margaritifera***	5	2
Fagus	9	5	***Sorbus herzogenrathense***	1	2
Glyptostrobus europaeus	1		***Symplocos casparyi***		1
Litsea sonntagii	1	1	***Symplocos gothanii***	1	3
Liquidambar magniloculata	7	2	***Symplocos lignitarum***	1	1
Magnolia allasonaiae	1		***Toddalia naviculaeformis***		1
Magnolia lignita	1	1	***Trigonobalanopsis exacantha***	2	3
***Ocotea* sp. A**	?	?	***Visnea germanica***		1
Pinus cf. *massalongi*	1		*Vitis* sp.		1

Table 5.1. List of the fruit and seed taxa forming the Candelo and Castellengo floras. The «subtropical» elements are marked in bold type.

Key-site 2: Cossato

Nearly 800 m East of the bridge of the main road Mottalciata-Cossato, a third outcrop of Pliocene sediments begins. It runs for 1 km in direction E30S and then, after the confluence of the Strona Stream, it continues for 3 km in direction E60S, where a sort of little canyon has been cut down. A particular site in this outcrop area (key-site 2 in Fig. 5.1) provided two layers rich in plant macrofossils (Cossato flora): mummified fruits and seeds in the lower one (CO1) and leaf impressions in the upper one (CO2: Fig. 5.2). These two layers are separated by a sterile bed just 40 cm thick. They were still deposited in a marginal-marine to tidal environment, as indicated by the sedimentary facies (Basilici, this vol.) and by the occurrence of typical Bivalvia (*Chamelea, Tellina, Lissochlamys, Paphia*) and *Thalassinoides*.

The CO1 Fruit and seed assemblage still shows the typical composition of the «Ca' Viettone FC» (*Magnolia lignita, Rehderodendron ehrenbergii Symplocos casparyi, Symplocos gothanii, Toddalia latisiliquata, Trigonobalanopsis exacantha*).

Actinidia faveolata	*Carpolithes cucurbitinus*	*Carpolithes gratioloides*	*Carpolithes minimus*
Carpolithes montioides	*Chamaecyparis* sp.	*Cymodocea* sp.	*Erica* sp. A
Eurya stigmosa	***Ficus potentilloides***	*Hypericum* sp. A	*Hypericum* cf. *tetrapterum*
«Litsea» sonntagii	*Magnolia allasoniae*	***Magnolia lignita***	*Mahonia staphyleaeformis*
Melissa elegans	*Paulownia cantalensis*	*Phytolacca salsoloides*	Pinaceae indet.
Pinus hampeana	*Potentilla supina*	*Proserpinaca reticulata*	*Quercus* sp.
Quercus sp. B	***Rehderodendron ehrenbergii***	*Rubus microspermus*	*Sambucus pulchella*
Selaginella moravica	*Sinomenium cantalense*	*Spirellea* aff. *bohemica*	***Symplocos casparyi***
Symplocos lignitarum	***Symplocos gothanii***	*Teucrium* sp. A	*Teucrium tatjanae*
Thalictrum sp.	***Toddalia latisiliquata***	***Toddalia rhenana***	***Trigonobalanopsis exacantha***
Viola sp.	*Vitis teutonica*	***Zanthoxylum ailanthiforme***	

Table 5.2 - List of the fruit and seed taxa found in layer «CO1» of Cossato. The «subtropical» elements are marked in bold type.

Both plant assemblages of Cossato experienced a consistent transport that could have biased the composition. The leaves are mostly reduced to small fragments, and only a few bedding planes are covered by almost complete laminae. The usually large-leafed *Platanus* (Plate 5.1, Fig. 27) and *Alnus* cf. *cecropiaefolia* (Plate 5.1, Fig. 28) are only represented by small-sized leaves or fragments of big ones. The frequent fragmentation and the imperfect state of preservation of leaves (cuticles are absent) hamper their systematic determination, though a few genera seem to be reliably determinable: *Acer* (Plate 5.1, Fig. 20), *Alnus* (Plate 5.1, Fig. 28), *Coriaria* (Plate 5.1, Fig. 30), *Fagus* (Plate 5.1, Fig. 13), *Liquidambar* (Plate 5.1, Fig. 23), *Ocotea* (Plate 5.1, Fig. 1), *Platanus* (Plate 5.1, Fig. 27), *Populus* (Plate 5.1, Fig. 6), *Salix* (Pl. 1, Figs 7, 37, 39) and *Ulmus* (Plate 5.1, Fig. 40). This genera just include 16 species out of 44, so that the remaining 28 taxa (probably species) are still to be considered *incertae sedis*. Plate 5.1 gives an impression of the preservation state and physiognomy of the leaf impressions found in layer CO2.

This rather diverse leaf assemblage has been employed for a palaeoclimate analysis based on leaf physiognomy: 21 dicotyledonous taxa out of 44 have an entire margin, which would indicate a mean annual temperature of 15.4 +/-2°C (Wolfe, 1979; Wing & Greenwood, 1993). The method suggested by Wiemann *et al.* (1998) provided slightly higher values of mean annual temperature: ca. 17 +/-2°C. Such values are in good agreement with those obtained on the basis of a floristic analysis of the seed assemblage CO1 (Tab. 5.2), i.e. 14-17 °C. The annual precipitation has been estimated to be higher than 100 cm per year.

The age of the Cossato flora cannot be precisely stated at present. It could still be Early Pliocene, as the underlying Candelo flora, but it could also be a bit younger. However, the occurrence of the pelecypod *Lissochlamys excisa* in the Cossato layers does not allow to consider an age younger than the early Middle Pliocene (Marasti & Raffi, 1976; Raffi & Marasti, 1982). From the climatostratigraphic point of view it should still belong to the «Brunssumian».

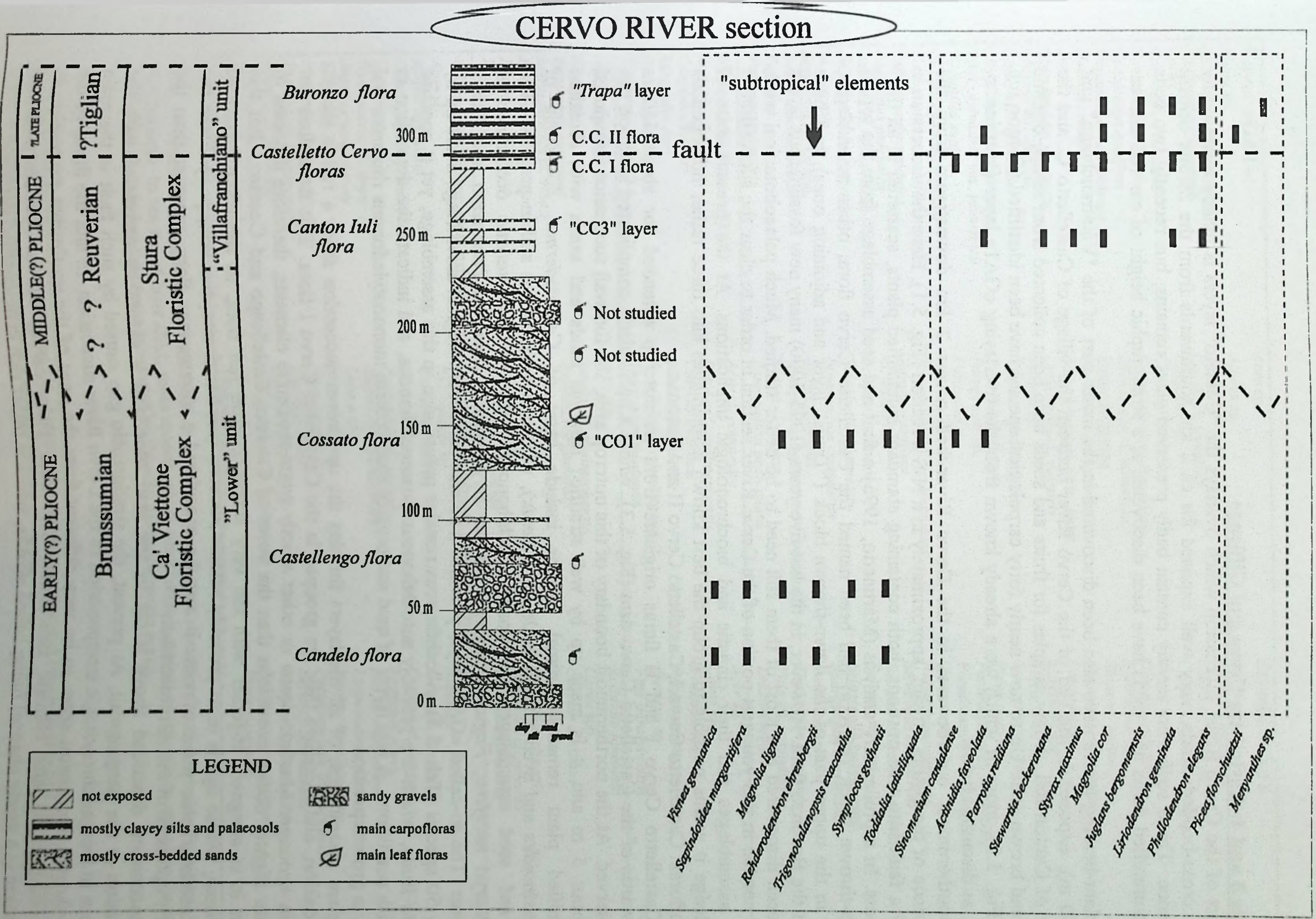


Fig. 5.2. Location of the main fossil floras within the Cervo River section (from Basilici, this volume) and distribution of a few selected taxa which characterise the different floras. The Candelo, Castellengo and Cossato floras are rich in «subtropical» elements and are assigned to the «Ca' Viettone Floristic Complex», tentatively correlated with the Brunssumian. The Castelletto Cervo flora (upthrown block of the fault) is assigned to the «Stura Floristic Complex», tentatively correlated with the Reuverian. The yougest floras (incl. «Buronzo» one) are devoid of strictly «Reuverian» elements and are floristically similar to the Tiglian one of The Netherlands, but they need to be studied in more detail.

Key-site 3 and 4: Castelletto Cervo and Gifflenga

The part of the Cervo River succession which overlays the "Cossato" layers is mainly made up by yellow cross-bedded sands, very well exposed for ca 2 km southwards from the Strona Stream confluence. These sediments mostly contain badly preserved plant remains, but recently two beds with mummified fruits and seeds have been discovered at a stratigraphic height of ca. 185 and ca. 210 m.

New plant-bearing layers have also been discovered in the lower part of the "Villafranchiano" unit (ca 260 m), exposed in the bed of the Cervo River between the village of Castelletto C. and the hamlet of Canton Iuli. A few samples for fruits and seeds have been collected from sands, organic muds and brown coal. Up to now nearly forty carpological species have been identified (Canton Iuli flora: Fig. 5.2), most of which were already known from the overlaying «GA1» layer (Martinetto, 1995), as discussed below.

The southernmost outcrop area in the Cervo River bed covers 2 km downstream from the confluence of the Ostola Stream, approximately in a N-S direction (Fig. 5.1). Here the succession is cut by a fault into two portions, both containing abundant mummified plants, scattered in all their thickness. In a preliminary analysis (Martinetto, 1995) a fruit and seed assemblage from the top of the up-thrown block («GA1») had been named the Castelletto Cervo flora; other assemblages, found in the upper part of the down-thrown block ("Trapa" layer and adjoining ones), had been named the Buronzo flora. However, in the last five years (1995-2000) many new fossiliferous layers have been discovered and most of them still need to be better studied. Much palaeobotanical work is still needed in this youngest portion of the Cervo River section in order to clear the succession of floral assemblages and their climatic and biochronologic implications. At the present state of knowledge it seems possible to group the best known assemblages into three rather homogenous palaeofloras: Castelletto Cervo I, Castelletto Cervo II and Buronzo.

The Castelletto Cervo I and II floras originate from an outcrop extended for about 350 m southwards of the Castelletto Cervo dam (Fig. 5.3), where a particularly complicated situation can be observed. At the northernmost boundary of this outcrop area, the footwall succession is exposed for about 5 m and it is made up by well stratified lagoonal muds and sands with abundant mummified plant remains. Animal remains include casts of *Cerastoderma*, domichnia of *Thalassinoides* and even a fossil turtle (cf. *Trionix*), whose investigation is still in progress. The fruit and seed assemblages are mostly allochthonous, with the characteristic occurrence of *Cyclocarya nucifera, Fagus decurrens, Juglans bergomensis, Stewartia beckerana* and *Styrax maximus*. The so-called «GA1» layer provided a diverse palaeocarpological assemblage made up by nearly 50 species (Tab. 5.3). Allochthonous remains prevail also in this assemblage, yet it contains *Ruppia* fruits, which are probably autochthonous/ipoautochthonous, and indicate the deposition in brackish conditions. A few layers of mud and organic mud contain monocotyledonous rhizomes and stems in growth position.

The plant assemblages of all the layers forming the up-thrown succession show a rather similar composition, and therefore they are grouped in the Castelletto Cervo I flora. This flora does not contain «younger Mastixioidean» or other strictly warm-temperate elements, therefore it seems to indicate slightly cooler conditions than the floras of Candelo, Castellengo and Cossato. For this reason it is assigned, together with the very similar Canton Iuli flora, to the «Stura Floristic Complex», whose age is most probably Middle Pliocene (see Martinetto, this vol., p. 5). From the climatostratigraphic point of view it may be considered a «Reuverian» flora, younger than the climatic optimum of the «Brunssumian».

The succession described above is cut by the fault zone, and it cannot be correlated with the succession at the hangingwall. At present, the stratigraphic gap caused by such fault is the main problem in the geochronologic interpretation of the Cervo River succession. In fact the floras of the down-thrown succession seem to be very different from the ones of the up-thrown succession in their composition and climatic indications. The main plant-bearing bed in the down-thrown succession is a sandy channel filling called «GA5», which is rather rich in mummified carpoids.

Layer «GA1»:

Ajuga sp.
Ampelopsis malvaeformis
Boehmeria lithuanica
Carex spp.
Carpolithes minimus
Cephalotaxus rhenana
Cyclocarya nucifera
Eupatorium cannabinum
Halesia crassa
Juncus sp.
Liriodendron geminata
Melissa aff. *elegans*
Najas cf. *irtyshensis*
Origanum cf. *vulgare*
Pinus sylvestris var. *pliocenica*
Potentilla supina
Pterocarya limburgensis
Ranunculus pseudoflammula
Rubus semirotundatus
Sambucus pulchella
Scirpus cf. *isolepioides*
Selaginella borysthenica
cf. *Sequoia*
Stewartia beckerana
Swida discimontana
Typha sp.
Vitis parasylvestris
Acer sp.
Alisma sp.
Aralia sp.
Carex cf. *aquatilis*
Carpinus sp.
Carya globosa
Ceratophyllum demersum
Dichostylis cf. *hamulosa*
Fagus decurrens
Hypericum tetrapterum
Lamiaceae gen. et sp. indet. B
Lysimachia cf. *vulgaris*
Mentha sp.
Nuphar canaliculatum
Parrotia reidiana
Polygonum sp.
Potentilla sp.
Quercus cf. *robur*
Ranunculus cf. *sceleratoides*
Ruppia maritima
cf. *Sassafras*
Scirpus mucronatus
Selaginella jeannettae
Sinomenium cantalense
Styrax maximus
(Symplocos lignitarum) (reworked?)
Urtica cf. *dioica*
Zannichellia pedicellata
Actinidia faveolata
Alnus sp.
Azolla tegelensis
Carex cf. *panicea*
Carpolithes cucurbitinus
Carya sp.
Chamaecyparis sp.
Eleocharis sp.
Ficus cf. *carica*
Juglans bergomensis
Lauraceae
Magnolia cor
Morus sibirica
Oenanthe cf. *aquatica*
Picea (leaves)
Potamogeton cf. *trichoides*
Pseudoeuryale limburgensis
Quercus sp.
Rubus microspermus
Sambucus bashkirica
Scirpus aff. *tabernaemontani*
Scirpus supinus
Selaginella kunovicensis
Sparganium neglectum
Swida krauselii
Thalictrum minimum
Vitis aff. *rotundifolia*
Zelkova ungeri

Castelletto Cervo I

«Pseudolarix» Layer:

Actinidia faveolata
Carpinus betulus
Magnolia cor
Potamogeton sp.
Sambucus pulchella
Acer cf. *campestre*
Betula cf. *cholmechensis*
Corylus avellana
Picea florschuetzii
Pseudolarix schmidtgenii
Thalictrum minimum
Acer sp.
Carex sp.
Fraxinus sp.
Polygonum sp.
Quercus sp.
Vitis parasylvestris

«GA5» flora:

Ajuga sp.
Eucommia europaea
Menispermum cf. *reidii*
Pterocarya limburgensis
Sambucus pulchella
Xanthium sp.
Acer sp.
Betula cf. *cholmechensis*
Juglans bergomensis
Phellodendron elegans
Quercus sp.
Selaginella sp.
Thalictrum minimum
Actinidia faveolata
Carex spp.
Corylus avellana
Magnolia cor
Picea florschuetzii
Staphylea cf. *pinnata*
Vitis parasylvestris

Castelletto Cervo II

«Trapa» Layer and adjoining layers(3 m above and below):

Acer sp.
Azolla tegelensis
Ceratophyllum demersum
Cyperus sp.
Hyosciamus cf. *niger*
Juglans bergomensis
Magnolia cor
Phellodendron elegans
Pterocarya limburgensis
Sambucus pulchella
Scirpus radicans
Symplocos aff. *paniculata*
Viola sp. *A*
Aldrovanda sp.
Carex cf. *panicea*
Chamaecyparis sp.
Euphorbia cf. *palustris*
Hypericum tetrapterum
Lemna sp.
Menyanthes sp.
Phytolacca? sp.
Quercus robur
Scirpus cf. *lacustris*
Selaginella ex gr. *pliocenica*
Trapa cf. *natans*
Vitis parasylvestris
Alnus sp.
Carpinus betulus
Cyperus cf. *longus*
Frangula alnus
Ilex cf. *aquifolium*
Liriodendron geminata
Nuphar canaliculatum
Pseudoeuryale limburgensis
Salvinia tuberculata
Scirpus cf. *pliocaenicus*
Sparganium neglectum
Viola neogenica

Buronzo

Tab. 5.3. Partial list of fruits and seeds found in selected layers of the Cervo River section between Castelletto Cervo and Buronzo. In the list of layer GA1, those species whose association is typical of the «Stura complex» have been underlined. A complete list of taxa is reported by Cavallo & Martinetto (in press).

Explanation of **Plate 5.1** (pages 30 and 31) - Margin and nervation patterns of leaves from layer CO2 of Cossato. Every single specimen is thought to represent a separate taxon.

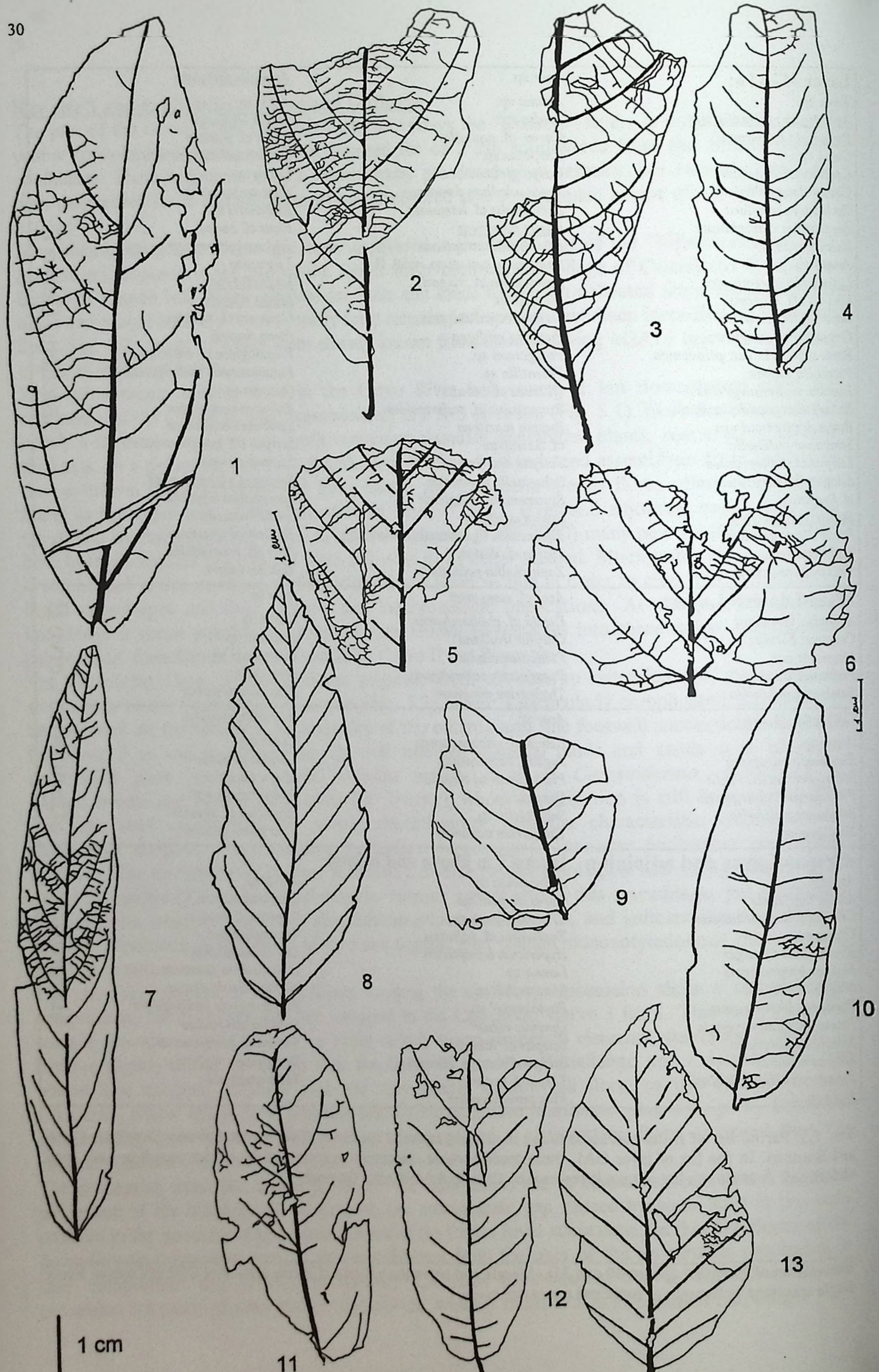
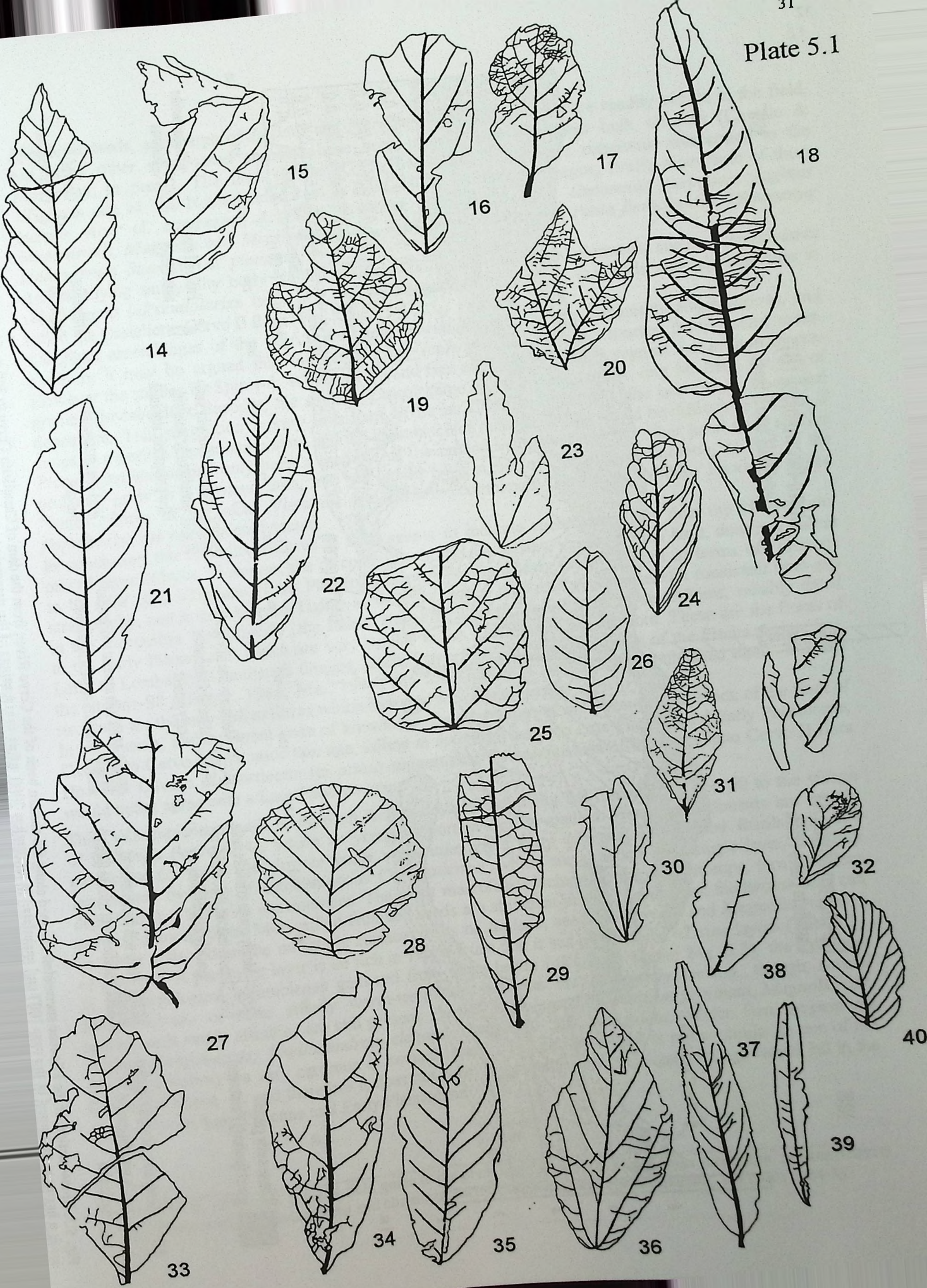

1
2
3
4
1 cm
5
6
1 cm
7
8
9
10
11
12
13
1 cm

Plate 5.1


14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40

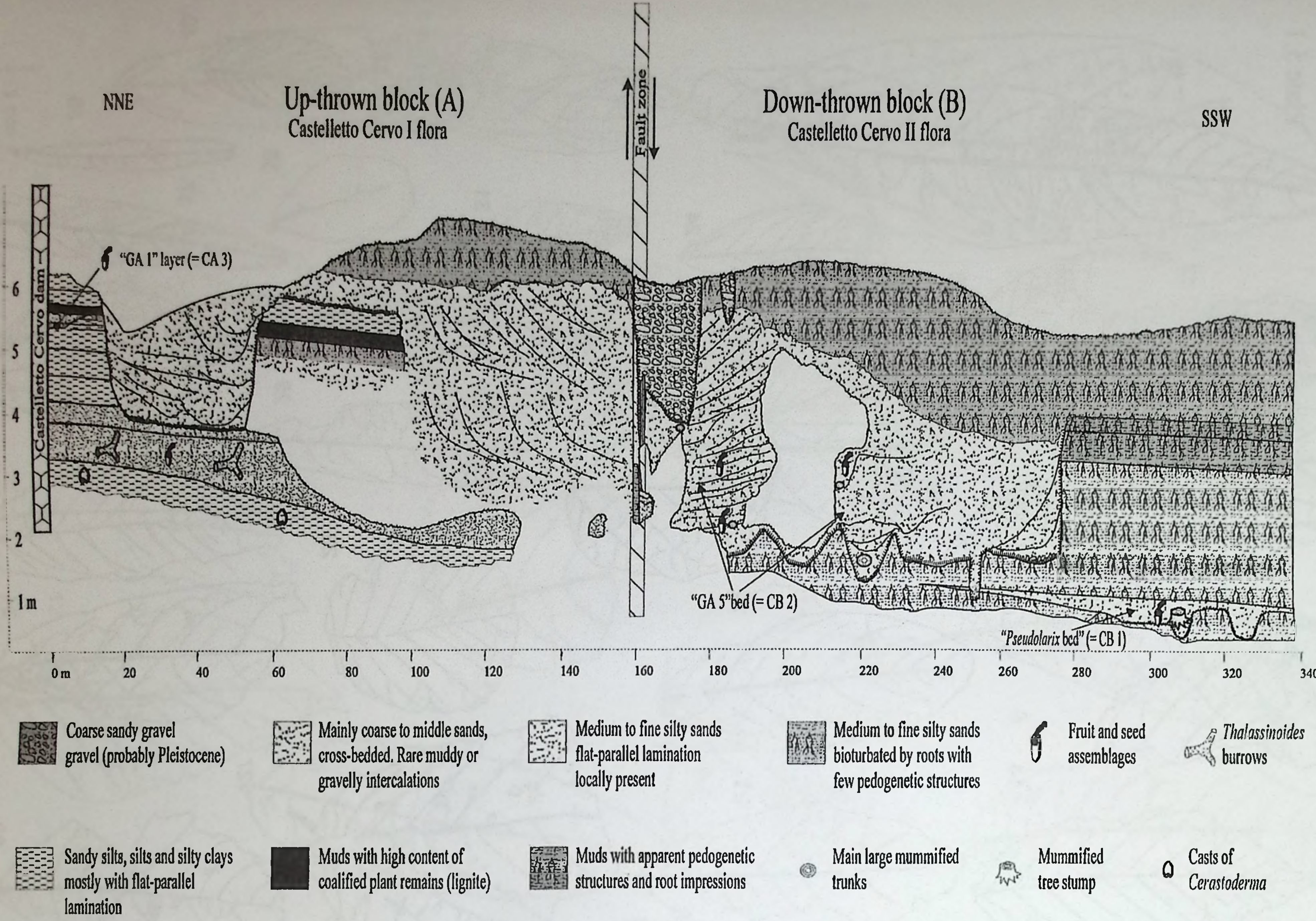


Fig. 5.3. Cross-section of the Pliocene succession exposed along the eastern bank of the Cervo River, from the dam of Castelletto Cervo to 340 m downstream (key-site 3). The section has been measured in the year 1997 and completed in November 2000, when new portions of the succession were exposed.

Magnolia seeds, endocarps of *Juglans* and *Pterocarya* and *Picea* cones are readily visible in the field, but many other small-sized carpoids have been isolated from sediment bulk samples (Cavallo & Martinetto, in press). The flora of the «GA5» bed (Tab. 5.3) shows consistent similarities to the «Tiglian» one of The Netherlands (Reid & Reid, 1915; Günther & Gregor, 1989), since both of them include: *Acer* cf. *campestre*, *Actinidia faveolata*, *Carpinus betulus*, *Eucommia europaea*, *Juglans bergomensis*, *Magnolia cor*, *Menispermum* sp., *Phellodendron elegans*, *Picea florschuetzii*, *Pterocarya limburgensis*, *Staphylea* cf. *pinnata*.
An underlying sandy-silty body yielded a similar flora, with additional elements, such as *Pseudolarix schmidtgenii* («*Pseudolarix*» layer: Fig. 5.3). The macroflora of these two beds and adjacent ones is called the Castelletto Cervo II flora (Fig. 5.2).
The plant assemblages of the «GA5» bed and «*Pseudolarix*» layer are apparently allochthonous, and therefore it may be argued that the carpological remains have been transported from distant areas. However the studies by Spicer & Wolfe (1987) and Gee *et al.* (1997) would suggest that even in coarse-grained fluvial/deltaic deposits, the source of most carpological remains is not very far from the site of deposition. This suggestion is very important as far as *Picea* is concerned: the occurrence of several cones in a perfect preservation state and the abundance of related needles would be difficult to explain if *Picea florschuetzii* had only been a member of the upland vegetation. On the other hand such species probably grew in a lowland area, and this could be a signal of climatic deterioration; in fact in the "warm" floras of the «Ca' Viettone» and «Stura» complexes (Early and Middle Pliocene) *Picea florschuetzii* has never been detected.
In conclusion the Castelletto Cervo II flora seems to indicate cooler conditions than the «Reuverian» one of layer «GA1». However, the discontinuity in the succession, caused by the fault, does not permit to be sure of a «Tiglian» (Late Pliocene) age of the Castelletto Cervo II flora in terms of climatic stratigraphy, and it may be post-Tiglian as well. In fact the fault might have caused a consistent time gap in the succession. Additionally, the Italian plant macrofossil record includes three floras, reliably dated to the Early Pleistocene, which are very similar to the Castelletto Cervo II flora. These are the floras of Leffe in Lombardy (Günther & Gregor, 1989; Ravazzi, 1995), and two floras of the Emilia region, i. e. the Stirone-S8 (Gregor, 1986; Mai, 1994) and the Enza ones (Martinetto, unpublished data). The last two ones are the only Italian floras which include *Picea florschuetzii*.
In conclusion, at the present state of knowledge the succession of the down-thrown block of the fault of Castelletto Cervo has an uncertain age, falling in the range between Late Pliocene and Early Pleistocene. However Cavallo & Martinetto (in press) suggest that the composition of the Castelletto Cervo II flora would better agree with a Late Pliocene age.

The "Villafranchiano" unit is exposed further downstream along the Cervo River bed till to the village of Gifflenga (key-site 4), where its youngest portion can be studied. Here, the sediments are mainly paralic sands, muds and brown coals with mummified plant remains. The animal fossils are only represented by casts of autochthonous *Cerastoderma*, which are abundant in a single layer, probably deposited in a brackish environment. The plant macrofossil include trunks, little stumps, fern rhizomes and leaf compressions. Mummified fruit and seeds are abundant in a few layers, and the largest ones can be easily collected on the outcrop's surface: fruits of *Juglans*, seeds of *Euryale* and *Magnolia*, cupules of *Quercus*. A particular layer is so rich in *Trapa* fruits that it has been named «*Trapa* layer» (Tab. 5.3). In the carpological assemblages gathered from these layers («Buronzo flora»: Fig. 5.2), the «younger Mastixioidean» or other strictly warm-temperate elements are completely lacking, though several species with exotic affinities are still present: *Euryale nodulosa*, *Liriodendron geminata*, *Magnolia cor*, *Juglans bergomensis*, *Phellodendron elegans*, *Symplocos* aff. *paniculata*. Water fern megaspores (*Azolla*, *Salvinia*) are very common in several layers. The Buronzo flora is rather similar to one of the Castelletto Cervo II, and therefore it does not seem to be much younger. Again, its age would fall in the range between Late Pliocene and Early Pleistocene

---

MARTINETTO E. - Key-sites 1 to 4: a field guide to the plant fossil sites of the Cervo River succession. *In* MARTINETTO E. (ed.): Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.4 (2001): 24-33.

6. THE PALYNOFLORA OF THE CASTELLETTO CERVO SUCCESSION (NW ITALY). A PRELIMINARY ACCOUNT - by C. RAVAZZI, M. ZANNI

Introduction

Along the course of the Cervo River (Biella, NW Italy), a thick succession of well-sorted, mainly fine sediments has been partially exposed by fluvial erosion. In the absence of a formal lithostratigrafic assessment, this succession can be provisionally divided (Martinetto, this volume, p. 23) into two units: the "lower" unit, mainly made up by shallow marine to tidal sands and subordiantely by ?fluvial gravels, and the "Villafranchiano" unit (Caramiello *et al.*, 1996), which comprises the transitional to continental sediments forming the uppermost 60 meters of the "Pliocene" succession (Basilici, this volume).

The "Villafranchiano" unit is cut by a normal fault (Giardino, this volume, p. 18), and thus it can be further subdivided in a down-thrown block and an up-thrown one. The chronostratigraphic setting of the whole succession is still debated. According to plant macrofossil assemblages, the Cervo succession spans a long time interval from (Early) Middle Pliocene to Late Pliocene, and may extend into Early Pleistocene (Martinetto, this volume, p. 33). The Vrica GSSP is used in this work as for the Plio-Pleistocene boundary (Aguirre & Pasini, 1985).

In this short note we present the results of pollen analysis of three samples, selected from distinct beds rich in plant macroremains, in order to provide a preliminary overview on the richness and composition of the pollen flora of the uppermost part of the Cervo succession.

Materials and methods

The following samples were studied: **(i)** GA1 bed - Silty sand rich in mummified plant debris (fruits and seeds in particular) from a well-stratified lagoonal succession (down-thrown block of the "Villafranchiano" unit) exposed a few meters upstream the Castelletto Cervo fault (Fig. 5.3 of this volume); **(ii)** "*Pseudolarix* bed" (PSX): sandy silt very rich in plant debris, cropping out a few meters downstream the same fault (Fig. 5.3). These two beds are exposed along the river bank, near Castelletto Cervo. They provided respectively macrofloral assemblages to the Castelletto Cervo I and Castelletto Cervo II floral assemblages (see Martinetto, this volume, p. 28). **(iii)** "*Trapa* bed": bioturbated clay gyttja with plant debris, stratigraphically located about 20 m above the "*Pseudolarix* bed". This bed was sampled close to the villages of Buronzo and Gifflenga, in an outcrop located on the right bank of the Cervo River (Martinetto, this volume, Fig. 5.1). The portion of the succession including the "*Trapa* bed" yielded several carpofloras forming, as a whole, the "Buronzo floral assemblage" (Martinetto, this volume, p . 28).

Samples were treated with HF 50% (repeated), NaOH 10% (repeated for *Trapa* layer), sodium hypocloride, sieved at 250µm and finally acetolysed. The pollen sum is over 1000 pollen grains, for PSX reaching 1500 grains due to the dominance of a single pollen type, *Carpinus* 3p, that accounts for 35,9% of the spectrum. The CNR pollen reference collection, key and atlases were used for identification (Huang, 1972; Punt *et al.*, 1977-1995; Reille, 1992, 1995, 1998; see also Tab. 6.1).

The identification of *Cathaya*, *Juglans* and *Pseudolarix* pollen

Before discussing the results of the pollen assemblages reported in table 6.1, we will briefly describe the identification of some pollen types of particular interest. In sample GA1 the dominant pollen type is *Cathaya*. In the past, *Cathaya* pollen grains were commonly included in the *Pinus Haploxylon* type (Rudolph, 1936). Despite some similarities, the distinction and the attribution of our pollen grains to *Cathaya* seems quite sure. According to Liu *et al.* (1997), the connection between the sacci and the corpus offers a reliable character for the diagnosis of this genus: in polar view, the outline of each saccus always originates from the margin of the corpus and not from its interior. The latter situation occurs in pollen of living species belonging to *Pinus* subgen. *Haploxylon*. Future observations at SEM could confirm our identification. Liu *et al.* (1997), in fact, underline as the most certain diagnostic character the presence of "irregularly spaced spinules and channels on the surface of the corpus and sacci except for the leptoma area on the distal surface of the grain" (see also Ying *et al.*, 1993).

Concerning the pollen grains attributed to the genus *Juglans*, the problem arisen is about the correct nomenclature of pollen types included in this genus. All *Juglans* pollen grains we have found have 5-7 pores in zono-position and 1-2 pores in panto-position. This pore configuration occurs in four living species: *J. cinerea*, *J mandshurica*, *J. ailantifolia*, and *J. cathayensis*. Stone & Broome (1975) have made a statistical study of pollen morphology also considering the frequency of isopolar/eteropolar grains into each living species. They concluded that pollen morphology reflects the original subdivision of the genus *Juglans* into four sections, as proposed by Dode (1906, 1909). In particular, the pollen of *J. cinerea*, belonging to section *Trachycaryon* Dode, is distinct from *Cardiocaryon* Dode for having a higher frequency of isopolar grains. Manning (1978) proposed the validation of *Trachycaryon* Dode ex Mann. as being a distinct section.

Manchester (1987), instead, following Hills *et al.* (1974), prefers to place all the aforementioned species in the single section *Cardiocaryon*. He also notes that the resemblance between the living *J. cinerea* and the fossil *J. tephrodes* Unger (= *J. bergomensis* Massalongo) is so striking that they could be considered the same species. If so, one should be able to confirm it by using the diagnostic characters proposed by Stone & Broome (1975) on pollen grains having more than seven pores. We are presently working on this problem. For the moment, we'll refer as *J.* sect. *Cardiocaryon* type (provisional name) all pollen grains with 7 to 10 pores, among which 1-2 heteropolar. This is the only pollen type of *Juglans* occurring in our material.

The down-thrown block of the "Villafranchiano" unit has provided a much reliable macrofossil record of *Pseudolarix* (seeds, cone scales), and one of the first of this kind in Italy (see Martinetto, 1998). As far as we know, pollen of *Pseudolarix* has been described only on fresh material (Erdtman, 1969; Ying *et al.*, 1993), and the diagnosis of *Pseudolarix* pollen from *P. sylvestris*-type Rudolph (1936) is still uncertain. An earlier, unpublished, report of fossil pollen of *Pseudolarix* is cited by Carraro (this vol., p. 59), however we do not know whether it is supported by appropriate diagnostic characters or not. Provisionally, we prefer to separate as *Pinus s.l.* type 1 a bisaccate grain having characters similar to those we observed in fresh material of *Pseudolarix*. Actually, this type is frequent in the sample where *Pseudolarix* scales were found. We are about to study fresh pollen of the living *Pseudolarix amabilis*, and we hope to find some possible diagnostic feature allowing a precise characterisation.

The pollen assemblages and reconstructed vegetation

- Sample 'GA1' (10,710 pollen grain/g) - *Cathaya* is the dominant arboreal pollen (16,2%). The other conifers are scarce; however, several Taxodiaceae (*Taxodium*-type, e.g. *Taxodium*, *Glyptostrobus*), *Sciadopytis* and Cupressaceae were found. Pollen from mesic broad-leaved trees is abundant, in particular: *Carya*, *Fagus*, *Pterocarya* and *Quercus*, *Pterocarya* and *Nyssa* indicates swamps (Emberger & Sabeti, 1962). The relatively high representation of herbaceous pollen (41,3%) suggests that habitats unsuitable for forest (e.g. watercourses and marshes and ponds) covered extensive areas. Most of Gramineae pollen is probably from local origin (bogs and other wetland areas), as also suggested by occurrence of Cyperaceae, *Sparganium*, *Typha*, and by the low values of herbs from terrestrial dry habitats. The relatively high pollen percent of Chenopodiaceae (16.6 %) and of *Limonium vulgare* group (Turner & Balckmore, 1984) (1.9 %) suggest the closeness to a brackish littoral environment.

- '*Pseudolarix* layer' (47,970 pollen grains/g) - The dominant pollen in this sample is *Carpinus* 3p-type (Ravazzi, 1993) (35.7 %). This type is similar to *Carpinus betulus* type, but is 3-porate instead of 4-porate. It is unrelated to *C. orientalis* Mill., and to *Ostrya*. but might have been related to a fossil species described in the Upper Pliocene of Poland (Szaferova, 1961). This plant probably dominated the mesic forest, associated with *Ulmus/Zelkova* type (6.1 %), *Ostrya/Carpinus orientalis* type and *Quercus* (2.8%). Among conifers, *Cathaya* and *Sciadopytis* pollen is missing, whereas *Picea excelsa*-type (Beug, 1961) is well represented.

Tab. 6.1. Part I	GA1 bed sample 1			'Pseudolarix bed" sample 1			'Trapa bed" sample 1		
Concentration (grains / g)	10707			47974			114094		
	grains counted	(%)	grains / g	grains counted	(%)	grains / g	grains counted	(%)	grains / g
Conifers									
Abies	5	0,5	52				10	1,0	1109
Cathaya	165	16,2	1730				4	0,4	444
Cedrus	6	0,6	63				9	0,9	998
Cupressaceae	10	1,0	105	7	0,5	221	7	1,1	1199
Larix				1	0,1	32			
Picea excelsa type (Beug, 1961)	32	3,1	336	150	9,9	4734	32	3,1	3548
Pinus (undifferentiated)	29	2,8	304	62	4,1	1957	37	3,6	4102
Pinus s.l. type 1				74	4,9	2336	12	1,2	1331
Pinus Haploxylon type (Rudolph 1936) type 2	3	0,3	31	5	0,3	158			
Pinus sylvestris type (Rudolph, 1936)	7	0,7	73	13	0,9	410			
Sciadopytis	10	1,0	105						
Taxodiaceae / Taxaceae (undifferentiated)	3	0,3	31						
Taxodium -type	14	1,4	147	3	0,2	95	2	0,2	222
Tsuga	28	2,7	294	28	1,8	884	19	1,8	2107
Undifferentiated bisaccate Conifers	34	3,3	357	17	1,1	537	24	2,3	2661
SUM OF CONIFERS	346	33,9	3628	360	23,7	11362	156	15,2	17297
Woody Angiosperms									
Acer negundo type	1	0,1	10				11	1,1	1220
Acer pseudoplatanus type				3	0,2	95	5	0,5	554
Alnus	17	1,7	178	121	8,0	3819	70	6,8	7761
Betula	12	1,2	126	39	2,6	1231	5	0,5	554
Carpinus betulus type	3	0,3	31	3	0,2	95	8	0,8	887
Carpinus 3p	3	0,3	31	543	35,7	17138			
Carya	48	4,7	503	9	0,6	284	41	4,0	4546
Castanea	1	0,1	10				1	0,1	111
Celastraceae							1	0,1	111
Celtis				5	0,3	158	3	0,2	283
Corylus				17	1,1	537	12	1,2	1331
Ericaceae	4	0,4	42	1	0,1	32	1	0,1	111
Eucommia	1	0,1	10						
Fagus	40	3,9	419				3	0,3	333
Frangula	1	0,1	10						
Fraxinus excelsior type (Punt et al., 1991)	2	0,2	21	4	0,3	126	31	3,0	3437
Hedera	2	0,2	21				3	0,3	333
Hypericum	2	0,2	21	2	0,1	63			
Ilex	3	0,3	31	1	0,1	32	1	0,1	111
Jasminum							3	0,3	333
Juglans sect. Cardiocaryon type prov.				2	0,1	63	42	4,1	4657
Liquidambar	3	0,3	31				3	0,3	333
Magnolia				1	0,1	32			
Myrica							11	1,1	1220
Nyssa	7	0,7	73						
Olea	3	0,3	31				1	0,1	111
Ostrya-Carpinus orientalis type (Torri et al., 1990)	4	0,4	42	50	3,3	1578	7	0,7	776
Palmae cf. *Trachycarpus*				4	0,3	126	16	1,6	1774
Parthenocissus	3	0,3	31				3	0,2	283
Platanus							1	0,1	111
Pterocarya	43	4,2	451	11	0,7	347	131	12,7	14525
Pulmonaria obscura type (Clarke, 1980) - cf. *Paulownia*				1	0,1	32			
Rosaceae ND	1	0,1	10	2	0,1	63	2	0,2	222
Rutaceae ND				1	0,1	32			
Quercus pedunculata type (Van Benthem et al., 1984)	29	2,8	304	42	2,8	1326	36	3,5	3992
Quercus rubra type (Van Benthem et al., 1984)							10	1,0	1109
Quercus ilex type (Van Benthem at al., 1984)							1	0,1	141
Salix							1	0,1	111
Sambucus ebulus type (Punt et al., 1976)	1	0,1	10				24	2,3	2661
Sambucus nigra type (Punt et al., 1976)	1	0,1	10	2	0,1	63			
Styrax	4	0,4	42						
Symplocos paniculata subtype (van der Meijden, 1987)				1	0,1	32	3	0,3	333
Symplocos n.d.				1	0,1	32			
Tilia							1	0,1	111
Ulmus / Zelkova type	7	0,7	73	92	6,1	2904	32	3,1	3548
Ulmus s.s.	1	0,1	10				3	0,2	283
Viburnum	2	0,2	21				1	0,1	111
Vitis	5	0,5	52	2	0,1	63	8	0,8	887
SUM OF WOODY ANGIOSPERMS	254	24.9	2664	960	63.2	30299	535	52,0	59310

Sample name	GA1 bed sample 1			'Pseudolarix bed" sample 1			'Trapa bed" sample 1		
Concentration (grains / g)	10707			47974			114094		
	grains counted	(%)	grains / g	grains counted	(%)	grains / g	grains counted	(%)	grains / g
Herbaceous Angiosperms									
Artemisia	5	0,5	52	8	0,5	252	3	0,3	333
Caltha	1	0,1	10						
Campanula							1	0,1	111
Caryophyllaceae	1	0,1	10	4	0,3	126	1	0,1	111
Chenopodiaceae	169	16,6	1772				1	0,1	111
Circaea							5	0,5	554
Compositae Asteroideae	8	0,8	84	1	0,1	32	1	0,1	141
Crassulaceae	2	0,2	21						
Galium	2	0,2	21						
Cyperaceae	42	4,1	440	5	0,3	158	114	11,1	12640
Filipendula				1	0,1	32			
Geranium							1	0,1	111
Gramineae	130	12,7	1363	106	7,0	3346	159	15,5	17629
Limonium vulgare group (Turner et al., 1984)	19	1,9	199						
Menyanthes				12	0,8		1	0,1	111
Mentha	1	0,1	10						
Myriophyllum							1	0,1	141
Nuphar				58	3,8	1831	11	1,1	1220
Oxyria	1	0,1	10						
Polygonum aviculare type (Van Leewen et al.,1988)							1	0,1	111
Polygonum persicaria type (Van Leeuwen et al., 1988)	1	0,1	10	1	0,1	32	1	0,1	141
Potamogeton	4	0,4	42				20	1,9	2218
Ranunculus	3	0,3	31						
Ranunculus aquatilis B32							3	0,3	333
Ranunculus Batrachium				1	0,1	32			
Scrophularia type	1	0,1	10						
Sparganium	21	2,1	220				1	0,1	111
Stachys							1	0,1	111
Thalictrum							1	0,1	141
Trapa							4	0,4	444
Typha	4	0,4	42				6	0,6	665
Umbelliferae	5	0,5	52	2	0,1	63			
Urtica dioica type (Punt et. al., 1984)				1	0,1	32			
Valerianella	1	0,1	10						
SUM OF HERBACEOUS ANGIOSPERMS	421	41,2	4415	200	13,2	6312	338	32,9	37487
POLLEN SUM	1021	100,0	10707	1520	100,0	47974	1029	100,0	114094
Pteridophytes									
Filicales, monolete spores	6			55			69		
Osmunda				3			6		
Type *Pteridium*				3 .			1		
Unknown type : spore 80 µm							3		
OTHER MICROFOSSILS									
Dinophyta							3		
Out of pollen sum	*Lythrum*						*Acer palmatum* type *Sagittaria sagittifolia*		

Tab. 6.1. Pollen spectra from Castelletto Cervo.

This type includes *P. abies* (L.) Karst., *P. smithiana* (Wall) Boiss. from Himalayas and others. Probably, the fossil *P. florschuetzii* Van der Hammen 1951, the cones of which were found in the '*Pseudolarix* layer', is also falling in this type. *Picea* pollen may be subject to a large taphonomic over-representation after floating (Ammann, 1994), so that one may not be sure about the abundance of *Picea* in the lowland area.

Probably its cover value in the surrounding vegetation was lower than, or similar to its pollen percentage (9.9 %). The same taphonomical effect is even more pronounced as far as *Pinus* s.l. pollen is concerned. Among this, we have temporarily distinguished *Pinus* s.l. type 1 (with 4.9 %) (see above). Most of the herbs are hydrophytes (e.g. *Nuphar*, *Menyanthes*) and Gramineae.

- '*Trapa* layer' (114,095 pollen grains/g) - This sample shows the highest pollen concentration and floristic diversity among broad-leaved pollen. Besides *Pterocarya*, *Alnus* and *Myrica* that are linked to wetlands, we have found moderate pollen percentages of *Carya*, *Juglans* sect. *Cardiocaryon* type prov., *Fraxinus excelsior* type, *Quercus*, *Ulmus/Zelkova* type, *Sambucus ebulus* type, *Acer negundo* type. Of particular interest the occurrence of *Palmae* cf. *Trachycarpus*. Taxodiaceae and *Cathaya* are sporadic. The relatively high value of herb pollen may be related to wetlands or hydrophytic communities (e.g. Cyperaceae, *Nuphar*, *Potamogeton* and Gramineae). Furthermore, in this sample, the occurrence of several grains of *Trapa* is noteworthy. This pollen is highly under-represented (0.4 %) if compared to the abundance of fruits (very common in the sediment) because of its low pollen production.

Pollen- to carpoflora comparison (preliminary)

The carpofloral assemblages of these and other samples from the same beds are presented by Martinetto (this issue). Generally speaking, there is a good fit between the composition of carpo- and palynofloral assemblages. Differential production and dispersal of pollen/propagules and taphonomical effects may explain some of the observed differences in frequency, e.g. the under-representation of some low-pollen producing plants, especially herbs (Lamiaceae sspp., *Trapa, Viola, Phellodendron*).

Remarkably, the macrofossil record of *Symplocos* sect. *Palura* in the down-thrown block of the "Villafranchiano" unit has been confirmed by pollen occurrence of *Symplocos paniculata* subtype (Van der Meijden, 1987), though with low values (0.1 - 0.3 %). We want to stress that *Symplocos* is commonly recorded only at the genus level by European palynologists, thus preventing the distinction of the species group living in ‘subtropical’, partially evergreen, forests from temperate species of cooler biomes.

Preliminary stratigraphic remarks

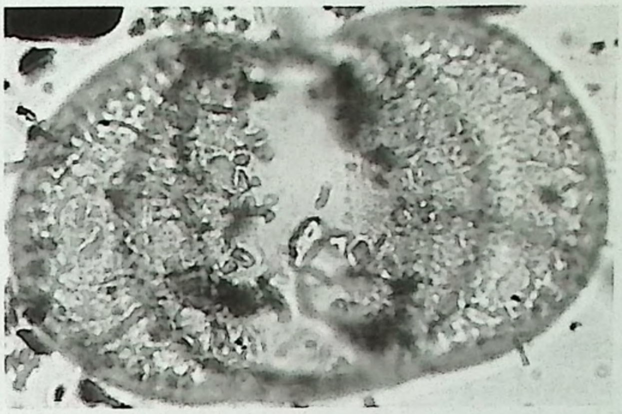
The two uppermost pollen+carpofloral spectra (down-thrown block of the "Villafranchiano" unit) of the Cervo River succession are missing *Sciadopytis* and *Nyssa* (both in pollen and carpoflora) and poor in Taxodiaceae and *Cathaya* (these are completely missing in the carpoflora). Therefore they should be likely referred to a floral complex distinct from the one comprising the 'GA1' palaeoflora. The latter should be referred to the Stura Floristic Complex, according to the subdivision proposed by Martinetto (1999). A detailed pollen and macrofloral study will define these differences in terms of biostratigraphy (biozones). However, even the youngest floras of the Cervo succession keep a rich group of exotic temperate elements with an Upper Pliocene-lowermost Pleistocene distribution in southern Europe (*Actinidia, Acer negundo* type, *Chamaecyparis, Liquidambar, Magnolia, Juglans* sect. *Cardiocaryon* type prov., *Phellodendron, Phytolacca* (?), *Pseudolarix, Symplocos paniculata* type). This is well known in the floras from Leffe - biogenic unit (Ravazzi, 1995), Stirone-Laurano section (layers S6-S9 by Gregor, 1990), and, outside the Po-Plain, in the following floras: Tegelen (Hammen, 1951; Zagwijn, 1963; Van der Burgh, 1974), Bernasso (Leroy & Roiron, 1996) and Nogaret (Leroy & Seret, 1992).

Plate 6.1 (p. 39) - Interesting pollen types from the Castelletto Cervo I (GA1) and Buronzo ("*Trapa* bed") successions. All photos x1000.
1, 2: ***Cathaya***, sample GA1 (concentration slide). 1: Optical section of marginal area; 2: Alveolate structure of the sacci. **3-5:** ***Limonium vulgare*** **group** (Turner *et al.*, 1984), sample GA1. 3: Polar view showing the reticulate structure with large lumina and the short surface echinae (slide 5). 4: Optical section (slide 3); 5: Polar view showing the reticuate structure with large lumina and the arrangement of the columellae (slide 3). **6, 7:** ***Limonium*** **group** (Turner *et al.*, 1984), sample GA1 (slide 3). 6: Optical section; 7: Polar view showing the reticulate structure with small lumina and the columellae arrangement. **8:** ***Trapa***. Sample "*Trapa* bed" (slide 3). **9:** ***Eucommia***. Sample GA1 (slide 4). **10, 11:** ***Symplocos paniculata*** **subtype** (van der Meijden, 1987). Sample "*Trapa* bed" (slide 4).

RAVAZZI C*. & ZANNI M*. - The palynoflora of the Castelletto Cervo succession (NW Italy). A preliminary account. *In* MARTINETTO E. (ed.): Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.4 (2001): 34-39. **Centro Geodinamica Alpina e Quaternaria, Piazza Cittadella 4, I-24129 Bergamo*

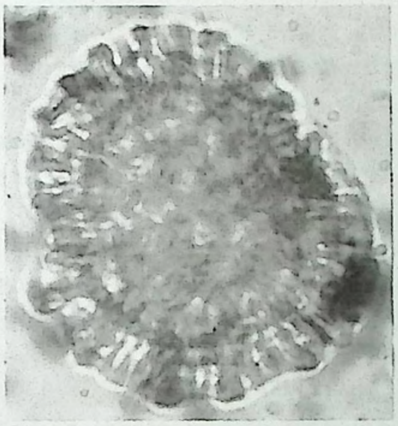
Plate 6.1

1

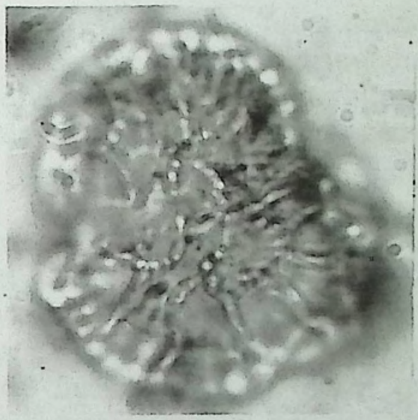


2

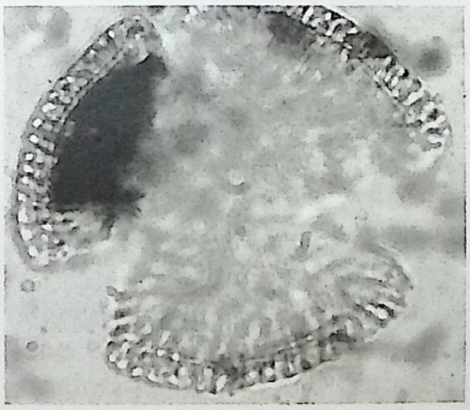
3



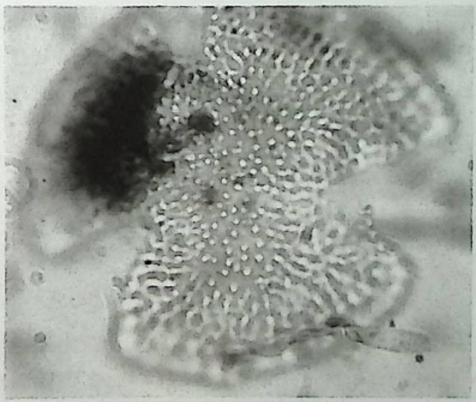
4



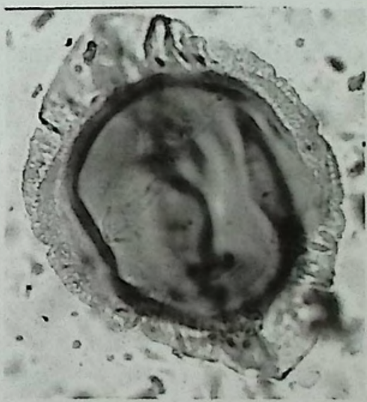
5



6



7



8

9

10

11

The Ivrea district

7. QUATERNARY ENVIRONMENTAL EVOLUTION OF THE IVREA DISTRICT

- by M. GIARDINO.

The Quaternary environmental evolution of the Ivrea district is characterised by the development of the impressive complex of end moraines which is named Ivrea Morainic Amphitheatre. The Quaternary geomorphological and geological development of this complex is mainly related to the expansions and retreats of the «Balteo» Glacier at the mouth of Aosta Valley during Pleistocene glaciations.
Yet, to outline a possible Quaternary morphological and geological evolution of the Ivrea district we have to consider that climatic variations (such as those of glaciations and stadials) act together with other factors (geodynamics, strength to erosion, - i.e. relative resistance of outcropping formations-) and with local phenomena (e.g. landslides and other dam phenomena) to cause depositional and erosional episodes in the area.

Among the studies conducted on the Ivrea Morainic Amphitheatre, only the most recent part of them (Carraro *et al.* 1991; Carraro, 1992; Gianotti, 1993; Enrietti, 1996; Arobba *et al.*, 1997; Cassulo, 1999) follows a correlation criteria based on a multi-variable interpretative model; a revision of the previous literature is now in progress at the Earth Science Department of the University of Torino. These new studies, together with geological field surveys following the allostratigraphic criteria, are devoted to locate and to trace accurately unconformities between the single units; to study litho- and morphostratigraphic relationships between the different groups of end-moraines of the Ivrea Morainic Amphitheatre (IMA); to compare the altimetrical attitude of basal unconformity surfaces on the substrate of the various depositional units have been made.
The relative age of allostratigraphic and geomorphic units has been enriched by analysing soil profiles; a few ages correlated with palaeomagnetic data, and isotopic numerical ages contributed to recognise three groups of end-moraines of the IMA (Fig. 7.1), from the outer to the inner:

the Borgo Group,
the Serra Group,
and the Bollengo Group.

Borgo Group

The Borgo Group is the outer and oldest of end moraines (this vol., p. 13; the remnants of the original landforms and sediments are preserved only on the left side of IMA. Long-term physical and chemical weathering of land surfaces produced thick weathering profiles and dark alteration colours (red to dark-reddish brown) on soils on the Borgo Group moraines. Erosional processes and watercourse dissection contributed in a general and locally strong reshaping of moraines; however, original patterns of landforms are still preserved due to post-glacial stream network deepening into original meltwater channels parallel to the ridges. Outwash deposits of Borgo Group often outcrop below a thick cover of polygenetic loess deposits.
Stratigraphic and geomorphic evidences show at least two stages during the glacial phase of Borgo Group. As mentioned elsewhere in this volume the outer and oldest one is contemporaneous to lacustrine deposits due to the obstruction of the Elvo River by the «Balteo» Glacier: palaeomagnetic studies on the lacustrine deposits (Carraro *et al.*, 1991) revealed a reverse polarity (Matuyama Chron, Early Pleistocene as correlated age).
The inner end moraines of the Borgo Group are interpreted as deposits of a later stage of the same glaciation (Carraro *et al.*, 1991); they show a great variety of facies, such as diamicton with silt and clay beds, sand and gravel, stratified and deformed clay and silts. The type and the internal features

of these deposits together with facies association suggest a predominant ice-marginal deposition of tills by sub-aquatic flows interbedded with glacial lacustrine and/or by mass movements with local fluvial sedimentation.

The Serra Group

The name of this Group comes from the "Serra" moraine, the most impressive landform in the whole IMA, which is composed of two linear (NW-SE trending), parallel ridges up to 18-km long. The majesty of this landform is due to its sharp longitudinal profile elevating up to 600 m (at Valle d'Aosta mouth) over the present-day alluvial plain of Dora Baltea River.

As shown in the Fig. 7.1, the "Serra" moraine is only the inner part of a wide end-moraines group. Geomorphic position and deposits pedostratigraphy of this part of the Serra Group allow to separate it from an outer and older one which is characterized by thicker soil profile (up to some meters) and darker soil colour (up to yellowish red).

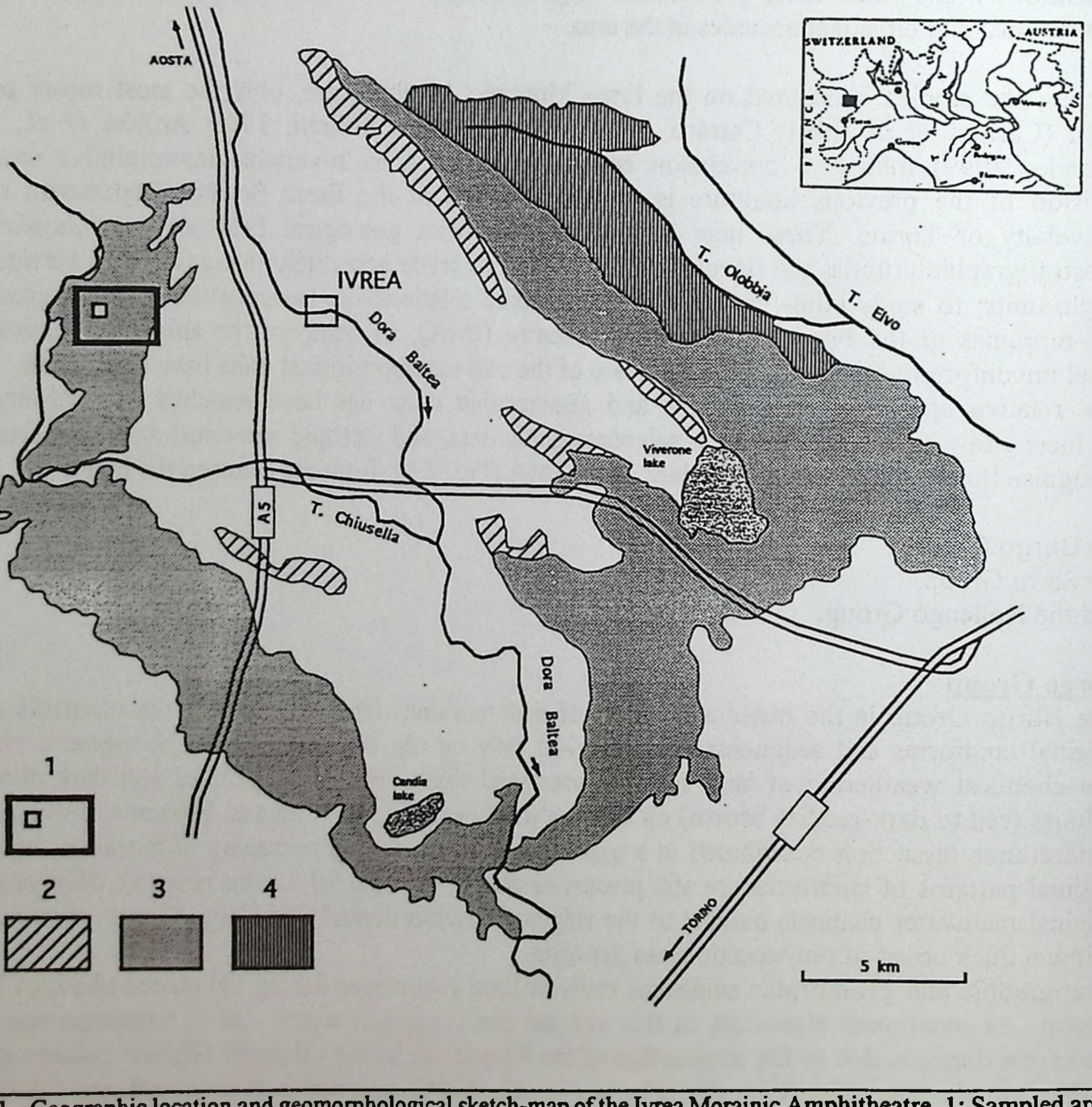


Fig. 7.1 - Geographic location and geomorphological sketch-map of the Ivrea Morainic Amphitheatre. 1: Sampled area for isotopic age estimate (Arobba *et al.*, 1997) see text for further information. 2: Bollengo-Albiano Group of terminal moraines. 3: Serra Group of terminal moraines. 4: Borgo Group of terminal moraines. Dora Baltea River and other local streams are in bold lines. Double lines (A4 and A5) are main highways of the Piemonte region.

As shown in the Fig. 7.1, the "Serra" moraine is only the inner part of a wide end-moraines group. Geomorphic position and deposits pedostratigraphy of this part of the Serra Group allow to separate it from an outer and older one which is characterized by thicker soil profile (up to some meters) and darker soil colour (up to yellowish red).
Outwash deposits of Serra Group moraines form terraced units in the inner part of IMA and a wide apron from the IMA to the Po River. The longitudinal profile of outer moraines of Serra Group shows only a few breaks: these are due to former head of meltwater valleys. Spill-way channel between ridges of terminal moraine locally are repeatedly terraced due to lowering of local base level.
The traditional Serra Group chronological interpretation of Middle Pleistocene age (Riss *Auct.*) used to be a debatable attribution, especially during the field surveying of the Second Edition of the Geological Map of Italy (Bortolami *et al.* 1967): some authors indicated the Serra group as belonging to the last glaciation, some others to the penultimate; so, in the current chronology, the possible interpretations for the Serra group were Middle Pleistocene or Upper Pleistocene.
Recent palynological and isotopic studies (Arobba *et al.*, 1997) were conducted on silty clay and peat deposits sampled at -52 m from ground level (585 m a.s.l.) in a core drilled near Alice Superiore lake (right lateral sector of the IMA). The pollen taxa indicate a forested environment characterized by a mesophilous formation typical of a cooler climate than those associated with the actual *Querco-carpinetum*. A sample of the deposit yielded an *ante quem* radiocarbon conventional age of >43.000 y. b. P. The age estimate and the stratigraphic location of the sampled layer (bounded above and below by glacial-fluvioglacial deposits) are in agreement with an Upper Pleistocene attribution of the whole Serra Group, being the silty clay and peat deposits an early Upper Pleistocene interstadial.

Bollengo Group

As shown by field-survey data about Borgo and Serra Group (Arobba *et al.*, 1997), the allostratigraphic units (corresponding to inner and younger ridges) rest on erosional surfaces developed on the substrate at progressively lower elevation. From this evidence it is clear that a sequence of «cut and fill» episodes occurred in the area. Also the erosional surfaces related to the various glacial units of Bollengo Group, the inner and more recent group of end-moraines in the IMA, are located at progressively lower elevations in the bedrock. This indicates that, in the same way already identified for older units of the Ivrea Amphitheatre, the glacier continued the erosional process also during the last glaciation and following retreat phases.
Bollengo Group testifies an important recessional stage of the last glaciation: stratigraphic relationships, inner geomorphic position and lower elevation of end moraines allow to estimate its possible recent age; this is in agreement with the light colour (up to yellowish brown) and thin profile (less than a meter) of soil development.
Fluvioglacial deposits of Bollengo Group constitute terraced sequences that cut and fill glacial and fluvioglacial deposits of older groups. Widespread lacustrine deposits witness the formation of a proglacial lake in between the glacial front and the previously formed terminal moraines. Candia and Viverone lakes are the remnants of this ancient basin. At first, the effluent stream followed a NW-SE trending depression up to the meltwater channel, then connecting to the outwash area of Serra Group apron: the palaeochannel of "Dora Morta" is due to entrenching of this water course in the previously formed fluvioglacial apron.

Despite of their conspicuous appearance beyond the surrounding drift plains, ridges of IMA end moraines are generally composed of relatively thin glacial ablation deposits (up to some tens of meters): often they result rock-cored.
The complexity of these landforms is not only due to multiple episodes of deposition: it also reflects lithological and structural characteristics of bedrock and former morphological setting of the area.

Bedrock geology of the IMA is composed of pre-Cenozoic basement rocks, Pliocene deltaic and shallow-marine sediments, and Early Pleistocene fluviatile deposits.

Basement rocks belong to three main structural domains of the Alpine chain: the Europe-vergent Australpine System (polycyclic micashists and metabasites with HP assemblage: Sesia-Lanzo Zone; Venturini, 1995, *cum bibl.*), the Southern Alps (lower-crust mafic rocks of Ivrea-Verbano Zone; Voshage *et al.*, 1990, *cum bibl.*) and the interposed Canavese Zone (Pre-Permian metamorphic basement rocks, Permo-Mesozoic covers and Tertiary ryolites; Biino & Compagnoni, 1989). In the area of IMA, the boundaries between these structural domains are marked by tectonic contacts named Canavese fault system, which is part of the Periadriatic-Insubric lineament.

While Alpine basement domains form the substrate for the most part of the inner IMA, Pliocene deltaic and shallow-marine sediments occur in the central and right-lateral sectors. In the outer area of IMA, glacial deposits overlie highly-altered sands, gravels and coarser deposits; they are alluvial-fan deposits of Early Pleistocene age, whose source-areas are shown by pebbles lithologies: very heterogeneous for those at the Valle d'Aosta mouth (Dora Baltea drainage system), relatively monotonous for those from minor valleys. Most of the original landforms are buried by IMA deposits, remnants being preserved only out of the left-lateral sector of IMA.

From the above field evidences it can be argued that complex setting of IMA bedrock reflects recent differential uplifting in the area. This phenomenon seems to be still active, since post-glacial rivers are quickly entrenching IMA glacial deposits and their bedrock. Some anomalies of the present-day drainage network could also be related to fluvial deviation phenomena enhanced by differential uplifting.

GIARDINO M. - Quaternary environmental evolution of the Ivrea district. *In* MARTINETTO E. (ed.): Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.4 (2001): 41-44.

8. Key-site 5: the Val Chiusella Pliocene succession - by E. MARTINETTO, G. BASILICI, G. PAVIA, D. VIOLANTI.

As reported elswhere in this volume, the westernmost Pliocene outcrops at the southern fringe of the Alps lie in the neighbourhood of Ivrea (province of Turin), where the best exposed profiles are found in a limited area bordering the Chiusella River, a tributary of the Dora Baltea River (Basilici *et al.*, 1977).

The Pliocene succession of Val Chiusella attracted the attention of many Italian geologists and palaeontologists in the second half of the last century, such as: Bruno, Baretti, Stoppani, Sacco and Marco (for references see Rabogliatti, 1953). These authors only provided very simple stratigraphic descriptions and did not care too much to the analysis of fossil assemblages. Rabogliatti (1953) collected, listed and figured several fossil molluscs from this area. Further studies were carried out by Barbieri *et al.* (1974), who provided a stratigraphic column of the succession and listed many foraminiferal taxa, and by Carraro *et al.* (1974). These two papers described an heterogeneous deposit at the top of the Pliocene succession, interpreted as «glaciomarine» (see chapter 9). However, according to Martinetto and Basilici *et al.* (1997), the stratigraphic relationships of the last deposit with the underlying Pliocene sediments seems to be different from those described by the former authors, and it will be discussed below.

The discovery of plant macrofossil assemblages in several layers of a 75 m thick profile (Martinetto, 1995), cropping out near the hamlet of Sento (section 1 in Fig. 8.1), provided an unprecedented possibility to gather palaeoenvironmental information and stimulated new

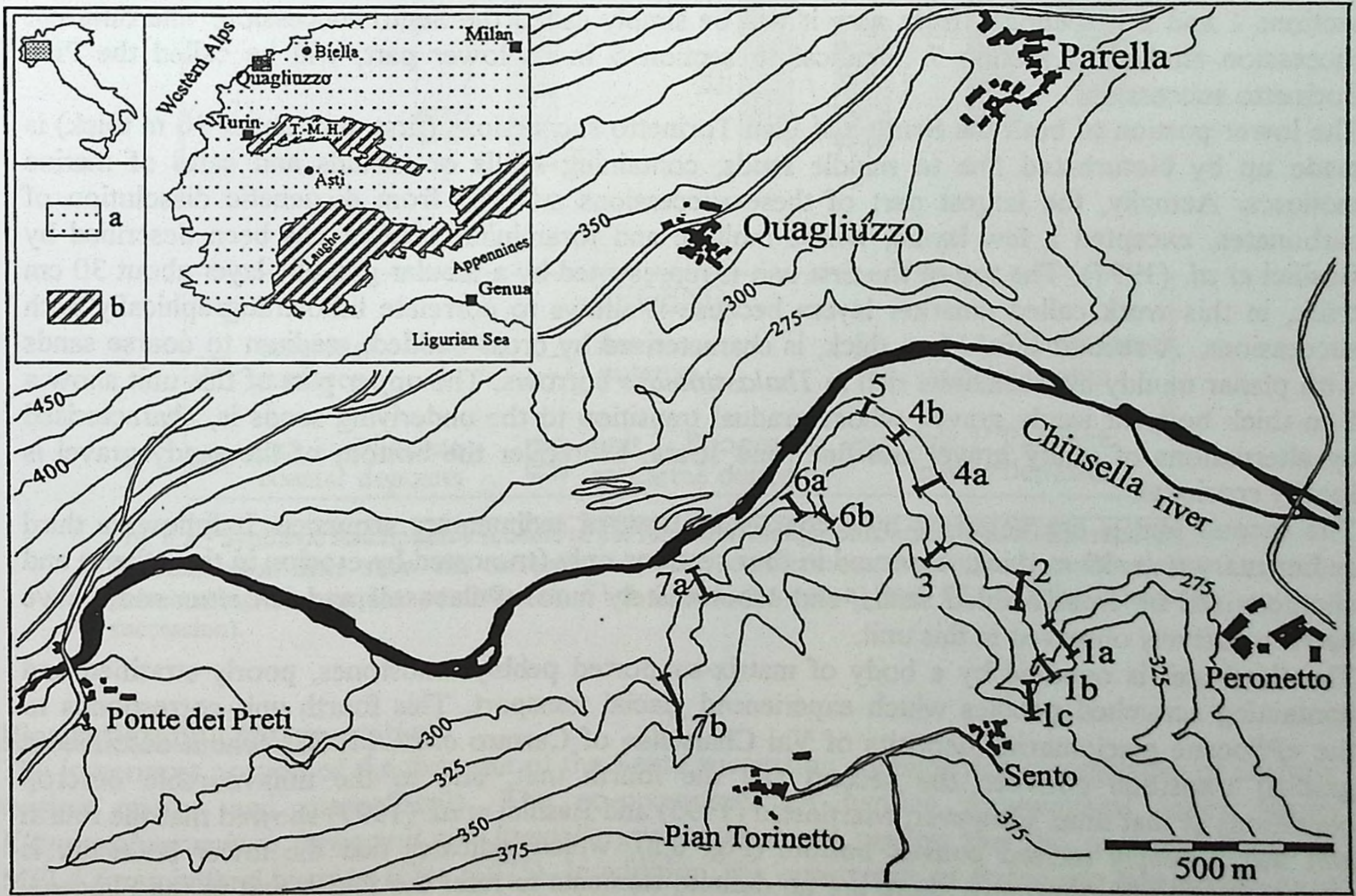


Fig. 8.1 - Sketch map of the lower course of the Chiusella River, where the Pliocene sediments are in outcrop. The traces of seven stratigraphic sections studied in the present work are shown north of the hamlets of Pian Torinetto and Sento. In the upper left corner: sketch map of the Cenozoic basins of NW Italy. a: Plio-Quaternary basin of the western Po Plain. b: Pre-Pliocene Cenozoic sediments. T.-M. H.: Turin-Monferrato hills.

investigations of the Val Chiusella succession, which are reported by Basilici *et al.* (1997) and recalled in this volume.

Lithostratigraphy and sedimentology

The Pliocene succession of Val Chiusella is transgressive on the crystalline rocks belonging to the Alpine orogen (Barbieri *et al.*, 1974) and it has been deposited at the NW margin of the marine basin which covered the Po Plain at that time (Fig. 8.1). The succession crops out in a few natural escarpments which border the course of the Chiusella River between the locality «Ponte dei Preti» and the village of Parella. Particularly nice exposures are visible in a ravine just north of Sento and in three steep walls north of Pian Torinetto (Fig. 8.1). These outcrops have been exploited for the analysis of seven stratigraphic sections. Sections 1 and 2 have been the object of careful facies analysis. Sections 3 to 7 have been analysed in a superficial way, in order to establish the thickness and stratigraphic relationships of four main lithostratigraphic units recognised in the Val Chiusella succession.

Strata are sub-horizontal, but a dipping of about 2 degrees towards SSE has been calculated by matching the altitude of the same layer in different sections. For the description we have divided the sedimentary succession in four informal sedimentary unit. The longest sections (1, 2, 7) show an analogous sedimentary succession, but only section 7 includes all the four sedimentary units, while sections 1 and 2 just include the three lower units, which have a tabular geometry with sub-horizontal lower boundaries (Fig. 8.2). On the other hand the analysis of sections 3 to 6 showed that the fourth unit has a deeply incised, convex lower boundary. As the succession studied in sections 1 and 2 is identical, from now it will be simply called the Sento succession. The different succession studied in section 7, identical to section 6 in its lower part, will be called the Pian Torinetto succession.

The lower portion of both the Sento and Pian Torinetto successions (first unit, about 30 m thick) is made up by bioturbated fine to middle sands, containing shells or moulds and casts of marine molluscs. Actually, the largest part of these successions suffered from diagenetic dissolution of carbonates, excepted a few layers, whose mollusc and foraminiral content has been described by Basilici *et al.* (1997). The top of the first unit is represented by a tabular gravelly layer about 30 cm thick, in this work called «marker layer» because it allows to correlate lithostratigraphically both successions. A second unit, 15 m thick, is characterised by cross-bedded, medium to coarse sands with planar muddy intercalations rich in *Thalassinoides* burrows. The upper part of this unit show a 8 m thick body of sandy gravel, whose gradual transition to the underlying sands is, characterised by alternations of sandy gravel and fine sand strata. Moreover the bottom of the sandy gravel is locally erosional.

The second unit is characterised by a coarsening upward sedimentary sequence. It follows a third sedimentary unit, 39 m thick, observed in four sections only (truncated by erosion in the others) and characterised by cross-bedded sands, and subordinately muds. Palaeosols and «*in situ*» roots have been exclusively observed in this unit.

The third unit is overlaid by a body of matrix-supported pebbly mudstones, poorly stratified and containing scratched pebbles which experienced glacial transport. This fourth unit corresponds to the «Pliocene glaciomarine deposits of Val Chiusella» of Carraro *et al.* (1974), whom described a gradual transition between the second and the fourth unit, due to the unfavourable outcrop conditions at that time. However, Martinetto (1995) and Basilici *et al.* (1997) showed that the fourth unit has a deeply incised convex bottom (Fig. 8.2), which indicates that the lower boundary is unconformable. Furthermore, there are no definite elements to refer the fourth unit to the Pliocene, and the marine fossils it contains have been interpreted as reworked by Basilici *et al.* (1997). For these reasons the genetic interpretation of such unit will require further investigations (see Carraro, this volume, p. 57).

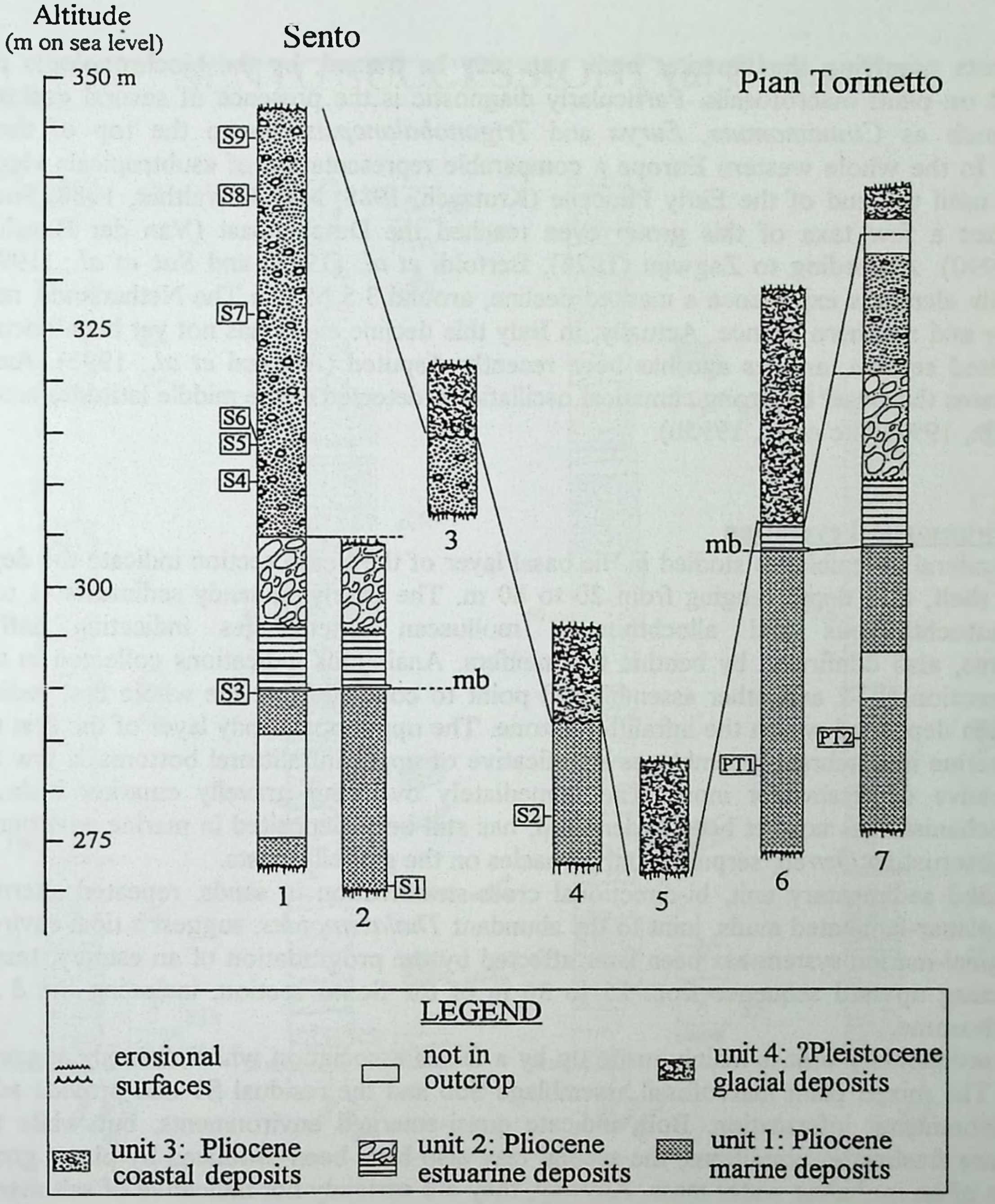


Fig. 8.2 - Synthetic stratigraphic scheme of the four lithostratigraphic units measured in sections 1-7. Continuous lines show the correlation of unit boundaries among different sections. The palaeontological samples are labelled: S1-9 (Sento succession) and PT1-2 (Pian Torinetto succession).

Biostratigraphic interpretation

The lowermost portion of the first unit of the Sento succession contains rich assemblages of shallow marine micro- and macrofossils. The co-occurrence of benthic foraminiferal index forms *Ellipsopolymorphina fornasinii* and *Buccella granulata* would suggest that this portion belongs to MPL4 foraminiferal biozone (Cita, 1975). In addition, the occurrence of *Bufonaria marginata* up to the «marker layer» would indicate that the whole first unit falls within subzone MPL4a of the latest Early Pliocene (Fig. 1.3). In facts such the gastropod species seems to disappear from the Po Plain Basin at the end of the Early Pliocene (Monegatti & Raffi in SPI, 1996) The plant macrofossil assemblages in the first unit (PT1, S1, S2) are in perfect agreement with those of the dated Early Pliocene successions of southern Piedmont (Martinetto, 1995; Cavallo & Martinetto, 1996).

The sediments overlying the «marker bed» can only be framed, by the biochronologic point of view, based on plant macrofossils. Particularly diagnostic is the presence of several «subtropical» elements, such as *Cinnamomum*, *Eurya* and *Trigonobalanopsis*, up to the top of the Sento succession. In the whole western Europe a comparable representation of «subtropical» elements is only found until the end of the Early Pliocene (Krutzsch, 1988; Mai & Walther, 1988; Suc *et al.*, 1995a), when a few taxa of this group even reached the Dutch coast (Van der Burgh, 1983; Zagwijn, 1990). According to Zagwijn (1974), Bertoldi *et al.* (1994) and Suc *et al.*, (1995b) the «subtropical» elements experience a marked decline, around 3.5 Ma, in The Netherlands, northern-central Italy and southern France. Actually, in Italy this decline event has not yet been documented in a calibrated section, and its age has been recently disputed (Abbazzi *et al.*, 1995). Anyway it surely predates the onset of strong climatical oscillations, detected at the middle latitudes around 3.0 Ma (Zagwijn, 1992; Suc *et al.*, 1995b).

Palaeoenvironmental evolution

The foraminiferal assemblages studied in the basal layer of the Sento section indicate the deposition within the shelf, at a depth ranging from 20 to 80 m. The overlying sandy sediments (1 to 21 m) contain autochthonous and allochthonous molluscan assemblages indicating infralittoral environments, also confirmed by benthic foraminifers. Analogous indications collected in the Pian Torinetto section (PT2 and other assemblages) point to conclude that the whole first sedimentary unit has been deposited within the infralittoral zone. The uppermost sandy layer of the first unit still contains marine invertebrate assemblages significative of upper infralittoral bottoms; a few taxa are even indicative of freshwater input. The immediately overlying gravelly «marker bed», whose genetic mechanism has not yet been understood, has still been deposited in marine environment, as proved by encrusting *Ostrea*, serpulids and barnacles on the gravelly clasts.

In the second sedimentary unit, bi-directional cross-stratification in sands, repeated alternance of sands and planar-laminated muds, joint to the abundant *Thalassinoides*, suggest a tidal environment. Such marginal-marine system has been later affected by the progradation of an estuary, testified by the coarsening upward sequence from 25 to 36 m of the Sento section, including the 8 m thick gravelly lithosome.

The third sedimentary unit is mainly made up by a facies association which strongly suggests tidal influence. The mixed plant macrofossil assemblage S6b and the residual S7 one provide additional palaeoenvironmental information. Both indicate quasi-emerged environments, but while the first one indicates freshwater conditions, the second may also have been produced by plants growing at the margin of an ipohaline water mass. Anyway, they are certainly not indicative of salt marsh plant communities. This datum integrates the sedimentological information in favour of a tidal palaeoenvironment characterised by ipohaline or freshwater conditions, at least in the supratidal zone. Finally, the sedimentological data suggest that also the uppermost part of the succession (69-75 m) underwent a tidal control, with sandy-muddy sedimentation on point bars of high-sinuosity tidal channels.

According to the palaeobotanical data, warm temperate and humid climatic conditions (mean annual temperature around 14-17 °C) seem to have persisted during the deposition of the whole Pliocene succession, whose top is marked by an erosional surface. The unconformably overlying fourth lithostratigraphic unit, yielding glacially transported cobbles, indeed testifies drastically different climatic conditions, suggesting a long time gap in the stratigraphic record

Plant macrofossils

Macro-palaeobotanical investigations have been carried out since 1992 in the Val Chiusella succession (Martinetto, 1993; Martinetto *et al.*, 1997), where all the outcrops have been carefully scanned in search of plant macrofossil-bearing layers. As a result, nine layers with poorly coalified plant remains have been found along the 75 m thick profile of Sento.

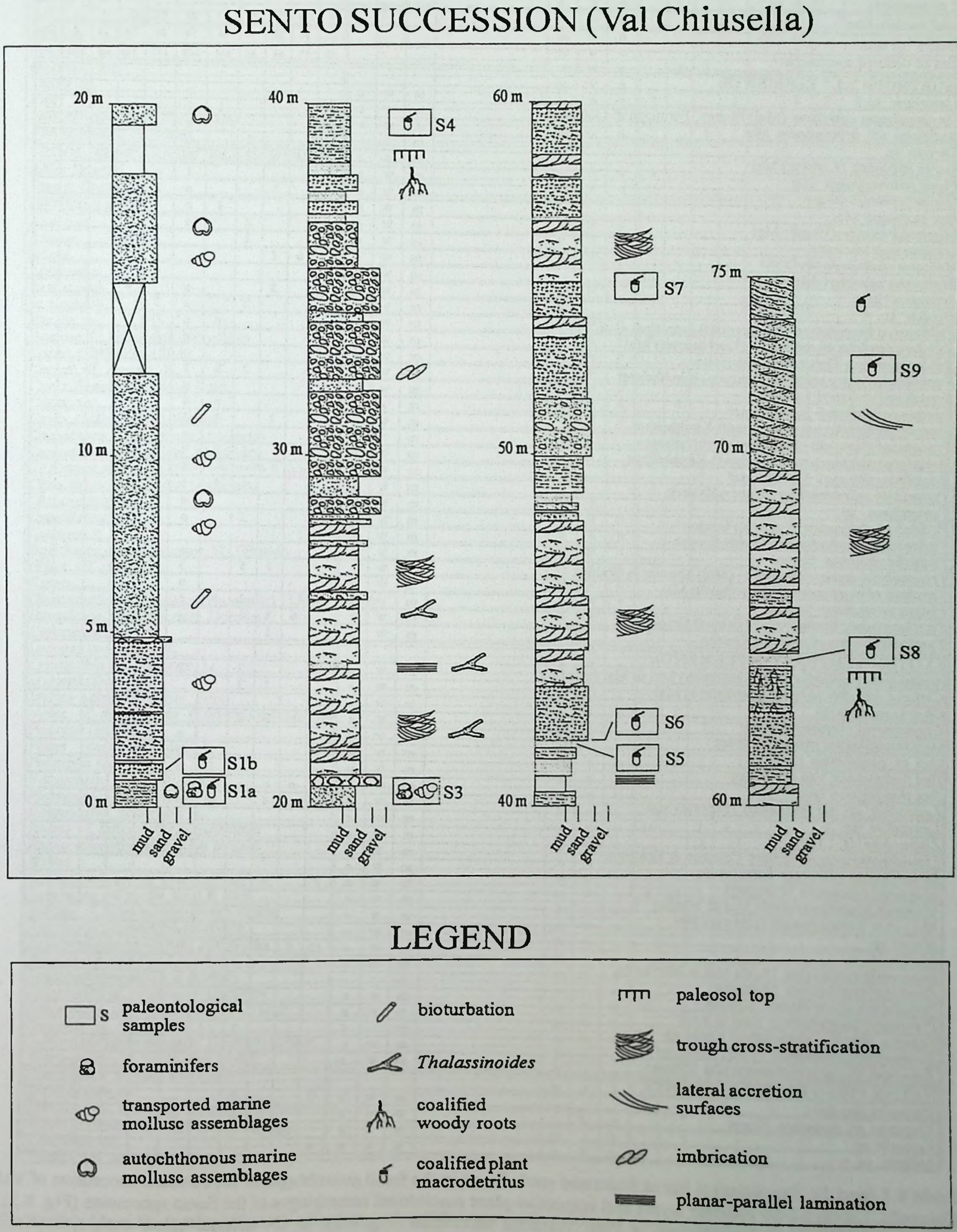


Fig. 8.3. Composite stratigraphic columns of the 75 m-thick Sento succession. The lower part (0-12 m) has been measured in section 2; the remaining part in section 1.

· Pliocene fruits and seeds from Val Chiusella (part 1)	Ecology			Layer/assemblage										
	I	II	III	PT1	S1a	S1b	S2	S4	S5	S6	S7a	S7b	S8	S9
n° of samples				1	1	2	2	2	6	2	5	2	2	3
Total volume (dm^3)				4	2.5	30	14	6.5	22	13	3	4	6	10
Total n° of taxa				22	11	25	30	21	70	26	54	16	8	44
Sum of counted specimens				52	17	68	56	161	268	133	30	48	207	41
"SUBTROPICAL" ELEMENTS:														
Alangium sp.	m	w	e						o					
Cinnamomum costatum (Mai) Pingen, Ferguson & Collinson	m	w	e					1	1	2				2
Distylium aff. *protogaeum* Mai	m	w	e						o					
Ehretia sp.	m	w	e				2		o					
Eurya stigmosa (Ludwig) Mai	m	w	e	2	24	6	2	29	30		3	17		5
Ficus potentilloides Mai	m	w	n	8					1	o				5
"Litsea" sonntagii Gregor	m	w	e	2		3			o	2				
Ilex saxonica Mai	m	w	n					1	o		o			o
Magnolia lignita (Unger) Mai	m	w	e				2		o	1				
Mallotus maii Martinetto	m	w	e	2			2				o			
Meliosma canavesaria Martinetto	m	w	e		6	1								
Meliosma miessleri Mai	m	w	e							o				
Coranaceae? indet.	m	w	n			3			o		o	2		
Ocotea sp. A	m	w	e				2		o	7				
Paleocarya macroptera (Brongniart) Jaenichen *et al.*	m	w						o	o	28				o
Rehderodendron ehrenbergii (Kirchheimer) Mai	m	w	e				o		o	1				
Sabia europaea Czeczott & Skirgiello	m	w	e									o		
Sapindoidea margaritifera (Ludwig) Kirchheimer	m	w					2	9	1				o	
Symplocos casparyi Ludwig	m	w	e						o		o			
Symplocos gothanii Kirchheimer	m	w	e					o	4					
Symplocos lignitarum (Quenstedt) Kirchheimer	m	w	e			1		1	3	3	o			
Symplocos minutula (Sternberg) Kirchheimer	m	w	e						o					
Symplocos salzhausensis (Ludwig) Kirchheimer	m	w	e				5	9	7		o			
Symplocos schereri Kirchheimer	m	w	e						4		3			
Tetraclinis salicornioides (Unger) Kvacek	m	w	n					1	1	37				o
Tetrastigma sp.	m	w	e						o					o
Toddalia latisiliquata (Ludwig) Gregor	m	w	e				2		o	4				
Toddalia naviculaeformis (Reid) Gregor	m	w	e							o		o		
Toddalia rhenana Gregor	m	w	e				7	4	o	2	o			
Trigonobalanopsis exacantha (Mai) Kvacek & Walther	m	w				1	5		3	2	o			o
Turpinia ettingshausenii (Engelhardt) Mai	m	w	e						o					
Visnea germanica Menzel	m	w	e				2	o	1	1				o
Zanthoxylum ailanthiforme (Gregor) Gregor	m	w	e		6	1	4				o			
Zanthoxylum mueller-stollii Gregor	m	w	e			1				o				
EXOTIC "TEMPERATE" ELEMENTS:														
Ampelopsis malvaeformis (Schlotheim) Mai in Mai & Gregor	m	w	e				2	1	1	1	o			
Cathaya van-der-burghii Gossmann in Mai	m	w	e			1	2			1				
Chamaecyparis sp.	m	w	e	2							10	4		
Cryptomeria rhenana Kilpper	m	w	e	10		3	2				o			
Hamamelidoideae gen. et sp. indet.	m	w	e						o					
Ilex cf. *cantalensis* Reid	m	w	n						o					
Ilex fortunensis Van der Burgh	m	w	n					1	o					
Ilex thuringiaca Mai	m	w	n		o	o			o					
Leucothoe aff. *narbonnensis* (Saporta) Mai	m	w	e			4			o					
Leucothoe sp. A	m	w	e						o					
Libocedrus (s. l.) sp.	m	w	e						o					
Liquidambar magniloculata Czeczott & Skirgiello	m	w	e				o		o	5	7			o
Liriodendron geminata Kirchheimer	m	w	e											2
Magnolia allasoniae Martinetto	m	w	e	2		6	20	2	o	3	o		o	o
Mahonia staphyleaeformis Mai & Walther	m	w	e			o		o	o		3			
Meliosma wetteraviensis (Ludwig) Mai	m	w	e										o	
Morus sp.	m	w	e						o					
Myrica sp. A	m	w	e	10	6	43	5	1						
Paulownia cantalensis (Reid) Mai in Martinetto	m	w	e								7	4		5
Phytolacca salsoloides Martinetto	m	?	e						o					
Pseudolarix schmidtgenii Krausel	m	w	e						o		o			
Pterocarya limburgensis Reid & Reid	m	w	e						o	1	o		o	
Sequoia abietina (Brongniart) Knobloch	m		e				2							
Sinomenium cantalense (Reid) Dorofeev	m	w	e						o		3			
Taiwania cf. *paracryptomerioides* Kilpper	m	w	e								o			
NATIVE "TEMPERATE" ELEMENTS:														
Carpinus betulus L.	m	w	n	2			2				10	2		o
Carpinus cf. *europaea* Negru	m	w	n			1	4		o					o
Coriaria sp.	m	w	n		18	3								
Melissa sp.	m	H	n	4										

Table 8.1 (part 1). Taxonomical list of fruits and seeds found in the fossil assemblages of the Pliocene succession of Val Chiusella. Labels S1-S9 indicate layers and respective plant macrofossil assemblages of the Sento succession (Fig. 8.3); PT1 indicates one layer/assemblage of Pian Torinetto succession (Fig. 8.2). In the column below each symbol are reported: a) the number of bulk samples; b) the total volume of sediment analysed; c) the total number of taxa identified; d) the sum of fruits, seeds and related structures counted for the quantitative analysis (continues at the following page).

- Pliocene fruits and seeds from Val Chiusella (part 2)	ECOL.			Layer/assemblage										
NATIVE "TEMPERATE" ELEMENTS (continuated):	I	II	III	PT1	S1a	S1b	S2	S4	S5	S6	S7a	S7b	S8	S9
Ostrya sp.	m	W	n						o					
Quercus cf. *robur* L.	m	W	n									2		2
Quercus sp. A	m	W	n					33	15					
Quercus sp. B	m	W	n					4	6					
Quercus spp.	m	W	n		6	1			o	1	o			
Taxus sp.	m	W	n						1					
Vitis	m	W	n	2			5		1	2	3			
Vitis parasylvestris Kirchheimer	m	W	n			1	2		o					
Vitis teutonica A. Braun	m	W	n			3	2		o		3			
"COOL TEMPERATE" ELEMENTS:														
Abies (leaves)	m	W	n	o					o		o	o		o
Tsuga (leaves)	m	W	e											o
OTHER TAXA:														
Acer spp.	m	W	n						o		o	2		o
Alisma	h	H	n								o	6		2
Alnus	h	W	n					1	o		3	o		7
Apiaceae											7			
Araliaceae	m	W												o
cf. *Staphelia*	m							1	10					o
Betula sp.	m	W	n											o
Boehmeria lithuanica Dorofeev	h	H	e	2							7			o
Carex aff. *fusca* Allioni	h	H	n											o
Carex aff. *remota* L.		H	n						o					
Carex flagellata Reid & Reid	h	H	n								o	o		
Carex sp.	h	H	n		6						o	o	2	o
Carex szaferi Mai & Walther	h	H	n								o			
Carpolithes cucurbitinus Martinetto					6	1				o				
Carpolithes gratioloides Martinetto				27										
Thalictrum minimum (Szafer) Martinetto & Walther						1	2							
Carpolithes montioides Martinetto				2										
Chenopodiaceae	m	H							o					
Cymodocea sp.	a	H	n				2							
Cyperus	h	H	n											o
Dulichium arundinaceum (L.) Britton	h	H	e								o	4		o
Erica aff. *carnea* L.	m	H	n	2										
Fagus	m	W	n				2							
Glyptostrobus europaeus (Brongniart) Unger (seeds)	h	W	e					1	o		o			o
Hypericum cf. *tertiaerum* Dorofeev	h	H	n											o
Hypericum sp.			n	4										
Lycopus europaeus L.	h	H	n										o	2
Lysimachia cf. *vulgaris* L.	h	H	n		6									
Myriophyllum sp.	a	H	n											o
Myrtus paleocommunis Friis	m	W	n						o					
Nyssa cf. *disseminata* (Ludwig) Kirchheimer	h	W	e					2	o		o	o	o	5
Pinaceae (seeds)	m	W							o		7	2		34
Pinus (cones or needles)	m	W	n						o	o	o	o		o
Potentilla supina L.	m	H	n											o
Ranunculus cf. *reidii* Szafer	h	H	n								7			o
Ranunculus gr. *aquatilis* L.	a	H	n									o		
Ranunculus sceleratus L.	h	H	n								7	4		
Rubus cf. *laticostatus* Kirchheimer	m	H	n	10		1	4	1	o		o			o
Rubus microspermus Reid & Reid	m	H	n			4					3			17
Rubus	m	H	n						o		o	2		
Salvinia miocenica Dorofeev	a	H	n											o
Sambucus pulchella Reid & Reid	m	W	n	2	12	3								
Scirpus cf. *tabernaemontani* Gmelin	h	H	n								o		96	o
Selaginella jeannettae Knobloch	m	H	n						o					o
Selaginella kunovicensis Knobloch	m	H	n											o
Selaginella magdae Knobloch	m	H	n											o
Selaginella moravica Knobloch	m	H	n						o					o
Selaginella gr. *pliocenica* Dorofeev	m	H	n							o	o			2
Selaginella aff. *selaginoides* (L.) Link	m	H	n	2										
Solanum cf. *dulcamara* L.	m	W	n								o			
Sorbus herzogenrathensis (Menzel) Gregor	m	W	n						2					
Sparganium cf. *neglectum* Beeby	h	H	n								o	2		o
Sparganium nanum Dorofeev	h	H	n	2					2		o	44		2
Sparganium sp.	h	H	n			1					3			
Spirellea aff. *bohemica* Knobloch & Mai				2			7			o				o
Swida gorbunovii (Dorofeev) Negru		W	n											o
Teucrium sp.	m	H	n											o
Thalictrum sp.	h	H	n								o			

Table 8.1 (part 2). In the columns «Ecology» the following ecological and phytogeographical information for each taxon is reported: I) m = mesic plants; h = hygrophilous; a = aquatic; II) woody (W) or herbaceous (H) plants; III) exotic (e) or native (n) genera. Taxa are listed in alphabetical order within five groups. Numbers in the sample columns indicate the percentage of each taxon (number of specimens of the taxon x 100/total number of specimens). «o» marks indicate taxa with low percentage (< 1%) in bulk samples.

Data on plant macrofossil assemblages have been collected through field observations and sediment bulk sampling. The number of samples collected in each plant macrofossil-bearing layer is much variable, as well as the total sediment volume which has been analysed (Tab. 8.1: 2.5-30 dm^3). When dried, the residues have been weighed and employed to observe the morphological characters of the plant parts, as well as to obtain taxonomical information on the source vegetation. The last target has been mostly achieved through palaeocarpological analyses.

As a whole 26 samples have been qualitatively analysed, and a representative sample for each layer has been selected for quantitative analysis and taxa percentage calculation. All the samples came from the Sento succession, with two exceptions: the sample yielding the S2 assemblage has been collected in a layer of section 4, easily correlatable with the interval around 10 m in the Sento succession; the assemblage PT1 comes from a layer 4 m above the base of section 6 of Pian Torinetto (see Figs. 8.1 and 8.2).

The plant macrofossil taxa gathered from the Pliocene succession of Val Chiusella have been identified by means of the palaeobotanical literature on the Neogene floras of Europe. A complete list of the identified taxa is reported in Table 8.1. They belong to 45 families and 84 genera, listed below according to the systematic order proposed by Takhtajan (1980). The Pteridophyta are represented by macrospores of Selaginellaceae (*Selaginella)* and Salviniaceae (*Salvinia*). Among the gymnosperms, the Pinaceae occur with *Abies, Cathaya, Pinus, Pseudolarix* and *Tsuga.* The Taxodiaceae are represented by *Cryptomeria* , *Taiwania* , *Glyptostrobus* and *Sequoia.* Three genera belong to the Cupressaceae: *Chamaecyparis, Libocedrus* (s. l.) and *Tetraclinis*. The Taxaceae are represented by *Taxus*.

It follows a large number of families and genera of angiosperms. Magnoliaceae: *Liriodendron, Magnolia,* Lauraceae: *Cinnamomum, Litsea?, Ocotea.* Menispermaceae: *Sinomenium.* Berberidaceae: *Mahonia.* Ranunculaceae: *Ranunculus, Thalictrum.* Hamamelidaceae: *Distylium,* Hamamelidoideae gen. et sp. indet., *Liquidambar.* Moraceae: *Ficus, Morus.* Urticaceae: *Boehmeria.* Fagaceae: *Fagus, Quercus* and *Trigonobalanopsis.* Betulaceae: *Alnus, Betula, Carpinus* and *Ostrya.* Myricaceae: *Myrica,* Juglandaceae: *Palaeocarya, Pterocarya.* Phytolaccaceae: *Phytolacca.* Chenopodiaceae gen. et sp. indet.. Theaceae: *Eurya, Visnea.* Guttiferae: *Hypericum.* Ericaceae: *Erica, Leucothoe.* Styracaceae: *Rehderodendron.* Symplocaceae: *Symplocos.* Primulaceae: *Lysimachia.* Euphorbiaceae: *Mallotus.* Rosaceae: *Potentilla, Rubus* and *Sorbus.* Myrtaceae: *Myrtus.* Haloragaceae: *Myriophyllum.* Rutaceae: *Toddalia, Zanthoxylum.* Staphyleaceae: *Turpinia.* Aceraceae: *Acer.* ?Sapindaceae: *Sapindoidea.* Sabiaceae: *Meliosma, Sabia.* Nyssaceae: *Nyssa.* Alangiaceae: *Alangium.* Cornaceae: *Swida.* Araliaceae: Araliaceae gen. et sp. indet.. Aquifoliaceae: *Ilex.* Vitaceae: *Ampelopsis, Vitis* and *Tetrastigma.* Caprifoliaceae: *Sambucus.* Boraginaceae: *Ehretia.* Lamiaceae: *Lycopus, Melissa, Teucrium.* Bignoniaceae: *Paulownia.* Alismataceae: *Alisma.*

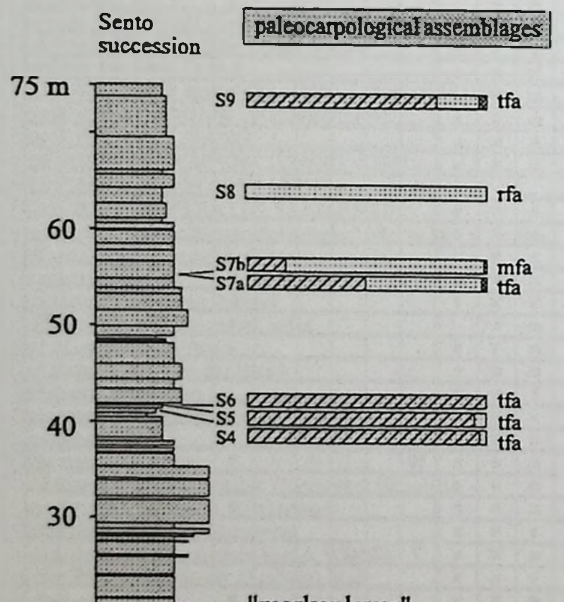


Fig. 8.4 - Bar-diagram displaying the percentage of specimens of mesic, hygrophilous and aquatic plants in the palaeocarpological assemblages S1-S9 of the Sento succession.

Potamogetonaceae: *Potamogeton.* Cymodoceaceae: *Cymodocea.* Cyperaceae: *Carex, Cyperus, Dulichium, Scirpus*. Typhaceae: *Sparganium.* Poaceae gen. et sp. indet.. Incertae sedis: *Carpolithes, Spirellea.*

Taphonomical and palaeoecological analysis (plants)

The taphonomical and palaeoecological interpretation of plant macrofossil assemblages has been based: *a)* on the arrangement, preservation state and abundance of plant macrofossils, as observed in the field; *b)* on the auto- and synecological information available for Recent relatives, as the large majority of the recovered fossil taxa belong to living genera; *c)* on the ratio of reproductive structures belonging to mesic, hygrophilous and aquatic plants in the residues of bulk samples (Fig. 8.4). The *a*, *b* and *c* type of information have been exploited for an integrated analysis, that deserves to be treated in detail for each plant-bearing layer of the Sento succession.

In the basal part of the succession, the layers which provided the assemblages S1a, S1b and S2 are made up by bioturbated silty sands. These sediments are characterised by a very low volumetric density of coalified plant macrofossils (< 5g/dm^3), dominated by abraded and partly round-edged wood fragments, often bearing *Teredolithes* borings. Also many fruit or seed specimens, whose size varies from 0.3 to 30 mm, are abraded. Leaf parts occur in subcentimetric fragments and no roots «*in situ*» have been noticed in the 21 basal meters of the Sento Succession. The palaeocarpological analysis shows that assemblages S1a, S1b and S2 are dominated by mesic terrestrial plants (Fig. 8.4). Actually, *Myrica* sp. A (43% in S1b) may also be considered a hygrophilous plant; in this case the percentage of hygrophilous taxa in S1b would grow up to 50%.

In consideration of the abundant record of marine invertebrates preserved in the basal portion of the Sento succession (Figs 8.1 and 8.3), S1a, S1b and S2 can be interpreted as transported fossil assemblages, made up by plant macrodetritus produced in emerged terrestrial conditions and drifted in the marine basin. Two *Cymodocea* fruits in S2 testify the existence of seagrass communities.

The layer S3 does not contain plant macrofossils, and the next fertile layer S4, made up by sandy muds with rare pebbles up to 20 mm, has been sampled in the third lithostratigraphic unit. The layer shows no sedimentary structures, but also traces of bioturbation are lacking. The volumetric density of plant macrofossils is rather high (about 40 g/dm^3), mostly due to the abundance of woody axes fragmented in 10-50 mm long segments, not abraded. Fruit or seed specimens are not abraded and also brittle structures are perfectly preserved. The size of the recovered specimens varies from 0.3 to 12 mm. Leaf fragments larger than 1 mm are very frequent, but just a few whole leaves have been observed in the field. No roots have been observed in layer S4, but the underlying one bears large root compressions (100-220 mm in cross section) and many smaller-sized root impressions, surely «*in situ*». The palaeocarpological assemblage S4 is dominated by taxa considered mesic terrestrial plants (Fig. 8.4), which points to exclude any autochthonous burial of the plant remains (hygrophilous and aquatic plants should be dominant, see Collinson, 1983). It can be concluded that the plant macrodetritus of the S4 assemblage, produced in emerged terrestrial conditions, has been drifted to the deposition site. The transport should have been short and probably as suspension load, since only fragmentation and no abrasion has been operated on plant remains.

The assemblages S5 and S6 have been extracted by layers mostly made up by middle to coarse cross-bedded sands, and subordinately by fine gravel and mud. The volumetric density of plant macrofossils is rather high (70 g/dm^3 in S5, 10 g/dm^3 in S6), mostly due to the abundance of sharp-edged woody fragments. Fruits and seeds are rather frequent and rarely abraded. The size of the specimens recovered in assemblages S5 and S6 varies from 0.3 to about 25 mm, but specimens larger than 5 mm are dominant. Leaf fragments are rare, silty lenses excepted, where also whole leaves have been observed in the field. Despite the presence of coalified woody roots (10-20 mm in cross section) in an underlying muddy layer, S5 and S6 are interpreted as transported assemblages. This conclusion is supported by the tractive structures observed in the coarse-grained embedding sediments, by the fragmentation and size-sorting of plant remains and by the dominance of mesic plants in the palaeocarpological assemblages (Fig. 8.4).

As a whole, the S4, S5 and S6 transported assemblages provide abundant palaeofloristic information on extra-local plant communities and allow to frame the Sento assemblages within the palaeofloristic units recently established for the Italian Pliocene (Martinetto, 1995).

The next deposit containing poorly coalified plant remains (S7) corresponds to a 50 cm thick interval of blackish sediments, cropping out on a steep inaccessible wall. Blocks fallen down at the base of the wall allowed to recognise two different lithologies: middle to fine muddy sands (S7a) and laminated sandy muds with rare, small sized «*in situ*» roots (S7b). Signs of bioturbation are lacking (root excluded). The volumetric density of plant macrofossils is very variable in different samples (10-30 g/dm^3). Woody axes make up the bulk of the residue; in S7a they are much fragmented and sometimes evidently abraded; in S7b very thin twigs are often preserved as specimens longer than 100 mm (field observation). Also leaf fragments shorter than 10 mm are frequent in the residue, and whole leaves have been observed in the muddy sediments (S7b). Coniferous needles are particularly frequent. The palaeocarpological assemblages S7a and S7b are characterised by a higher percentage of hygrophilous plants in comparison with the underlying layers. The dominance of such plants together with the presence of roots and the scarce fragmentation of brittle elements (Fig. 8.4), allows to consider S7b as a mixed fossil assemblage. The remains of mesic plants, which could not live in the same environmental conditions as the dominant hygrophilous ones, were transported into the depositional environment from better drained areas. On the other hand, the assemblage S7a, preserved in sandy sediments, can be interpreted as transported, for the same reasons already expressed above for S5 and S6.

In conclusion, the S7b assemblage provides a documentation of a local plant community. The palaeocarpological percentages (Tab. 8.1) suggest that the herbs *Sparganium nanum, Alisma* sp., *Ranunculus sceleratus* and *Sparganium* cf. *neglectum* were its most important constituents. Additionally, *Carex* spp., *Dulichium arundinaceum* and *Ranunculus* gr. *aquatilis* might be part of such plant community. These species are indicative of a sedge marsh or reed vegetation («Rörichten und Groβseggen Sümpfe»: Mai, 1985) developed in freshwater conditions. Only *Ranunculus sceleratus* can tolerate brackish conditions. The rare remains of hygrophilous trees (*Alnus, Glyptostrobus* and *Nyssa*) are not significant to demonstrate their presence in the autochthonous palaeovegetation.

The assemblage S8 comes from a laminated muddy layer rich in poorly coalified plant macrofossils, located around 63.5 m in the Sento succession. The volumetric density of plant macrofossils approximates 15 g/dm^3; segmented rhizomes, fine stems and leaf fragments of monocotyledons are dominant. Woody fragments and leaves of dicotyledons have also been observed. The palaeocarpological assemblage S8 is nearly monotypic, because *Scirpus* cf. *tabernaemontani* makes up 96% of the recovered specimens. This is indeed an hygrophilous species which dominated the autochthonous palaeocommunity, probably including also *Carex* sp. and Poaceae. It is difficult to admit that the taxonomical record of the «*in situ*» ancient plant community could have been so heavily biased by taphonomical processes to include only three taxa. Therefore this oligotypic assemblage can be interpreted as the result of unfavourable palaeoecological factors, possibly by instable brackish water conditions, which are tolerated by the living *Scirpus tabernaemontani* (Mai, 1985). The trees *Magnolia allasoniae* and *Nyssa* cf. *disseminata*, whose seeds have been found in S8, probably grew at some distance from the deposition site. *Sapindoidea margaritifera* and *Meliosma wetteraviensis*, though reported under S8 in Table 8.1, have been collected in a fine sandy layer a few centimetres above.

The symbol S9 has been employed for two plant macrofossil assemblages sampled in adjacent layers, belonging to the 69 to 75 m portion of the Sento succession. The cross-laminated fine to very fine silty sands are not bioturbated and contain coalified plant macrofossils (15 g/dm^3): thin wood fragments (< 10 mm), badly preserved angiosperm leaves and needles of Pinaceae. Sporadic large logs (100-200 mm in diameter) with unidentified borings of biotic origin have been observed in the field. The palaeocarpological assemblage S9 is dominated by mesic terrestrial plants (Fig. 8.4). If we add that no rooting structures have been observed, and most plant remains are finely fragmented, it can be concluded that S9 is a transported assemblage of terrestrial plant remains. The few recovered hygrophilous (*Alnus, Alisma, Cyperus, Lycopus, Nyssa, Sparganium*) and aquatic plants (*Myriophyllum, Salvinia*) are indicative of freshwater environments, whereas the only species tolerating brackish conditions is *Scirpus* cf. *tabernaemontani*, actually very rare in this layer.

Palaeoclimatical analysis

The palaeoclimatical conditions have been reconstructed on a floristic base, by analysing the climatical constraints which control the distribution of the Recent relatives of the Val Chiusella fossil plants. Two groups of palaeoclimate indicators have been recognised in the Val Chiusella assemblages:

- "tropical-subtropical" elements. Genera growing in intertropical types of vegetation but also passing into the «subtropical vegetation zone» of SE Asia (Hou, 1983) or even exclusive of it. As the bulk of the Val Chiusella taxa corresponds to genera of the wet subtropics of Asia and America (*Meliosma, Symplocos,* Theaceae, etc.), this group will be shortly called the «subtropical elements».
- «temperate» elements. Genera with a distribution centred in the «mid» temperate belt of the Boreal hemisphere, with more or less broad latitudinal extension (*Acer, Fagus, Liriodendron,* etc.). Their range partly overlaps the one of the foregoing group.

«Cool-temperate» elements are insignificant in the Sento assemblages: sporadic *Abies* and *Tsuga* remains can be explained admitting long distance transport from the nearby Alps. Alternatively, the presence of rare heterotopic specimens in lowland places, warmer than their usual habitat, must be inferred.

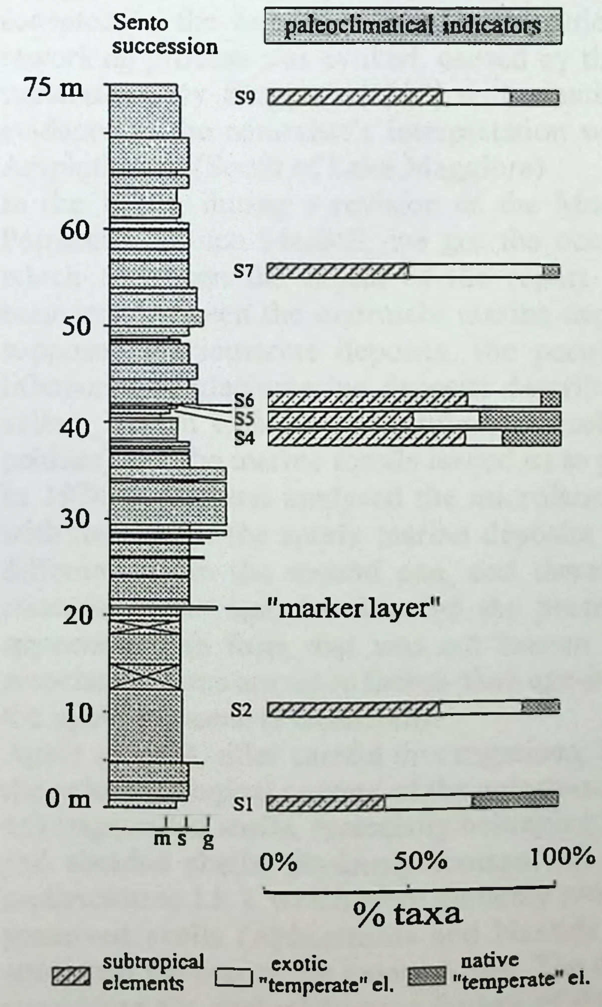


Fig. 8.5 - Bar-diagram displaying the percentage of taxa of «subtropical», exotic and native «temperate» elements in the palaeocarpological assemblages S1-S9 of the Sento succession.

The palaeoclimatical reconstruction has been based on the analysis of the percentage of taxa belonging to each group of palaeoclimate indicators. Non-significative taxa have been excluded from the total number of taxa, as well as hygrophilous and aquatic plants, since they conceal the palaeoclimatical signal better evidenced by mesic plants.

The ratio of «subtropical» versus «temperate» elements is shown in Fig. 8.5, where the «temperate» genera still present in the native European flora have been separated from those extinct in Europe («exotic»). The fact that the percentage of «subtropical» elements exceeds the 40% in all the Sento assemblages represents a highly significant datum. Its moderate variations (+/- 15%) can be the cause of multiple factors: palaeoecological (differences between plant communities), taphonomical (e.g.: size selection of plant remains, width of the source area) and palaeoclimatical ones (temperature change). If we consider that analogous percentage variations occur in different samples of the same layer (Martinetto, unpublished data) or in adjacent layers (see Fig. 8.5 for values in layers S4 and S5), it must be concluded that on the ground of these small-scale variations no climatical change can be demonstrated from the bottom to the top of the

Sento succession.

From the floristic point of view, the co-occurrence of *Alangium, Cinnamomum, Cryptomeria, Eurya, Fagus, Liquidambar, Magnolia, Meliosma, Symplocos, Ternstroemia* and *Turpinia* in the Val Chiusella assemblages suggests an analogy with Recent communities of the "Evergreen Broad-Leaved Forest" of SE Asia (Wang, 1961; Hou, 1983), which can be exploited as an actualistic model for palaeoclimatic reconstruction.

Actually the climatic indications of the Sento floras are wholly comparable to those Benasso, Breolungi, Candelo, Castellengo, Ca' Viettone, Crava di Morozzo, Pocapaglia, Ronco Biellese (Fig. 1.2), grouped in the Ca' Viettone «Florenkomplex», whose climatic interpretation is reported in chapter 1.

MARTINETTO E., BASILICI G., PAVIA G., VIOLANTI D. - Key-site 5: the Val Chiusella Pliocene succession. *In* MARTINETTO E. (ed.): Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.4 (2001): 45-56.

9. THE PROBLEM OF THE «PLIOCENE GLACIOMARINE DEPOSITS OF VAL CHIUSELLA»: STATE OF THE ART - by F. CARRARO

The tormented history of the «Pliocene glaciomarine deposits of Val Chiusella» is emblematic of a certain way of conducting geological researches, which was largely employed since a few years ago, and is not yet totally abandoned: the approach and the development of the research have been heavily conditioned by the rage for suggesting new interpretations or, on the contrary, by the dogmatism, which caused a freezing of the knowledge. In this perspective, data analysis is biased in favour of the evidences which are congruent with the preferred interpretation, and against the ones which are in disagreement.

In 1877, the hobby naturalist and building surveyor Luigi Bruno of Ivrea, in one of his many papers on the Morainc Amphitheatre of Ivrea, reported the presence of a formation with peculiar characters in the deep incision of Val Chiusella, which was in between the Pliocene marine sediments and the glacial deposits of the amphitheatre. Such formation showed the contemporary presence of marine fossils and faceted and striated pebbles, therefore it was interpreted by Bruno as a glaciomarine deposit of Pliocene age.

The scientific establishment of that time (F. Sacco and B. Gastaldi) definitely rejected Bruno's interpretation, which was heterodox in the frame of the Pliocene palaeoclimatic model, universally accepted in the late XIX century. In order to explain the fossil content of such formation, a reworking process was evoked, caused by the «Balteo» glacier when eroding the formations of the substrate. Only Stoppani (1880) enthusiastically agreed with Bruno, even bringing an additional evidence to the naturalist's interpretation with the description of similar deposits in the Verbano Amphitheatre (South of Lake Maggiore)

In the 1970s, during a revision of the Morainc Amphitheatre of Ivrea, with the friends Franco Petrucci e Franco Medioli, we got the occasion to visit the «Borra Grande» (= Sento) outcrop, which had been the object of the report by Bruno: the seemingly stratigraphic nature of the boundary between the «normal» marine deposits of the Pliocene and the overlying ones, i. e. the supposed glaciomarine deposits, the peculiar lithofacies of the last ones (very similar to the lithofacies of glaciomarine deposits described by Armstrong & Brown (1954) in the Fraser River valley, British Columbia: stratified, scarcely coherent, and rich in smooth, faceted, and striated pebbles) and the marine fossils leaded us to propose again Bruno's interpretation.

In 1974 F. Barbieri analysed the microfaunal content of the foregoing unit and, by comparing it with the one of the surely marine deposits below, he concluded that the first one was «markedly different» from the second one, and therefore it cannot be its reworked product. In particular, concerning the age, he detected the presence, sometimes with a good frequency, of *Bolivina appenninica* (a form that was not known later than Pliocene) and concluded that: «though the associated forms are more facies- than age-indicators» .... «as a whole they occur more frequently in the upper Pliocene (Piacenzian)».

Again in 1974, after careful investigations, P.G. Caretto (see Carraro *et al.*, 1974) distinguished in the palaeontological content of the «glaciomarine» three components:

«1) fragmented shells, essentially belonging to small and medium-sized Gasteropods; 2) fragmented and abraded shells, obviously transported, mostly belonging to large-sized species (e. g. *Venus pedemontana* Lk.), which were certainly reworked from the underlying marine formation; 3) better preserved shells (Aphorrhaids and Nassids [sic!]): the Aphorraids in particular had preserved a consistent portion of the external lip». The oligotypic component at point 3 had been preliminarily considered the «autochthonous fauna» of the same sediment, testifying the deposition on a marine bottom.

In 1982, with a graduation thesis surveyed by Arturo Paganelli, Eliana Cerchio analysed the palynological content of the supposed «glaciomarine», which was considered «sufficiently meaningful». The pollen flora included «Tertiary elements» which experienced a progressive extinction between the end of the Pliocene and the lower Pleistocene (*Ginkgo*, *Taxodium*, *Sciadopitys, Liriodendron, Cephalotaxus, Sequoia, Microcachrys, Pseudolarix, Cedrus, Tsuga, Keteleeria, Trachycarpus, Liquidambar, Engelhardtia*, etc., and also *Pinus haploxylon* type), so the age of the deposit was deduced to be «certainly earlier than Pleistocene..... since it is possible to exclude whatever contamination of the palynoflora because the pollen grains are prevalently well preserved and the contamination would not be in agreement with the mainly Pliocene composition of the palynoflora». In addition, the «considerable presence of alpine phytoclimate.... seems to testify a deposition in cold climatic conditions». In conclusion, «the abundance of plants growing in wetlands, such as *Microcachrys, Taxodium, Liquidambar*, together with *Sabbatia, Triglochin* and *Cyperaceae* .... induce to believe that the sedimentation took place in a sub-aquatic environment». In particular, «the presence of *Triglochin, Artemisia*, Chenopodiacee and *Sabbatia*, groups which include both freshwater and halophytic forms whose palynological distinction is impossible», led Cerchio to conclude that «the sedimentation took place in brackish water surrounded by a mainland covered by wetlands».

In the meantime, in the world's geological literature began to assume definition the Pliocene climatic deterioration, which today is positioned around 2.5÷2.4 my; this circumstance gave further support to the interpretation initially proposed by Bruno.

At the beginning of the 1990s Elena Zanella started the palaeomagnetic study of the succession encompassing the boundary between the «normal» marine deposits of the Pliocene and the supposed glaciomarine ones: Her main aim was to verify the effectively stratigraphic nature of the boundary, and not to obtain chronological information. However, the grain size of the foregoing deposits was found to be unsuitable for this kind of investigation.

But Franco Gianotti in 1992 thought to upset the apple-cart: in his graduation thesis on the evolution of the left lateral portion of the Morainc Amphitheatre of Ivrea, he found and described a formation with the same features of the «glaciomarine» of Val Chiusella, but in this case below the formation there was an alluvial gravely formation with a decidedly well-developed palaeosol on the top, i. e. a certainly continental deposit. This situation necessarily implies that the deposition of the supposed «glaciomarine», unlike the Val Chiusella situation, should have been preceded by a regression, whose entity and duration permitted the sedimentation of the gravely continental formation and the development of the palaeosol (in analogy with the Quaternary soils of Piedmont: a few hundreds of ky).

The fact that Pliocene regression-transgression cycles had not been detected in Piedmont at that time, made the «Pliocene glaciomarine» absolutely inconsistent with the regional geologic context.

However, Cavalli & Vigna (1995), in a recent study of the underground of the southern Piedmont plain, described an unconformity, within the Pliocene succession, which they interpreted as the product of a temporary, rapid regression. This new evidence, concerning a geochronologic interval for which updated revisions are available for just a few sites, seems to open the discussion again.

An additional datum, which seems to go in the same direction, is the acknowledged presence of Pliocene glacial deposits (continental, in this case) in the section of Val Fornace near Varese, Lombardy, (see Uggeri, 1994; 1995).

At this point it seems to me right to declare that, personally, I gave up to support Bruno's hypothesis rather then another one. I believe it is time to start a multidisciplinary study, away from the conditioning of interpretative models, which should start from an extremely accurate geological survey. About this, it must be emphasised that the number and quality of the outcrops on the right slope of the Chiusella valley was very scarce in the past. Furthermore, the outcrops were ephemeral, so that those studied by each author did not coincide with the ones studied by the foregoing ones, and this situation had a relevant role in the development of the tormented history I told.

The intense flooding event of November 1994 produced a wide denudation of the continuous and impenetrable plant cover, and the present situation can finally permit a reliable survey.

CARRARO F. - The problem of the «Pliocene glaciomarine deposits of Val Chiusella»: state of the art. *In* MARTINETTO E. (ed.): Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.4 (2001): 57-58.

Pliocene deposits north of Torino

10. KEY-SITE 6: THE RICH PALAEOFLORA OF THE CA' VIETTONE SUCCESSION - by R. BERTOLDI & E. MARTINETTO

In the vicinity of Levone Canavese (25 km north of Torino, NW Italy) the Ca' Viettone brook erodes a succession of alluvial fan sediments (Allason *et al.*, 1981) including many lithotypes: muds, sands, and gravels. Only the basal part of the outcropping succession (5 m), which yields abundant plant remains with a low-rank coalification («mummified»), proved to be suitable for palaeocarpological and palynological analyses. In the overlying layers the organic matter has been oxidised. The results of the palaeocarpological and palynological analyses have been compared in order to get a better palaeofloral documentation.

Fruits and seeds have been gathered through bulk sampling and surface picking in twenty-one outcrops, lying between sections 1 and 21, nearly 1 km along the bed of the brook (Fig. 10.1). All of the recovered assemblages are interpreted as the record of the same, extremely rich, palaeoflora. This includes 130 taxa (Tab. 10.1), belonging to 41 exotic genera and 48 native ones (Martinetto, 1995; Bertoldi & Martinetto, 1995).

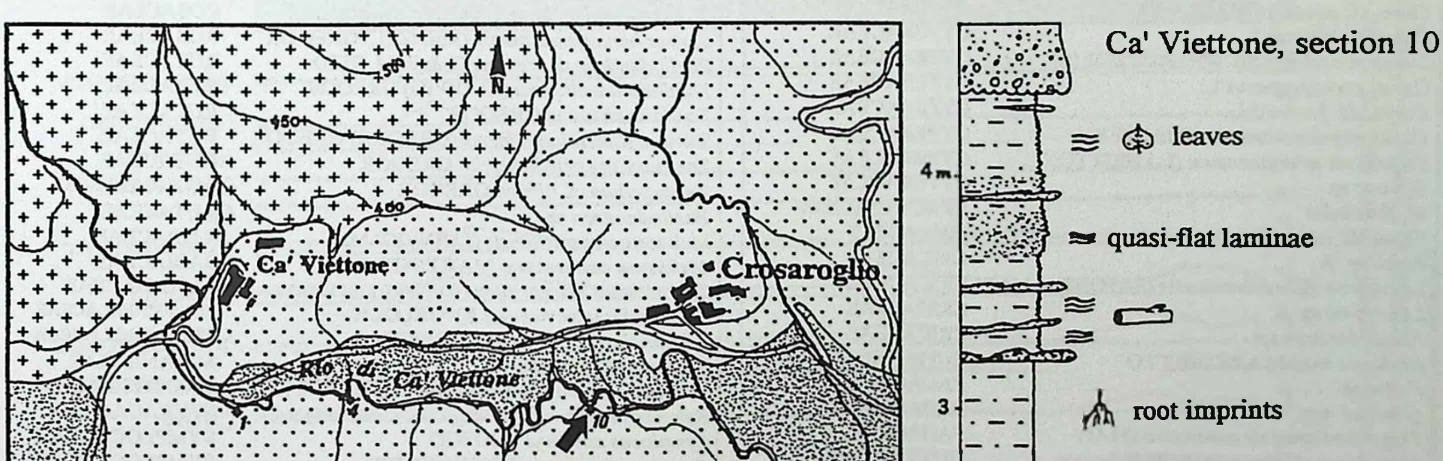


Fig. 10.1. Simplified geologic map of the Ca' Viettone site. The asterisks indicate the position of the sections where palaeobotanical sampling has been carried out; the arrow indicates section 10, whose stratigraphic column is shown to the right. W= Intenza Well.

LIST OF TAXA	FAMILY
Acer (sect. *Platanoidea*)	ACERACEAE
Actinidia sp.	ACTINIDIACEAE
Alisma sp.	ALISMATACEAE
Oenanthe sp. A	APIACEAE
Ilex cf. *cantalensis* REID	AQUIFOLIACEAE
Ilex cf. *fortunensis* VAN DER BURGH	AQUIFOLIACEAE
Ilex saxonica MAI	AQUIFOLIACEAE
Ilex thuringiaca MAI	AQUIFOLIACEAE
Aralia sp.	ARALIACEAE
Mahonia staphyleaeforme MAI & WALTHER	BERBERIDACEAE
Alnus sp.	BETULACEAE
Carpinus betulus L.	BETULACEAE
Carpinus cf. *europaea* NEGRU	BETULACEAE
Paulownia cantalensis MAI in MARTINETTO	BIGNONIACEAE
Ehretia sp.	BORAGINACEAE
Capparaceae gen. et sp. indet.	**CAPPARIDACEAE**
Sambucus pulchella C. & E.M. REID	CAPRIFOLIACEAE
Swida aff. *gorbunovii* DOROFEEV	CORNACEAE
Swida discimontana MAI	CORNACEAE
?Cornaceae indet.	**CORNACEAE?**
Chamaecyparis sp.	CUPRESSACEAE
Tetraclinis salicornioides (UNGER) KVACEK	CUPRESSACEAE
Carex cf. *aquatilis* WALENBG.	CYPERACEAE
Carex cf. *loliacea* L.	CYPERACEAE
Carex paucifloroides WELICZKIEWICZ	CYPERACEAE
Carex pseudocyperus L.	CYPERACEAE
Carex aff. *fusca* ALL.	CYPERACEAE
Cladium paleomariscus DOROFEEV	CYPERACEAE
Dulichium arundinaceum (L.) BRITTON	CYPERACEAE
Scirpus sp.	CYPERACEAE
cf. *Staphelia*	**EPACRIDACEAE**
Erica aff. *carnea* L.	ERICACEAE
Erica sp. A	ERICACEAE
Leucothoe aff. *narbonnensis* (SAPORTA) MAI	ERICACEAE
Leucothoe sp. A	ERICACEAE
Rhododendron sp.	ERICACEAE
***Mallotus maii* MARTINETTO**	EUPHORBIACEAE
Fagus sp.	FAGACEAE
Quercus spp.	FAGACEAE
Trigonobalanopsis exacantha (MAI)	FAGACEAE
Hypericum cf. *tetrapterum* FRIES	GUTTIFERAE
Hypericum sp. C	GUTTIFERAE
Hypericum sp. D	GUTTIFERAE
Proserpinaca reticulata C. & E. M. REID	HALORAGACEAE
Distylium aff. *protogeum* MAI	HAMAMELIDACEAE
Hamamelidoideae gen. et sp. indet.	HAMAMELIDACEAE
Liquidambar magniloculata CZECZOTT	HAMAMELIDACEAE
Carpolithes cucurbitinus MARTINETTO	INCERTAE SEDIS
Carpolithes gratioloides MARTINETTO	INCERTAE SEDIS
Carpolithes montioides MARTINETTO	INCERTAE SEDIS
Carpolithes sp. A-E (5 specie)	INCERTAE SEDIS
cf. *Ostrya*	INCERTAE SEDIS
***Spirellea* sp.**	INCERTAE SEDIS
Juglans bergomensis (BALSAMO-CRIVELLI)	JUGLANDACEAE
Palcocarya macroptera (BRONGNIART) JAENICHEN et al.	JUGLANDACEAE
Pterocarya sp.	JUGLANDACEAE
Ajuga antiqua C. & E. M. REID	LAMIACEAE
Lamiaceae gen. et sp. indet. C	LAMIACEAE
Lycopus europaeus L.	LAMIACEAE
Melissa sp. A	LAMIACEAE
Mentha sp.	LAMIACEAE
Cinnamomum costatum (MAI) PINGEN et al.	LAURACEA
cf. *Lindera*	LAURACEAE
Ocotea sp. A	LAURACEAE
Phobe sp.	LAURACEAE
***Litsea sonntagii* GREGOR**	**LAURACEAE**
Liriodendron geminata KIRCHHEIMER	MAGNOLIACEAE
Magnolia allasoniae MARTINETTO	MAGNOLIACEAE
Magnolia lignita (UNGER) MAI	MAGNOLIACEAE
Cyclea palatinati-bavariae GREGOR	MENISPERMACEAE
Sinomenium cantalense (REID) DOROFEEV	MENISPERMACEAE
Ficus potentilloides MAI	MORACEAE
Myrtus paleocommunis FRIIS	MYRTACEAE
Nuphar cf. *canaliculatum* C. & E. M. REID	NYMPHAEACEAE
Nyssa disseminata (LUDWIG) KIRCHHEIMER	NYSSACEAE
Abies sp. (foglie)	PINACEAE
Cathaya van-der-burghii GOSSMANN	PINACEAE
Pinus cf. *massalongii* SISMONDA	PINACEAE
Pinus cf. *spinosa* HERBST	PINACEAE
Pinus hampeana (UNGER) HEER	PINACEAE
Pinus peuce GRISEBACH	PINACEAE
Polygonum sp.	POLYGONACEAE
Potamogeton cf. *polymorphus* DOROFEEV	POTAMOGETONACEAE
Ranunculus cf. *tanaiticus* DOROFEEV	RANUNCULACEAE
Frangula cf. *solitaria* GREGOR	RHAMNACEAE
Rubus cf. *laticostatus* KIRCHHEIMER	ROSACEAE
Rubus microspermus C. & E. M. REID	ROSACEAE
Rubus semirotundatus LANCUCKA-SRODONIOWA	ROSACEAE
Sorbus herzogenrathensis (MENZEL) GREGOR	ROSACEAE
Phellodendron cf. *elegans* C. & E. M. REID	RUTACEAE
Toddalia latisiliquata (LUDWIG) GREGOR	RUTACEAE
Toddalia rhenana GREGOR	RUTACEAE
Zanthoxylum ailanthiforme (GREGOR) GREGOR	RUTACEAE
Zanthoxylum mueller-stollii GREGOR	RUTACEAE
Zanthoxylum cf. *tiffneyi* GREGOR	RUTACEAE
***Phellodendron* sp.**	RUTACEAE
Meliosma wetteraviensis (LUDWIG) MAI	SABIACEAE
***Meliosma canavesana* MARTINETTO**	SABIACEAE
Sapindoidea margaritifera (LUDWIG) KIRCHHEIMER	SAPINDACEAE
Selaginella kunovicensis KNOBLOCH	SELAGINELLACEAE
Selaginella moravica KNOBLOCH	SELAGINELLACEAE
Solanum cf. *dulcamara* L.	SOLANACEAE
Turpinia cf. *ettingshausenii* (ENGELHARDT) MAI	STAPHYLEACEAE
Rehderodendron ehrenbergii (KIRCHHEIMER) MAI	STYRACACEAE
Symplocos casparyi LUDWIG	SYMPLOCACEAE
Symplocos gothanii KIRCHHEIMER	SYMPLOCACEAE
Symplocos lignitarum (QUENSTEDT) KIRCHHEIMER	SYMPLOCACEAE
Symplocos salzhausensis (LUDWIG) KIRCHHEIMER	SYMPLOCACEAE
Symplocos schereri KIRCHHEIMER	SYMPLOCACEAE
Symplocos sp. A	SYMPLOCACEAE
***Symplocos schereri* KIRCHHEIMER**	SYMPLOCACEAE
Cryptomeria rhenana KILPPER	TAXODIACEAE
Sequoia abietina (BRONGNIART) KNOBLOCH	TAXODIACEAE
Taiwania sp.	TAXODIACEAE
Eurya stigmosa (LUDWIG) MAI	THEACEAE
Hartia quinqueangularis (MENZEL) MAI	THEACEAE
Ternstroemia reniformis (CHANDLER) MAI	THEACEAE
Visnea germanica MENZEL	THEACEAE
Craigia bronnii (UNGER) KVACEK et al.	TILIACEAE
Sparganium nanum DOROFEEV	TYPHACEAE
Boehmeria lithuanica DOROFEEV	URTICACEAE
Viola sp.	VIOLACEAE
Ampelopsis malvaeformis (SCHLOTHEIM) MAI	VITACEAE
Tetrastigma chandlerae KIRCHHEIMER.	VITACEAE
Vitis parasylvestris KIRCHHEIMER	VITACEAE
Vitis teutonica A. BRAUN	VITACEAE

Table 10.1 - Updated list of carpological taxa found in the Cà Viettone site. Taxa to be escluded (Bertoldi & Martinetto, 1995): *Arctostaphyloides* cf. *menzelii* KIRCHHEIMER (Ericaceae), cf. *Girroniera* (Ulmaceae), Menispermaceae gen. et sp. indet., *Nyssa sibirica* DOROFEEV (Nyssaceae), *Phellodendron lusaticum* KIRCHHEIMER (Rutaceae), *Symplocos wiesaensis* KIRCHHEIMER (Symplocaceae) and *Spirellea* aff. *bohemica* KNOBLOCH & MAI (Incertae sedis). The names of recently revised/detected taxa are marked in bold type.

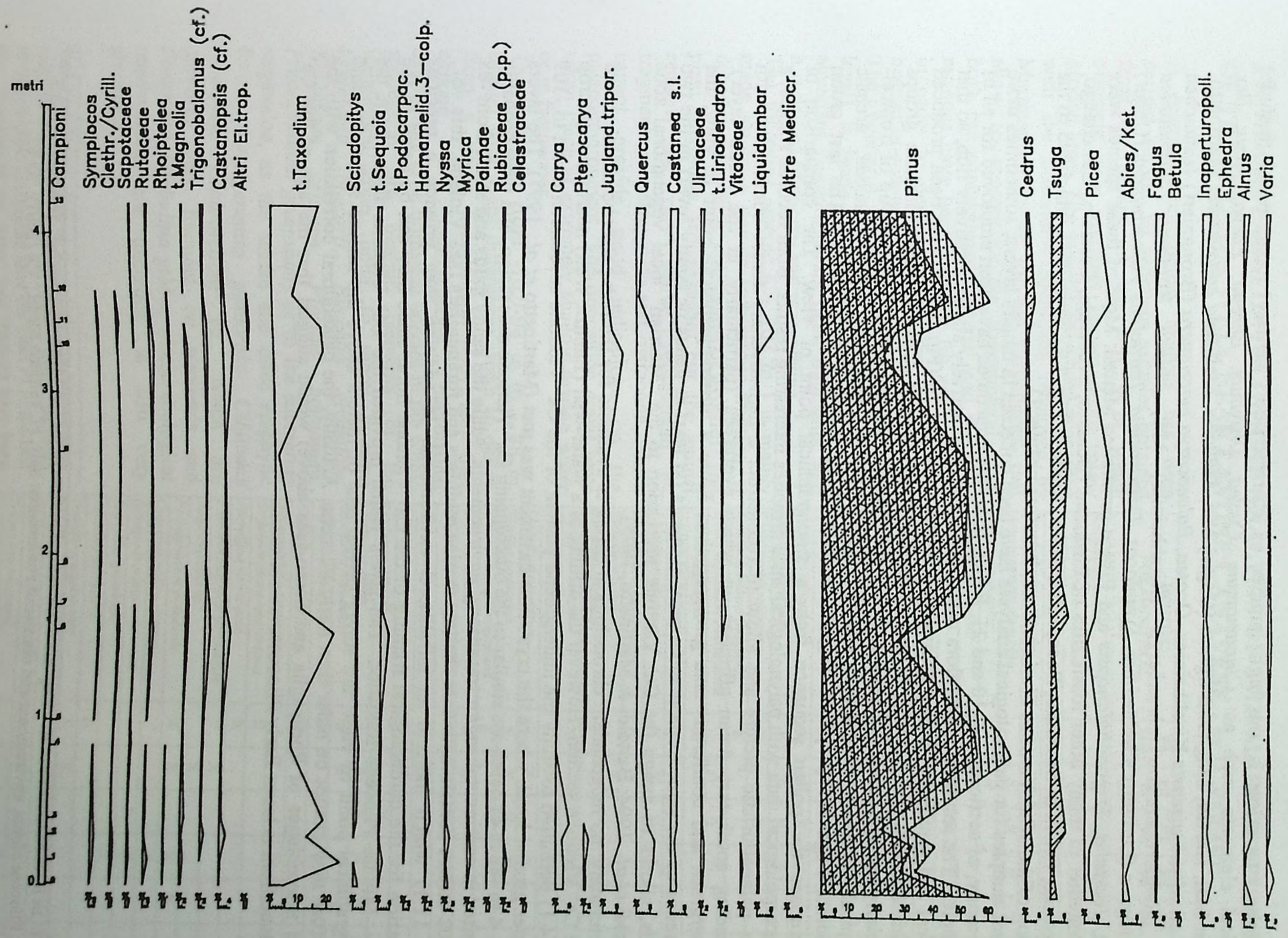


Fig. 10.2 - Pollen diagram of Arboreal Plants (PA) of section 10, Ca' Viettone. Percentages are referred to the whole of PA. The order of each pollen taxon depends on the vegetational group, i. e. from top to bottom: *-- tropical-subtropical elements; *-- Taxodiaceae group; *-- Warm temperate and/or temperate deciduous trees; *-- Pinaceae group (*Picea-Abies* excluded); *-- mountain elements; *-- other PA, indeterminate grains included.

Particularly interesting is the high number of characteristic "Tertiary" taxa, which include subtropical elements such as: *Cinnamomum*, *Cyclea*, *Distylium*, *Ehretia*, *Eurya*, *Ficus*, *Ilex saxonica* Mai, *Hartia*, *Magnolia lignita* (Unger) Mai, *Mallotus*, *Meliosma canavesana* Martinetto, *Myrica* cf. *altenburgensis* Kirchheimer, *Ocotea*, *Palaeocarya macroptera* (Brongniart) Jaehnichen *et al.*, *Rehderodendron ehrenbergii* (Kirchheimer) Mai, several Rutaceae, *Sapindoidea margaritigera* (Ludwig) Kirchheimer, *Symplocos*, *Ternstroemia*, *Tetraclinis salicornioides* (Unger) Kvacek, *Toddalia*, *Trigonobalanopsis* and *Visnea germanica* Menzel. Most of these species were found together in many other fossil sites of Piedmont (Benasso, Breolungi, Candelo, Castellengo, Ca' Viettone, Crava di Morozzo, Pocapaglia, Ronco Biellese: Fig. 1.2), a situation which led to the definition of the «Ca' Viettone Floristic Complex» (see chapter 1).

Sediment samples for palynological analyses have been collected in muddy layers, sometimes more or less sandy, of sections 1, 4, 10 and 21. Pollen enrichment methods have been employed for all of the samples. The resulting pollen flora was found to be quantitatively and qualitatively rich, so that analytical and synthetical pollen diagrams, referred to section 10 (Fig. 10.1), have been produced (Bertoldi & Martinetto, 1996). In the pollen sequence the so called "Tertiary" floristic groups particularly emerge. They are represented by the Taxodiaceae group and by the group of tropical-subtropical elements: *Symplocos*, *Clethraceae*/*Cyrillaceae*, *Magnolia* type, *Rutaceae*, archaic tricolporate Fagaceae (*p. p.* cf. *Trigonobalanus*), *Rhoiptelea*, etc. (Fig. 10.2) . The last group characterises the pollen sequence from a stratigraphical point of view. The comparison of palaeocarpological data with palynological ones provides interesting results. Both records suggest a similar palaeofloristic picture and allow to reconstruct a high-diversity forest community with outstanding south-east Asian affinities, in which evergreen (particularly in the shrub layer), summergreen and coniferous taxa grew together. From a biostratigraphical point of view, the occurrence of the same tropical-subtropical elements (at least at genus or family level) in the two records, allows to assign the Ca' Viettone succession to the "Macrian" local vegetational zone (Bertoldi *et al.*, 1994; Bertoldi & Martinetto, 1995).

Unfortunately, no independent chronological dating is available for the rich palaeobotanical record of the Ca' Viettone section. However the drilling of a water-well (Intenza Well) nearby the outcrop (Fig. 4.1) permitted to study the underground portion of the Ca' Viettone succession down to -109 m under ground level, where the crystalline basement was met (Martinetto *et al.*, 1997). The layers from -4 to -88 m of depth are similar to the outcropping Ca' Viettone succession, and were probably deposited in continental and/or transitional environments, while the sandy muds and sands from -88 to -102 meters contain abundant shallow marine molluscs and foraminifers (see Violanti, this vol., Tab. 11.1) which indicate an infralittoral environment. In addition they provide a precious indication for the chronological framing of the Ca' Viettone flora, since they can be dated to the Early- Middle Pliocene transition. The layers which provided the Ca' Viettone flora, from the stratigraphical point of view, are surely several tens of meters above the marine sediments, and therefore they cannot be older than Early Pliocene. Actually, the palaeofloral correlation with the dated assemblages of Pocapaglia and Sento (see above) would suggest that the age of the Ca' Viettone flora is latest Early Pliocene.

BERTOLDI R. & MARTINETTO E. - Key-site 6: the rich palaeoflora of the Ca' Viettone succession. *In* MARTINETTO E. (ed.): Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.4 (2001): 59-62.

11. MICROPALAEONTOLOGICAL ANALYSIS OF THE MARINE SEDIMENTS OF THE INTENZA WELL NEAR LEVONE CANAVESE - by D. VIOLANTI

A micropalaeontological analysis has been carried out on 10 sediment samples obtained from the drilling of the well, 9 of which originate from precisely known depth below ground level. The samples have been processed with the floatation techniques employed by Martinetto (1994a) for the carpofloras, that allow to concentrate the foraminiferal tests; both the concentrated material and the total residues have been analysed for each sample, in order to determine also the species with heavier or sediment-filled tests.

The lowermost sample (– 108 m below ground level) is made up by yellowish sands with abundant Fe-oxides, rare plant fragments, and it is devoid of micro- and macrofauna.

The following sample (– 102 m) is mainly made up by a coarse terrigenous fraction; it contains a few little aggregates of gypsum. The plant fragments are abundant but the animal remains are very scarce, represented by fragments of pelecypods and ostracods, which cannot provide good indications on the palaeoenvironment. The deposition could have taken place in extremely shallow marine water or in freshwater.

The sediments from -102/-98 m to - 88 m, though with slight differences, seem to derive from a single sedimentary body and they contain a homogeneous microfaunal assemblage. The dominant species in the whole succession are benthic elements of the infralittoral zone, bond to sandy bottoms (*Ammonia beccarii, Buccella granulata, Elphidium crispum, Florilus boueanum, Protelphidium granosum*) or to the submarine vegetation, as the sessile and often epiphytic forms *Asterigerinata planorbis, Cibicides lobatulus, Glabratellina* sp., which are presently very frequent on seaweeds and *Posidonia. Globulina gibba*, whose ecological requirements are uncertain, is also very abundant.

BENTHIC FORAMINIFERAL TAXA	PI 102-98	PI 98	PI 94	PI 90	PI 90-88	PI 88
Ammonia beccarii		X	X	X	X	X
Ammonia parkinsoniana						X
Ammonia perlucida	X					
Amphicoryna proxima	X					
Asterigerinata planorbis		X	X	X	X	X
Bolivina variabilis		X				
Brizalina spathulata		X				
Buccella granulata	X	X	X	X	X	X
Bulimina fusiformis	X	X	X	X		X
Bulimina lappa		X				
Bulimina minima	X					
Cancris auriculus	X					
Cassidulina carinata	X					
Cibicidella variabilis	X					X
Cibicides lobatulus	X	X	X	X		
Cibicides refulgens		X	X	X		X
Cibicidoides ungerianus	X		X			
Cribroelphidium decipiens	X					
Cribroelphidium semistriatum		X	X	X		X
Dorothia gibbosa	X					X
Elphidium aculeatum	X					
Elphidium advenum	X	X	X	X		X
Elphidium complanatum	X	X				
Elphidium crispum		X		X		X
Elphidium incertum				X		
Elphidium lessonii	X			X		
Elphidium macellum	X	X	X	X		X
Elphidium poyeanum	X	X		X		X
Florilus boueanum	X	X	X	X		X
Fursenkoina schreibersiana	X					
Glabratellina sp.	X	X				
Glandulina laevigata		X				
Globobulimina affinis	X	X				
Globobulimina pyrula	X	X				
Globocassidulina subglobosa			X			
Globulina gibba		X	X	X	X	
Globulina fissicostata	X	X		X		X
Globulina tuberculata				X		
Heterolepa bellincionii	X					
Neoconorbina terquemi				X		
Orthomorphina tenuicostata	X					
Parrellina verriculata	X					
Planorbulina mediterranensis		X				
Polymorphina sp.		X				X
Protelphidium granosum	X	X		X	X	X
Quinqueloculina aspera				X		X
Quinqueloculina seminulum			X	X		X
Reussella spinulosa				X		
Rosalina globularis	X					
Textularia agglutinans	X	X				X
Textularia sagittula						X
Triloculina tricarinata				X		
Triloculina trigonula				X		X
Valvulineria bradyana				X		

Tab. 11.1. Distribution of foraminifers in nine samples collected from the core of the Intenza Well. The depth of each sample is reported after the label PI in the first line. Samples PI108, PI102 and PI88-80 have been omitted (barren).

The planktic foraminifers are scarce in percentage (P/P+B <10%), and represented by *Globigerinoides trilobus, Gs. obliquus obliquus, Gs. obliquus extremus, Globigerina apertura, G. bulloides, G. woodi, Neogloboquadrina acostaensis* and *Orbulina universa*. Both the planktic and benthic forms are very well preserved. Only rare tests of *Sagrina* sp., with a different preservation state, might have been reworked.

In the lower sample (-102/-98 m) of the foregoing group, the species typical of fine grained sediments (*Bulimina lappa, Bulimina minima*) are more frequent. The same is true for those species which indicate a deeper bottom, distributed from the circalittoral zone downwards (*Amphicoryna proxima, Cancris auriculus, Cassidulina carinata, Dorothia gibbosa, Orthomorphina tenuicostata, Cibicidoides ungerianus, Globobulimina affinis, Textularia sagittula, Heterolepa bellincioni*). In this sample the ratio P/P+B is around 10-15%. The depositional environment seems to be at the boundary between the circalittoral and infralittoral zones.

In the remaining samples, up to - 88 m from ground level, the circalittoral forms are absent, therefore a slight reduction in depth can be suggested, distinctly passing to the infralittoral zone.

In addition, several oscillations in the percentages of the total microfauna and of the different species have been observed, but there is a general trend towards a reduction of the number of taxa and specimens from the bottom to the top of the marine portion of the sedimentary succession. Nevertheless the palaeonvironmental changes are not so marked.

The biostratigraphic analysis is based on a few significant species, both planktic and benthic. The planktic assemblage is devoid of zone index-taxa and the presence of *Globigerina apertura, G. woodi, Globigerinoides obliquus extremus, Neogloboquadrina acostaensis* only allows to sign out an interval from Late Miocene (Tortonian) to part of the Upper Pliocene (Kennett & Srinivasan, 1983). The presence of benthic species strictly limited to the Pliocene, such as *Orthomorphina tenuicostata*, or restricted to the Early-Middle Pliocene as *Globulina tuberculata, Globulina fissicostata*, or known only from the Middle Pliocene onwards, as *Buccella granulata* (AGIP, 1982), permits to assign the microfaunas to the boundary between Early and Middle Pliocene, with major indications for the older part of the interval (presence of *Globulina tuberculata*). It is worth noticing that the planktic fauna is dominated by species of warm to warm-temperate waters (*Globigerinoides trilobus, Orbulina universa*), while the temperate to cool-temperate Globigerins are rare. The foraminiferal assemblage of the Intenza Well seems to be in good correlation, both from the biostratigraphic and palaeoenvironmental point of view, with the recently studied Sento ones of the Val Chiusella Pliocene (Basilici *et al.*, 1997). The Intenza Well microfaunas seems to be different for the markedly infralittoral character and probably for a predominance of the forms related to the submarine plant communities (*Asterigerinata planorbis* etc.).

VIOLANTI D. - Micropalaeontological analysis of the marine sediments of the Intenza Well near Levone Canavese. *In* MARTINETTO E. (ed.): Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.4 (2001): 63-64.

12. Key-site 7: the fossil forest of Stura di Lanzo - by R. Bertoldi & E. Martinetto

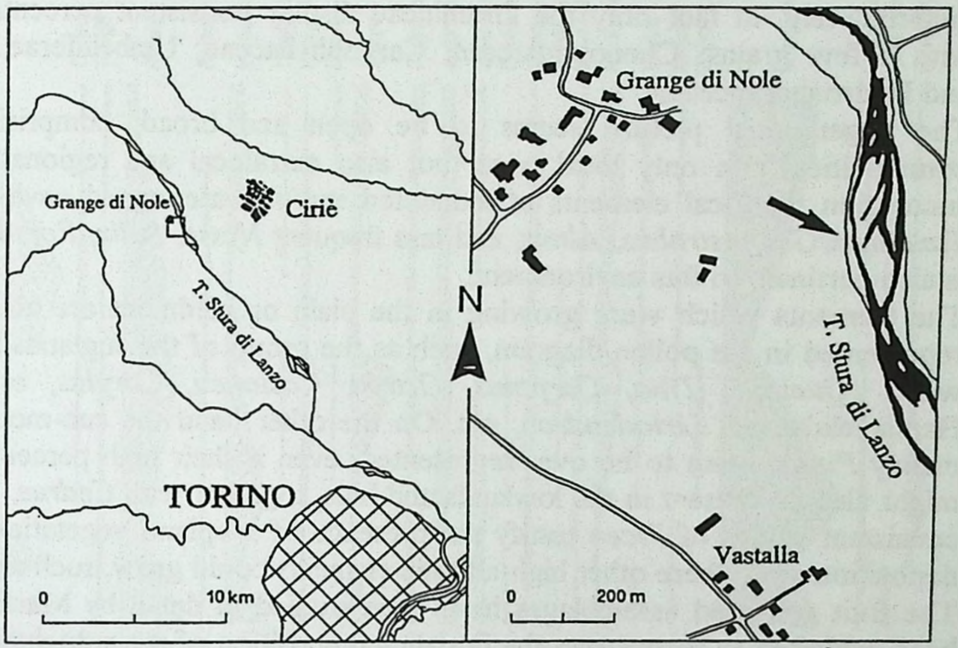


Fig. 12.1. Map showing the location of the Stura di Lanzo outcrop.

In the vicinity of the village of Nole Canavese, about 20 km north of Turin (Fig. 12.1), a succession of freshwater sediments crops out for about 2 Km along the bed of the Stura di Lanzo River. Additionally, the erosion caused by the river in the late 1980s on a fine-grained portion of such succession exposed several mummified tree stumps, forming a fossil forest.

These deposits, cropping out for a thickness of 7 m, belong to the lithostratigraphic unit known as «Villafranchiano» and are thought to be of Pliocene age depending on the palaebotanical content (Martinetto, 1994a). They provided a huge variety of plant macrofossils: woods, roots, leaves (both compressions and impressions) and diaspores. The palaeobotanical investigations were concentrated on a particular portion of the outcrop (arrow in Fig. 12.1), for the abundance and diversity of compressed plant remains in 1 m of its thickness (Fig. 12.2). Pollen assemblages had been preliminarily analysed by Cerchio *et al.* (1990) and have been newly investigated by one of the authors (R. B.) in the late 1990s.

The pollen flora detected in this last occasion is characterised by three arboreal taxa with high, though fluctuating, pollen percentages: *Pinus* (different types), *Alnus* and *Taxodium*-type (*Taxodium/Glyptostrobus*). Among the AP only *Picea*, *Inaperturopollenites* (Cupressaceae *p.p.*), *Carya*, *Pterocarya* together with other Juglandaceae (*Engelhardtia-Platycarya, Juglans*) and Ulmaceae show consistent pollen percentages, while the remaining taxa occur with low pollen percentages (e. g. *Sciadopitys, Tsuga, Cedrus, Abies, Fagus, Liquidambar* and other tricolpate Hamamelidaceae) or even with a few grains (e. g. *Sequoia*-type, *Liriodendron*, *Magnolia*-type, *Nyssa, Quercus, Castanea, Corylus, Carpinus, Ostrya, Acer, Tilia, Betula*, etc.). The absence of characteristic tropical-subtropical elements in this

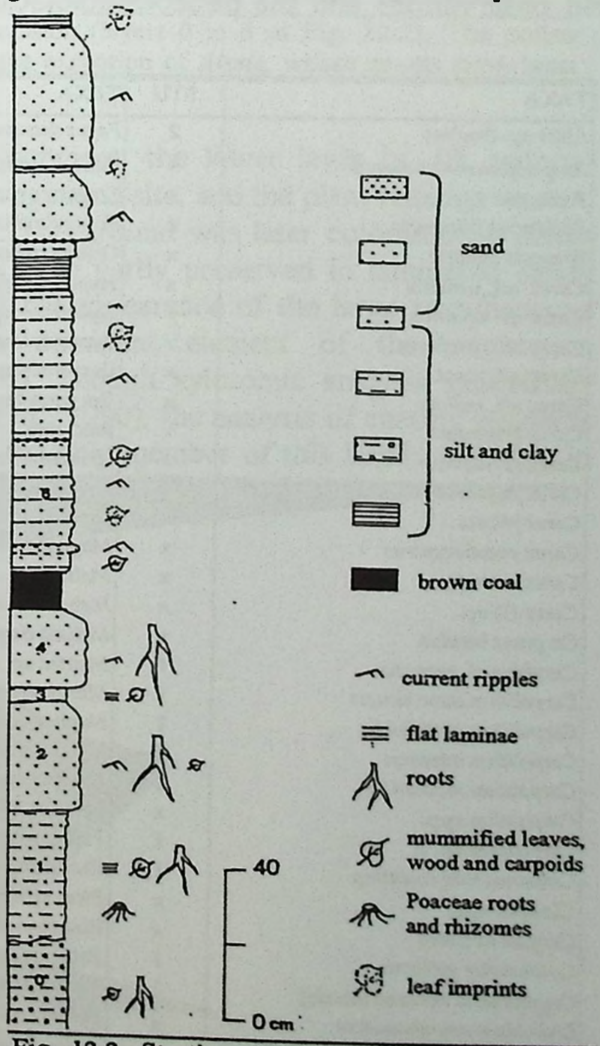


Fig. 12.2. Stratigraphic column of the Stura di Lanzo section, measured in the point indicated by the arrow in Fig. 12.1

pollen flora is regarded as an important feature.The NAP are scarce, both qualitatively and quantitatively, in fact only the Gramineae display consistent percentages, while other taxa occur with a few grains: Chenopodiaceae, Caryophyllaceae, Umbelliferae, Cyperaceae, Ranunculaceae and Hydrocharitaceae.

The vegetational picture seems to be open and broad, comprising different types of plant communities, non only local ones, but also extralocal and regional. However, along the whole succession the local elements of inundated and/or waterlogged environments prevail, in particular *Taxodium/Glyptostrobus, Alnus*, and less frequent *Nyssa, Salix, Populus*, etc. The majority of NAP is also pertinent to this environment.

The elements which were growing in the plain or piedmont are abundant, and seemingly under-represented in the pollen diagram, such as the group of the Juglandaceae, the elements of the oak-wood (*Quercus, Tilia, Carpinus, Ostrya, Castanea, Corylus*, etc.), *Liquidambar* and other Hamamelidaceae, *Liriodendron*, etc. On the other hand the sub-mountain and mountain conifers, mainly *Pinus*, seem to be over-represented, even if their high percentages suggest that these trees might also be present in the lowlands and hills, together with *Cedrus, Tsuga* and Cupressaceae. The consistent values of *Picea* testify the presence of a upland vegetation belt, rather distant from the deposition site, where other high-altitude elements could grow, such as *Abies, Fagus* and *Betula*.

The fruit and seed assemblages have been studied in detail by Martinetto (1994a), and they have been exploited to reconstruct the floristic composition of the autochthonous plant communities. The field observations and the palaeocarpological analysis of 4 selected layers (Fig. 12.2) allowed to

TAXA	STU	TAXA	STU	TAXA	STU
Abies sp. (foglie)	2	*Fagus decurrens*	x	*Proserpinaca reticulata*	f
Ampelopsis malvaeformis	x	*Ficus* cf. *carica*	x	*Prunus* (*Padus*) aff. *padus*	x
Apiaceae	x	*Fragaria* sp.	1	*Pterocarya limburgensis*	1
Boehmeria lithuanica	x	*Frangula alnus*	x	*Ranunculus* gr. *aquatilis*	x
Brasenia victoria	x	*Glyptostrobus europaeus*	ff	*Ranunculus pseudoflammula*	ff
Carex aff. *pendula*	x	*Hypericum* sp. A	x	*Ranunculus reidii*	x
Carex cf. *aquatilis*	x	*Hypericum* sp.	ff	*Ranunculus sceleratus*	x
Carex aff. *atrofusca*	x	*Ilex cantalensis*	1	*Rubus* cf. *laticostatus*	x
Carex aff. *fusca*	x	*Ilex fortunensis*	1	*Rubus microspermus*	f
Carex aff. *remota*	x	*Itea europaea*	1	cf. *Rumex* sp.	x
Carex brizoides	x	*Juncus* sp.	x	*Sabia europaea*	1
Carex cf. *loliacea*	x	*Liriodendron geminata*	x	*Salvinia tuberculata*	x
Carex flagellata	x	*Ludwigia* sp. A	x	*Sambucus pulchella*	1
Carex plicata	x	*Lycopus europaeus*	x	*Scindapsites crassus*	x
Carex pseudocyperus	x	*Magnolia cor*	x	*Schizophragma polonica*	x
Carex rostrata	x	*Malus* sp.	x	*Scirpus mucronatus*	x
Carex (?) sp.	x	*Meliosma wetteraviensis*	x	*Scirpus radicans*	x
Carpinus betulus	x	*Melissa elegans*	x	*Scirpus sylvaticus*	x
Carpinus cf. *europaea*	f	*Mentha* sp. A	f	*Selaginella* cf. *malesovicensis*	1
Carpolithes cucurbitinus	f	*Morus sibirica*	x	*Selaginella kunovicensis*	f
Carpolithes gratioloides	1	*Nuphar canaliculatum*	x	*Sequoia abietina* (cones)	2
Carpolithes minimus	f	*Nyssa disseminata*	1	*Sparganium nanum*	x
Carpolithes montioides	1	*Oenanthe* sp. A	x	*Styrax maximus*	x
Carpolithes spp.	x	*Parrotia reidiana*	f	*Ternstroemia* sp.	1
Carpolithes sp. A	f	*Paulownia cantalensis*	x	*Toddalia* cf. *rhenana*	x
Cinnamomum costatum	1	*Phellodendron elegans*	x	*Tsuga* sp. (foglie)	2
Cladium spp.	x	*Picea* sp. (foglie)	1	*Typha* sp.	x
Corylus avellana	x	Pinaceae indet. (semi)	x	*Viola bergaensis*	x
Cotoneaster gailensis	1	*Polygonum* sp.	x	*Viola neogenica*	x
Cryptomeria rhenana (seeds)	2	*Potamogeton* cf. *polymorphus*	x	*Viola* sp. A	x
Dulichium arundinaceum	x	*Potamogeton* sp. C	1	*Vitis parasylvestris*	x
Eleocharis ovata	x	*Potentilla* sp.	x	*Wikstroemia thomasii*	x
Epiprennites reniculus	x	*Potentilla supina*	fff		

Table 12.2 - List of the fossil fruit and seed species of Stura di Lanzo.

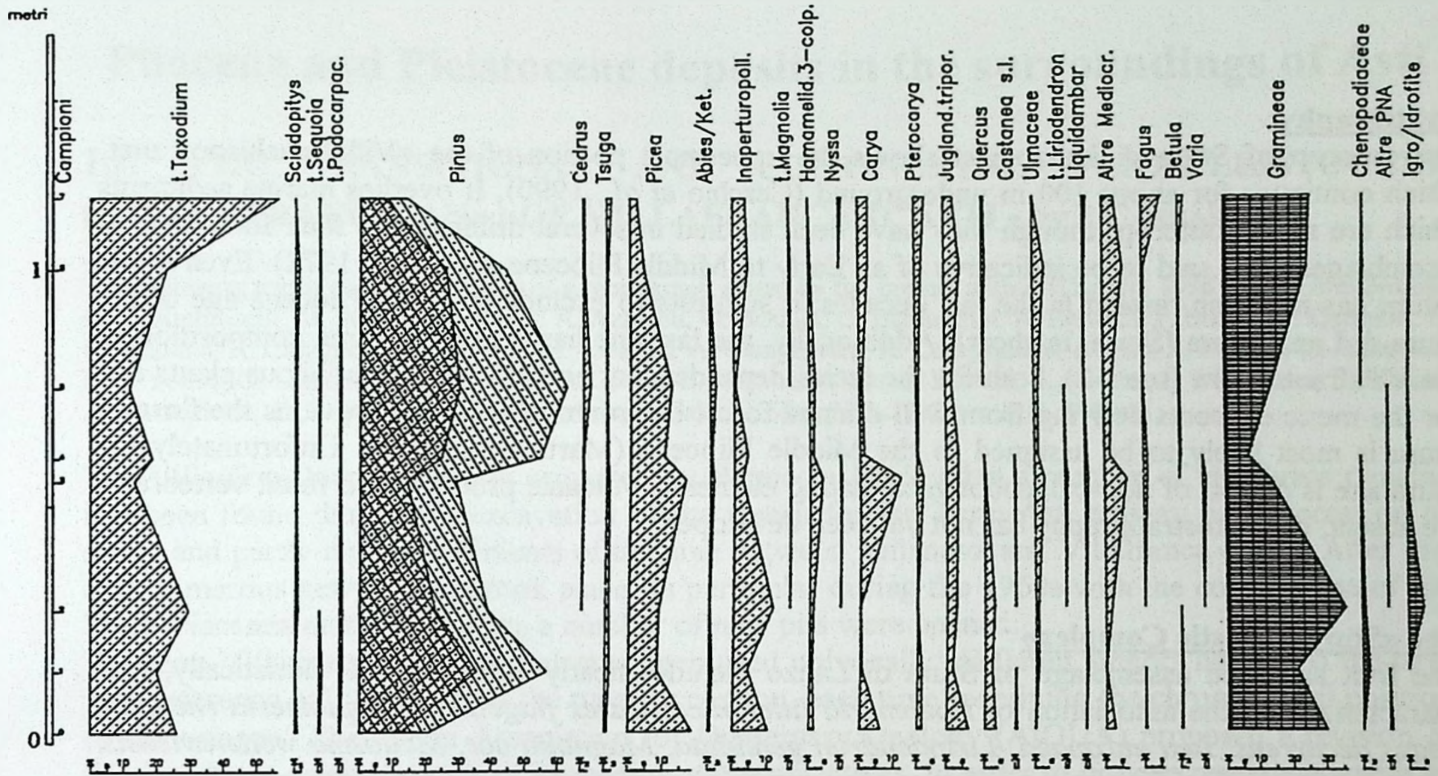


Fig. 12.3. Analytic pollen diagram of the Stura di Lanzo succession (layers 0 to 6 in Fig. 12.2). The pollen percentages have been calculated on the sum of the AP, with the exception of *Alnus*, whose counts have been omitted from the pollen sum due to its overwhelming abundance.

detect a vegetational succession in the local palaeonvironment: the lower layer (n. 0), without sedimentary structures, was probably deposited in a non-vegetated site, and the plant remains were incorporated into the sediment after a certain transport. The ground was later colonised by *Alnus* and hygrophilous herbs, whose rooting structures have been partly preserved in laminated sandy muds (second layer, n.1). The third layer (n. 3) testifies the appearance of the large taxodiaceous tree *Glyptostrobus europaeus*, which becomes the dominant element of the vegetation (taxodiaceous swamp forest) up to the top layer (n. 6). Though xylotomic analysis generically referred the fossil stumps to the Taxodiaceae (Cerchio *et al.*, 1990), the analysis of canopy elements allowed to conclude that *Glyptostrobus europaeus* was the only member of this family growing in the fossil forest (Martinetto, 1994a and b).

The palaeoenvironment, during the full development of the fossil forest, has been reconstructed as swamp whose deepest ponds were occupied by aquatic plants, such as *Nuphar*, *Proserpinaca*, *Potamogeton*, *Ranunculus* cf. *hederaceus*, *Salvinia*, *Brasenia*. The areas with a shallower water level were covered by trees of *Alnus* and *Glyptostrobus* accompanied by herbaceous plants belonging to native European genera (*Hypericum*, *Carex*, *Scirpus*, Apiaceae, *Ranunculus*, *Lycopus*, *Mentha*, *Cladium*, *Juncus*, *Alisma*, *Eleocharis*, *Typha*) and to a few "exotic» ones (*Dulichium*, *Boehmeria* and *Epipremnites*).

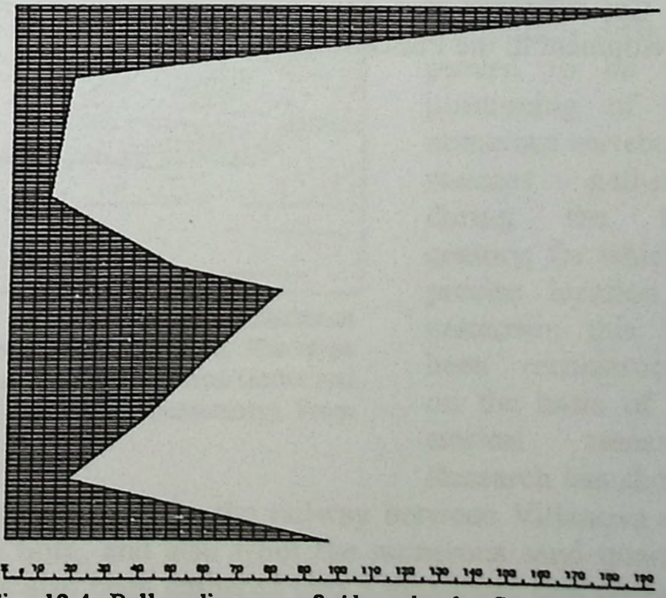


Fig. 12.4. Pollen diagram of *Alnus* in the Stura di Lanzo succession; the percentage has been calculated by reference to the sum of the remaining AP, therefore it often exceeds 100%..

Stratigraphy

The outcrop of Stura di Lanzo just shows the uppermost portion of the «Villafranchiano» unit, which continues for about 100 m underground (Cerchio *et al.*, 1990). It overlies marine sediments which are not in outcrop, though they have been studied in several drillings and their foraminiferal assemblages were said to be indicative of an Early to Middle Pliocene age (ENI, 1972). Even if this datum has not been revised in the last decades, it suggests to exclude an Early Pliocene age of the Stura di Lanzo flora (Stura, in short). Additionally, the last one has nearly the same composition of the Villafranca flora (see 5.3), both for the facies-dependendent aquatic and hygrophilous plants and for the mesic elements deriving from well-drained forest environments. For this reasons the flora of Stura is most likely to be assigned to the Middle Pliocene (Martinetto, 1995). Unfortunately the Stura site is devoid of non-palaeobotanical dating elements: volcanic products and fossil vertebrates are absent; magnetostratigraphy has not yet been developed.

The «Stura Floristic Complex»

The fruit and seed assemblage of Stura di Lanzo includes nearly 100 taxa and, floristically, it is characterized by the association of *Boehmeria lithuanica, Carex flagellata, Cryptomeria rhenana, Fagus decurrens, Itea europaea, Liriodendron geminata, Magnolia cor, Meliosma wetteraviensis, Nyssa disseminata, Parrotia reidiana, Proserpinaca reticulata, Sequoia abietina, Stewartia beckerana* and *Styrax maximus*. It still includes a few subtropical elements (*Cinnamomum costatum, Sabia europaea, Toddalia rhenana*), but in reduced number and percentage in comparison with the assemblages of the Ca' Viettone complex (Early Pliocene).

The same floristic features were also found in a few other fossil floras of the «Villafranchiano» unit, which were grouped in the «Stura Floristic Complex». According to the climatostratigraphic interpretation cited above (chapter 1) this Floristic Complex should represent a vegetational phase which occurred in the Middle Pliocene, and possibly also in the latest Early Pliocene.

The floristic difference between Ca' Viettone and Stura assemblages has been confirmed by palynological analyses; by comparing the pollen diagrams of Ca' Viettone and Stura (Fig. 12.3), it is easy to notice that the tropical-subtropical elements (*Symplocos, Clethraceae/Cyrillaceae, Rutaceae*, archaic tricolporate Fagaceae, *Rhoiptelea*) are absent in the second one. Therefore, not only the possibly local carpoflora, but also the far-transported palynoflora permits to establish that the Ca' Viettone and Stura sections have recorded two distinguishable stages of vegetation development in the Pliocene of the Po Plain.

BERTOLDI R. & MARTINETTO E. - Key-site 7: the fossil forest of Stura di Lanzo. *In* MARTINETTO E. (ed.): Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.4 (2001): 65-68.

Pliocene and Pleistocene deposits in the surroundings of Asti

13. THE TRANSITIONAL AND CONTINENTAL PLIO-PLEISTOCENE («VILLAFRANCHIAN») OF VILLAFRANCA D'ASTI - by F. CARRARO

The following text is a partial abstract of a monograph edited by the present author (Carraro, 1996), with contributions of: P. Ambrosetti, M. Angela-Franchini, A. Azzaroli, G. Basilici, G. Belluomini, R. Bertoldi, P. Boano, D. Bormioli, F. Campanino, R. Caramiello, F. Carraro, M. Cerasoli, A. Ciangherotti, R. Compagnoni, D. Esu, E. Ferrero, G. Ficcarelli, M.G. Forno, G. Genovese, M. Giardino, 0. Girotti, E. Gliozzi, R. Lanza, D. Mai, L. Manfra, E. Martinetto, F. Masini, A. Moscariello, G. Pavia, A. Perotto, R. Polino, B. Sala, C. Siniscalco, D. Torre & D. Violanti.

The Villanfranchian stage was proposed by Pareto in 1865, after a number of vertebrate remains had been found during the excavation of the trench for the Turin-Asti railway in a succession of sandy and partly muddy sediments of the area between Villanova and Villafranca d'Asti. After this date numerous new findings took place, in particular during the 1960s with the construction of the Turin-Piacenza motorway, when a number of new pits were opened.

The term Villafranchian has not always been used univocally: different authors have used the term with reference only to a part of the type-succession, each time redefining the chronological position of the «stage». The Italian Association for Quaternary Geology (AIQUA) proposed a revision of this important «stage» as one of its medium-term objectives, in order to provide researchers with an updated definifion. This revision was divided into three phases: (1) survey for a detailed, and hitherto lacking, geological map of the type-area. On the basis of gathered data, an interpretative stratigraphic and structural model was proposed; (2) a critical re-evaluation of the large amounts of palaeontological material put together in the course of a century of research. Particularly difficult proved to be the positioning of the numerous vertebrate remains gathered during the last century, for which a precise location is unknown; this has been reconstructed on the basis of historical research. Research has shown that two separate routes were originally planned and built for the railway between Villanova and Villafranca and that mammal finds come from both, and also from the numerous sand quarries opened in the vicinity. Palaeontological data has also been gathered into a data-base; this contains all information concerning each find, both original and deriving from research, and useful for defining the type, the stratigraphic position, the systematic significance and its current museum

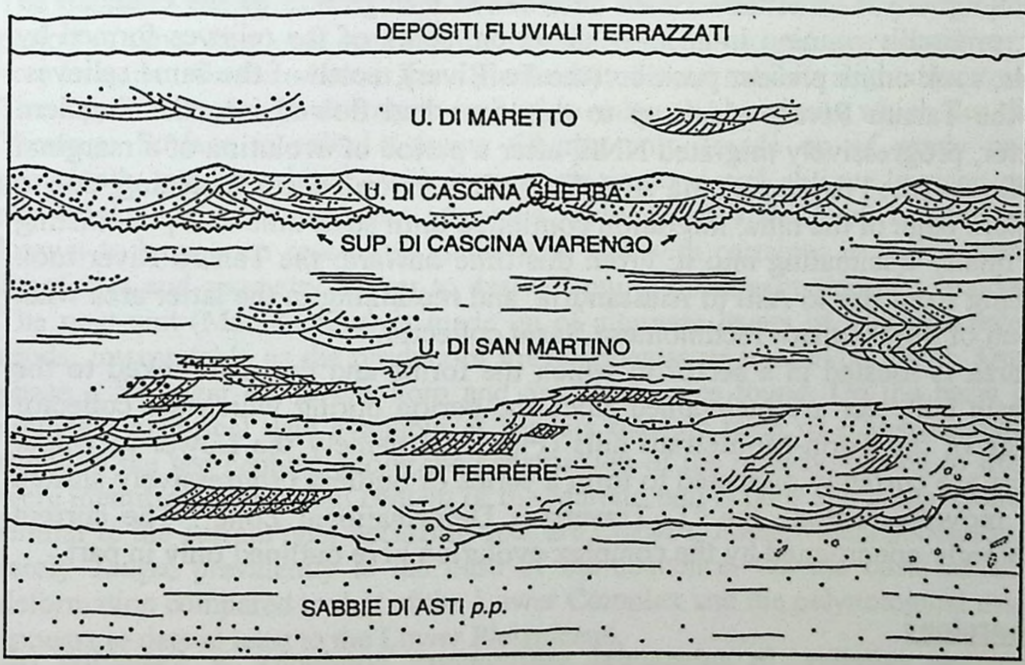


Fig.13.1 - Stratigraphic sketch of the Plio-Quaternary succession in the Villafranca d'Asti area. The Sabbie di Asti are a shallow marine marine sandy formation. The «type Villafranchian» succession is made up by the Ferrere, San Martino, Cascina Gerba and Maretto units. Depositi fluviali terrazzati = terraced fluvial deposits (Quaternary). From Boano & Forno in Carraro, 1996.

location; (3) analysis of data collected during the previous phases by specialists operating in different fields; comparison of the different interpretations; comparison of these interpretations and the interpretative model proposed.

The revision which has been carried out (Carraro, 1996) has allowed the development of an interpretative model which, although not very detailed, presents a good degree of coherence in its general formulation. According to this model the Villafranchian type-succession presents an important sedimentary hiatus, emphasized by a slight angular discordance. Furthermore the data resulting from the revision of the rich palaeontological content of a number of sediments, indicate a Middle Pliocene-Lower Pleistocene age, which is very different from that proposed by Pareto, who suggested a Pleistocene age. These two circumstances suggest that, on the basis of the general principles of stratigraphy, the term Villafranchian extended to a formal chronostratographic unit (stage) should be abandoned. It is however considered appropriate to mantain the use of the term as an adjective applied to some terms (e. g. Villafranchian fauna or Villafranchian facies) given that both are consolidated and have a univocal meaning in the literature.

Geomrphology

Morphologically, the Villafranca d'Asti area is located in a wider region which during the Upper Pleistocene exhibited important variations in the hydrographic pattern, due to a significant geodynamic evolution. The area currently coinciding with the Poirino Plateau, which develops immediately to the W of the Villafranchian type-area, originally constituted the continuation of the eastern flank of the Southern Piedmontese Plain. During the Upper Pleistocene the combined effect of the northward migration of the Asti Syncline axis and the fluvial aggradation occuring on the northernmost edge of the Southern Piedmontese Basin determined a migration of the collector of such basin. The collector, originally running in an E-W direction, south of the relieves formed by the Turin-Monferrato Hills, took on its present position (the Po River), north of the same relieves. During the same period the Tanaro River, which up to this time had flowed into the Southern Piedmontese Basin collector, progressively migrated NNE, after a period of evolution of a marginal structure of the Langhe relieves (the Fossano Living Anticline). This determined a flattening, due to lateral erosion, of the western edge of the hills; migration continued until such time as a pre-existing incision was intercepted, finally tracimating into it. From this time onward, the Tanaro River took on its current course, running from Bra to Asti to Alessandria, and reutilizing in the latter area what had previously been the bed of the Southern Piedmontese Basin collector.

The Villafranchian type-area is located in a sector in which the forms and deposits linked to the Southern Piedmontese Basin collector are maintained since the period during which the collector followed the southern edge of the Turin-Monferrato hills (Fig. 1.1), namely the Lower to Upper Pleistocene. These deposits are currently dissected to form a series of outliers progressively shifted southward by the recent movement along the "T. Traversola Deformational Zone". The current hydrographic net is consistently conditioned by the complex evolution here outlined only in part.

Stratigraphy and palaeontology

The Villafranchian succession overlies, in substantial sedimentary continuity, a formation of infralittoral marine sands ("Sabbie di Asti Fm" *p.p.*). These are mostly horizontally stratified (with local tidal structures), rich in molluscs and can be chronologically referred to the Early-Middle Pliocene. Within the type-succession, which Pareto proposed as Villafranchian stage (1865), the survey reported by Carraro (1996) has identified two main complexes, separated by an important erosional surface (the "Cascina Viarengo" Surface).

Certainly, the Lower Complex represents the ending of the Middle Pliocene regression cycle. The Upper Complex is on the whole an aggradational sequence, that is to say devoid of terracing episodes, very similar to that of the Lower Complex. Nevertheless the Upper Complex was formed in a different environment, i. e. a plain located far from the sea, while the Lower one was formed in a coastal plain. The Upper Complex is also considerably younger than the Lower one.

The Lower Complex (Fig. 13.1) is made up by (from bottom to top) two units: the Ferrere Unit, composed of coarse yellow sands, with local shifts to fine gravel lenses, characterized by oblique and prevalently planar lamineae; the thickness varies from 5 to 25 m. Its palaeontological content is made up of numerous remains of continental vertebrates, in particular mastodonts, as well as marine molluscs; the majority of proboscideans comes from this unit. In general the Ferrere Unit is interpreted as being one deltaic system in the progradation phase, interfingered with beach sediments. It is seemingly assignable to the Middle Pliocene. The relationship with lower-lying marine sediments is one of substantial sedimentary continuity.

The most recent term of the Lower Complex is the San Martino Unit; this is a heterogeneous formation, made up of silty-clayey sediments developing in coastal swamps, intercalated to sandy bodies resulting from fluvial channel infilling. The relationship with the lower-lying Ferrere unit is again one of substantial stratigraphic continuity, even if local erosional episodes of limited spatial entity have been found. Within this unit, which varies from 20 to 65 m, heteropic relationships are diffuse and local interdigitations with the lower-lying Ferrere unit have also been identified. The majority of the well-known Villafranchian palaeontological remains come from this unit. In particular it has been possible to prove beyond doubt that the remains of *Mastodon arvernensis, Stephanorhinus jeanvireti, Mesopithecus monspessulanum, Leptobos stenometopon, Mauremys* sp., *Tapirus arvenensis, Sus minor, Cervus pardinensis* and *Eucladoceros* sp. belong to this unit.

Swampy levels are rich in mollusc associations: during the geological surveys a total of 19 species of extinct pulmonates have been identified: both their local stratigraphic position and the correlation with Sardinian, German, and French successions indicates a Middle Pliocene age. In conclusion the San Martino unit appears to date to the Middle Pliocene, based on its palaeontological content, on magnetostratigraphic data (see below) and on the substantial continuity with the underlying Ferrere unit.

The Cascina Viarengo Surface appears to have been modelled by a hydrographic net during a prolonged period of time. The local organisation of this surface is sometimes sub-planar while at other times it is very irregular. On the whole it has a planar attitude and exhibits slight dips towards the West.

The Upper Complex is also made up of two units: the basal one which lies directly above the Cascina Viarengo Surface is called Cascina Gherba unit. (made up of sandy or sandy-gravely deposits, prevalently grey or whitish, with large scale concave and oblique laminar stratification. This forms a sub-tabular body the thickness of which varies from 4 to 15 m. No palaeontolotogical remains are known to have been recovered in the past and with certainty in these sediments, which in terms of lithofacies and geometry appear to derive from the sedimentation of a braided watercourse in a plain.

The next unit (Maretto unit) is made up of alternate layers of ashgrey clayey loams with occasional sands, interpretable as the product of the sedimentation in alluvial plains. During the recent revisional phase a fragment of *Cervus* horn and *Sus* tooth were found. On the basis of a re-evaluation of the abundant historical data available, it appears that the teeth of *Elephas gromovi* and *E. meridionalis*, found in the last century during the construction of the railway, belong to this unit, while no mollusca were identified. The pollen content of the Maretto unit is poor and is represented by an association very similar to the current one; occurring taxa are *Corylus, Pinus,* Chenopodiaceae, Cichorioideae and more rarely *Tsuga*, prevalently at the base of the sequence. On the basis of a much smaller degree of deformation compared to that of the Lower Complex and the palynological association, the Maretto unit appears to date at least to the Lower Pleistocene.

The Upper Complex is also truncated at the top by a fluvial erosional surface, which cuts the succession identified by Pareto as the Villafranchian. Above the foregoing surface there is a complex of terraced fluvial deposits which are also fossiliferous: a heterogeneous fauna in terms of chronology, environment and climate has been identified, made up of *Elephas antiquus, E. primigenius, Equus sussemburnensis-bressanus, E. hasinus, Marmota* sp., ecc.

Carraro F. - The transitional and continental Plio-Pleistocene («Villafranchian») of Villafranca d'Asti - *In* Martinetto E. (ed.): Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.4 (2001): 58-61.

14. KEY-SITES 8 AND 9: THE «VILLAFRANCHIAN» FLORAS OF THE R.D.B. QUARRY AND ARBOSCHIO - by E. MARTINETTO

R.D.B. Quarry (Villafranca d'Asti)

Since the 1970s the best outcrop of the «Villafranchian» type-succession has been represented by the quarry of the R.D.B. brickyard, which is close to the village of Villafranca d'Asti. Unfortunately in the late 1990s the quarrying has been stopped and the conditions outcrop got worst and worst. In the year 2000 the quarry was definitively filled up, and only a 15m-high wall was left as a documentation of the «historical» section.

Actually this succession, exposed for about 40 m of thicknees, totally belongs to the San Martino unit, i. e. to a restricted portion of the «Villafranchian» type-succession, whose age is seemingly Middle Pliocene, and not Plio-Pleistocene as supposed by former authors (e. g. Lona & Bertoldi, 1973). The succession (Fig. 14.1) is made up by sandy and muddy layers, which are bluish-grey in the basal 10 m and ochre-coloured (oxided) above. The palaeoenvironment is reconstructed as a coastal swamp in a deltaic plain (Basilici in Carraro, 1996).

This outcrop provided a variety of fossils: vertebrates of the Triversa Mammal Unit (Azzaroli, 1977; De Giuli *et al.*, 1983), molluscs and plant macrofossils. The last ones have been studied by Günther & Gregor (1989), Mai (1995b) and Martinetto & Mai (in Carraro, 1996), whom assigned the carpofloras (Tab. 14.2) to the «Stura Floristic Complex» for the characteristic association of *Boehmeria lithuanica, Fagus decurrens, Itea europaea, Meliosma wetteraviensis, Nyssa disseminata, Parrotia reidiana, Proserpinaca reticulata, Styrax maximus.* The only «subtropical» elements are *Ficus potentilloides, Toddalia naviculaeformis* and *Toddalia rhenana,* which are absolutely not so varied and abundant as in the floras of the «Ca' Viettone» complex.

Leaf assemblages	freq.
R4 (9 m):	
Acer tricuspidatum Bronn	rr
Alnus gaudinii (Heer)	ff
monocots	f
"*Pteris*" sp.	rr
R5 (17-18 m):	
Byttneriophyllum tiliaefolium (Al. Braun)	f
Glyptostrobus europaeus (Brongniart)	ff
Taxodium dubium (Sternberg)	1
R6 (close to layer R5, sampled in 1991):	
Acer tricuspidatum Bronn	ff
Alnus gaudinii (Heer)	f
Byttneriophyllum tiliaefolium (Al. Braun)	r
Glyptostrobus europaeus (Brongniart)	ff
monocots	ff
R7 (19-20 m):	
Acer tricuspidatum Bronn	rr
Alnus gaudinii (Heer)	ff
monocots	f
R8 (36 m):	
Acer tricuspidatum Bronn	r
Alnus gaudinii (Heer)	ff
Alnus cf. *glutinosa* (L.)	r
Glyptostrobus europaeus (Brongniart)	f
monocots	f
Taxodium dubium (Sternberg)	2

Table 14.1. Semi-quantitative list of taxa forming leaf-imprint assemblages in the middle and upper part of the R.D.B. Quarry succession. The stratigraphic position of fossiliferous layers R4-R8 is reported in Fig. 14.1. **ff**, very frequent; **f**, frequent; **r**, rare; **rr**, very rare ; **1, 2:** number of specimens.

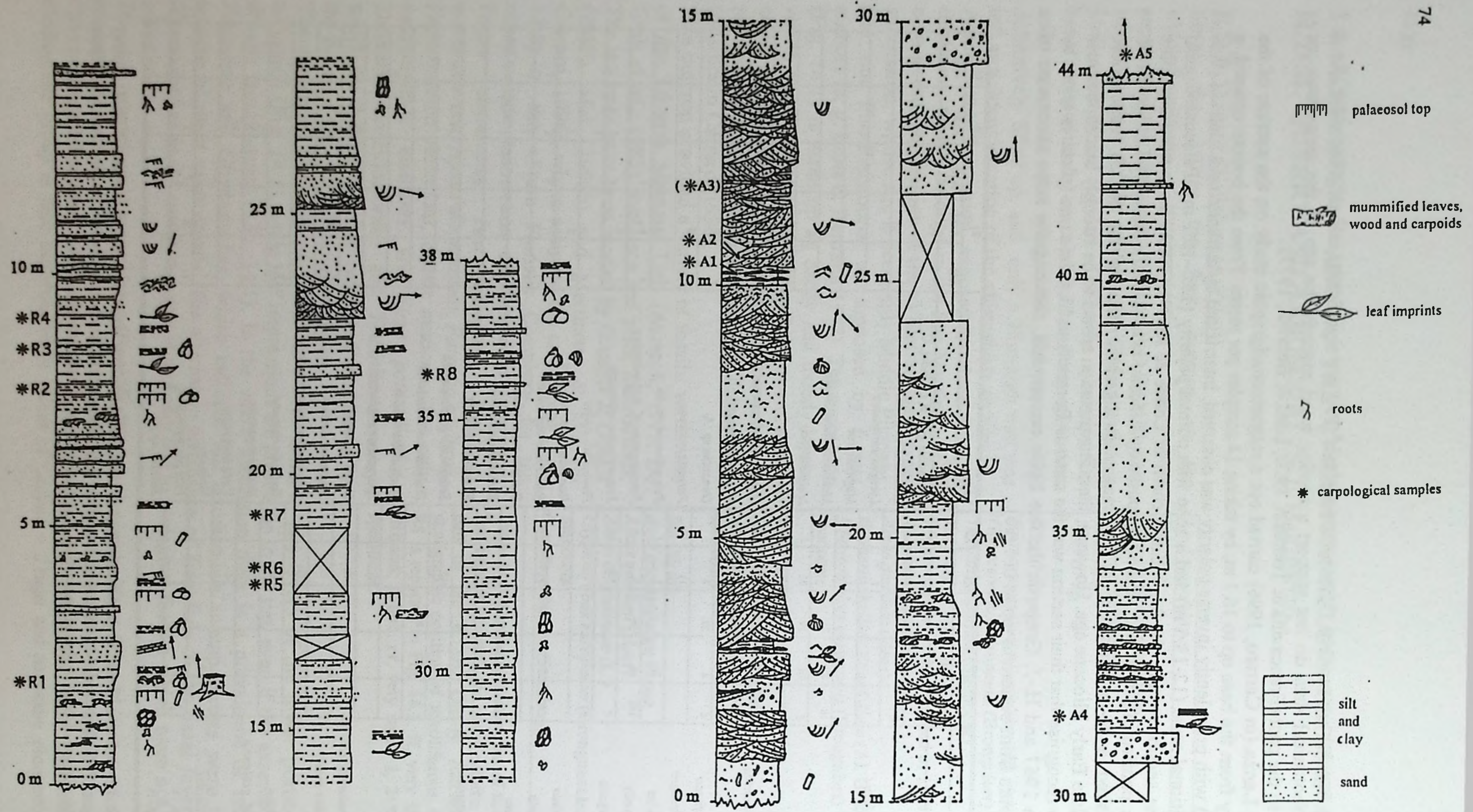
The foregoing fruit and seed taxa have been found in two layers of the lower portion of the succesion (Fig. 14.1), while leaf impressions are present up to the top, even if the assemblages are always species-poor (Tab. 14.1). In the whole succession there is a prevalence of remains of *Taxodium* and *Glyptostrobus*, which indicates that taxodiaceous swamp forests were the main sources of plant macrofossils. The alternative dominance of *Taxodium* in the basal layers and of *Glyptostrobus* in the overlying ones is probably due to ecological factors which have not yet been understood.

The rich palynological assemblages (Bertoldi, 1996) in the lower 20 m (Fig. 14.2) are composed of alternatingly dominant Taxodiacae (t. *Taxodium/Glyptostrobus*, t. *Sequoia*), *Sciadopitys, Nyssa, Myrica,* Celestraceae, tricolpate Hamamelidaceae (such as *Parrotia, Hamamelis* and *Distylium).* The Mediocratic group is also sizeable, while values of *Cedrus* + *Tsuga* and montane elements *(Picea,* *Abies, Fagus, Betula)* are modest. Other arboreal plants (PA) are significant, in particular alder. As a whole, palaeobotanical data do not support a cooling trend towards the top of the succession, as hypothesized in the past (Francavilla & Tomadin, 1970; Lona & Bertoldi, 1973).

Bormioli and Lanza (in Carraro, 1996) carried out a magnetostratigraphic study on the section of the R.D.B. Quarry from the base up to 16.1 m, by taking 14 samples per metre. From the bottom upward, a zone (0-12 m) with prevalently inverse polarity was observed, interrupted by a transitional interval (1.5-3 m), a transitional zone (12-13.5 m) and a zone with normal pojarity (13.5-16.1 m). Palaeontological data locate the section within the 2A (Gauss) chron of Cande & Kent's (1992) magnetostratigraphic scale, thereby confirming what was already proposed by Lindsay *et al.* (1980). Recently Lindsay *et al.* (1997) published a re-interpretation of the magnetostratigraphic data of the R.D.B. succession, suggesting a late Early Pliocene age. However, their interpretation seems to be strongly biased, because they failed to recognise that their section was the same as Bormioli and Lanza's one (pictures taken by D. H. Mai in 1967 and H.-J. Gregor in the late 1980s can prove it, showing the same succession of sediment colours from bottom to top as in 1996).

Layer	R1			R2	R3
Sample	A01	A1M	A1O	A1W	A2A
Acer sp.					1
Acer sp. A	3		3		
Actinidia faveolata				2	
Ajuga antiqua				1	
Alisma sp.	18	82	2		
Alnus sp.	f	14	19	21	f
Apiaceae indet.	1				
Boehmeria lithuanica		4	1	3	35
Callitriche sp.		2	2		
Carex aff. *atrofusca*	4	4	22	2	
Carex aff. *pallescens*				11	17
Carex aff. *remota*		2		1	1
Carex cf. *aquatilis*	158	60	56	3	
Carex cf. *laevigata*	1			32	14
Carex cf. *loliacea*	67		4		
Carex cf. *pendula*				7	
Carex cf. *plicata*				f	
Carex flagellata				1	
Carex plicata				2	
Carex pseudocyperus		1			
Carex sp.		2		15	
Carex szaferi		12	8		
Carex (?) sp. 7					1
Carpinus sp.				2	
Carpolithes cucurbitinus				12	1
Caryophyllaceae indet.		1			
Cirsium sp.				13	
Corylus avellana				f	
Cotoneaster cf. *gailensis*				3	
Erica sp. A				4	
Ficus potentilloides		1			
Hypericum sp. A	2	1			
Hypericum sp. B				f	
Lamiaceae gen. et sp. indet. C		1			
Liriodendron geminata	1				
Lycopus europaeus	3			1	
Magnolia cor	4				
Meliosma wetteraviensis	1			1	
Melissaitalica	5	9			
Mentha sp. A		12			
Nuphar canaliculatum	1		9		
Nyssa disseminata	f	49	3		
Oenanthe sp. A	f	2	2	2	
Parrotia reidiana	f	ff	f		
Peucedanum moebii					2
Potamogeton cf. *polymorphus*	4	1	1		
Proserpinaca reticulata	1	3			
Prunus aff. *padus*				1	
Ranunculus gr. *aquatilis*	19	2		3	
Rubus microspermus			3	f	f
Salvinia tuberculata				7	
Sambucus pulchella				1	
Sassafras ludwigii	f	1	2		
Selaginella gr. *pliocenica*				14	
Sinomenium cantalense	2				
Sparganium nanum	2				
Sparganium neglectum	1	1			
Styrax maximus				8	
Taxodium dubium	f	31	1		
Toddalia naviculaeformis			2		
Toddalia rhenana	9				
Viola bergaensis		8		2	
Viola neogenica				12	
Viola sp.	2				
Vitis parasylvestris	f	18	f	1	
Zelkova ungeri	f				

Table 14.2. List of taxa found in palaeocarpological samples taken from layers R1, R2, R3 of the R.D.B. Quarry succession of Villafranca d'Asti (San Martino unit). The stratigraphic position is shown in Fig. 14.1. Numbers indicate abundance of taxa in the palaeocarpological assemblages of each sample; **ff**, very frequent; **f**, frequent.



14.1. Stratigraphic sections of the R.D.B and Arboschio quarries. From Basilici in Carraro, 1996.

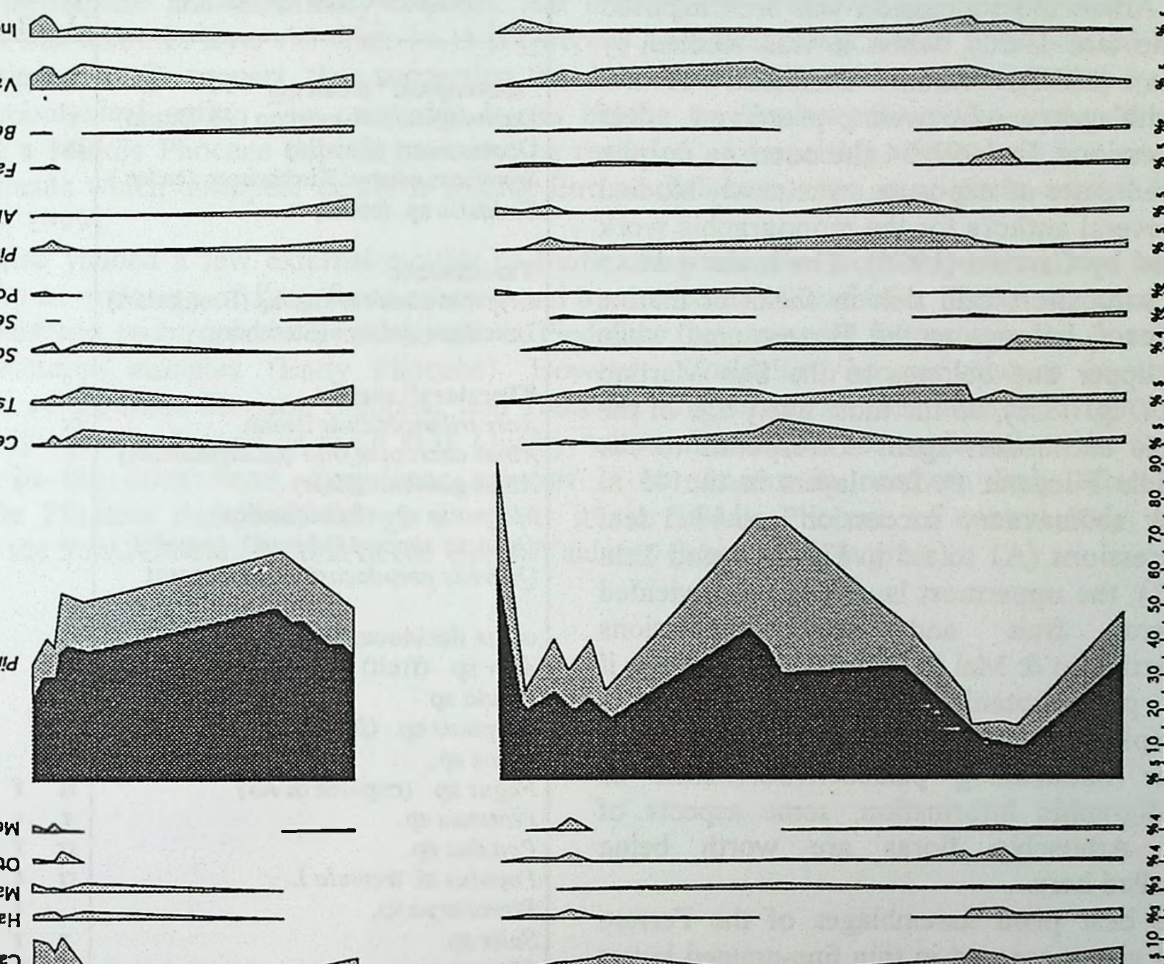


Fig.14.2. Pollen diagram of the R.D.B Quarry section. From Bertoldi in Carraro, 1996.

Arboschio succession

The Arboschio succession was well exposed in the late 1960s, when it was studied by Pavia (1970), whom described several assemblages of well preserved leaf impressions. In 1992-94 the outcrop, despite its bad state of exposure, was newly studied by several authors for the monographic work edited by Carraro (1996). The lower part of the succession, still rich in shells of marine molluscs, belongs to the Ferrere unit, while the upper one belongs to the San Martino unit (Fig. 13.1), so the most likely age of the whole succession again corresponds to the Middle Pliocene. A few layers in the 45 m thick sedimentary succession provided leaf impressions (A1 to A5 in Fig. 14.1 and Tab. 14.3); the uppermost layer (A5) also yielded several fruit and seed impressions (Martinetto & Mai in Carraro, 1996). Even if the palaeobotanical record is scanty, in comparison with other sites, and it does not offer outstanding palaeoenvironmental or stratigraphic information, some aspects of the Arboschio floras are worth being recalled here.

The best plant assemblages of the Ferrere unit are conserved in thin fine-grained layers alternated with sandy ones. The leaf types described by Pavia (1970) in this stratigraphic interval agree very well with the ones reported by Martinetto & Mai (in Carraro, 1996) from the muddy layer (A1) located ca. 10 m from the base of the stratigraphic column by Basilici (in Carraro, 1996), as shown in Fig. 14.1. This layer has been sampled in the early 1990s, when it was still well exposed, but in 1999 also this portion of the outcrop has been completely destroyed. Most of the fossil leaves belong to deciduous taxa *Alnus* (incl. *Corylus heeri* Sismonda), *Carpinus, Fagus, Quercus* (incl. *Castanea*), *Pterocarya, Carya, Populus, Salix, Ulmus, Zelkova, Liquidambar, Platanus, Acer*.

ARBOSCHIO QUARRY	A 1	A 2	A 3	A 4	A 5
"subtropical" elements					
Daphnogene polymorpha (Al. Braun)	r	r	rr		r
Ocotea heeri (Gaudin)	rr	r	rr		
Symplocos schereri Kirchheimer (endoc.)					1
Toddalia sp. (seeds)					2
Taxodiaceae					
Glyptostrobus europaeus (Brongniart)				rr	
Taxodium dubium (Sternberg)				f	
"Terziary" species					
Acer tricuspidatum Bronn	rr			r	
Alnus cecropiaefolia (Ettingshausen)	r	r	rr		
Alnus gaudinii (Heer)		rr		ff	
Magnolia sp. (fructification)					1
Quercus sapperi (Menzel) (cupule)					f
Quercus pseudocastanea Goeppert					ff
other deciduous trees					
Acer sp. (fruit)					1
Betula sp.			1		
Carpinus sp. (fruit)					1
Celtis sp.			1		
Fagus sp. (cupules in A5)	ff	f	ff		2
Platanus sp.	r	r	r		
Populus sp.	rr	f	rr		
Populus cf. *tremula* L.	rr	r			
Pterocarya sp.		f			
Salix sp.	r	r	f		
Ulmus sp.	f	ff	ff		
others					
"*Bambusa*" cf. *astensis* Peola	rr				
Monocotyledones indet.				f	
Pinus (*Strobus*) cf. *peuce* (cone)					1
"*Pteris*" sp.				f	

Table 14.3. Distribution and frequency of taxa in layers A1-A5 of the Arboschio succession. **ff**, very frequent; **f**, frequent; **r**, rare; **rr**, very rare ; **1, 2:** number of specimens. Where not specified the fossil represent leaf imprints.

The sediments in the middle part of the succession yet belong to the Sam Martino unit, and they were deposited in abandoned deltaic/fluvial channels or in small lakes and swamps. The richest plant assemblages in this interval were described by Pavia (1970), while Martinetto & Mai (in Carraro, 1996) were not able to gather much new material, due to the unfavourable outcrop conditions in the 1990s. Particularly interesting is one of the oldest records in Italy of a massive occurrence of fruits of *Trapa* cf. *natans* L.

The uppermost portion of the Arboschio section, still exposed at present, is characterised by a moderate marine ingression, testified by the occurrence of the bivalve *Cerastoderma edule* in a thin sandy layer, which at least indicates brackish conditions. Even this part of the succession yields terrestrial plant remains (impressions only), which have been sampled in the 1990s, and mostly consist in incomplete and chaotically disposed leaf impressions preserved in massive mud. The commonest leaf taxon in layer A5 (Fig. 14.1) is *Quercus pseudocastanea* which is associated with cupules assigned to *Q. sapperi*, thus suggesting that both taxa might have been produced by the same palaeobotanical entity. The remaining leaves belong to *Daphnogene polymorpha*, whose presence in a Middle Pliocene deposit must not be regarded as surprising, since it is just one of several elements which disappear earlier in Middle Europe (Miocene) than in northern-central Italy (Martinetto, 1999).

Layer A5 also yielded a few external moulds of fruits and seeds, the most important ones being produced by an endocarp of *Symplocos schereri* and by two seeds of *Toddalia*. These two taxa are usually considered «subtropical» elements, and in Piedmont they are only frequent in the floras of the Ca' Viettone complex (Early Pliocene). However, *Toddalia rhenana* occurs in three assemblages of the Stura Floristic Complex, and *Toddalia naviculaeformis* has been reported from the Middle Pliocene sediments of the R.D.B. Quarry, whose floras have been referred to the Stura Complex. On the other hand, *Symplocos schereri* is not known in northern Italy after the Early/Middle Pliocene transition, though it occurs in the Middle Pliocene of central Italy, and precisely in the Santa Barbara section of the Upper Valdarno (Martinetto, in press).

MARTINETTO E. - Key-sites 8 and 9: the «Villafranchian» floras of the R.D.B. Quarry and Arboschio. *In* MARTINETTO E. (ed.): Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.4 (2001): 73-77.

REFERENCES

Abbazzi L., Ficcarelli G. & Torre D. 1995. Deer fauna from the Aulla quarry (Val di Magra, Northern Apennines). Biochronological remarks. Riv. It. Paleont. Strat., 101 (3): 341-348.

AGIP 1982. Foraminiferi padani. Atlante iconografico e distribuzione stratigrafica. 52 pls.

Aguirre & Pasini G. 1985. The Plio-Pleistocene boundary. Episodes, 8: 116-120.

Allason B., Carraro F., Ghibaudo G., Paganelli A., & Ricci B. 1981. Prove palinologiche dell'età pleistocenica inferiore di depositi "villafranchiani" in Piemonte. Geogr. Fis. Dinam. Quat. 4: 39-47.

Ammann B. 1994. Differential flotation of saccate pollen - A nuisance and a chance. Dissertationes Botanicae 234: 101 - 110.

Armstrong J.E. & Brown W.L. 1954. Late Winsconsin marine drift and associated sediments of the lower Fraser Valley, British Columbia, Canada. Bull. Geol. Soc. America, 65.

Arobba D., Calderoni G., Caramiello R., Carraro F., Giardino M. & Quagliolo P. 1997. Palynological and radiometric evidence of a last glacial-interstadial from peat sediments in the Ivrea Morainic Amphitheatre (NW-Italy). Geol. Insubr. 2(2): 143-148.

Azzaroli A. 1977. The Villafranchian Stage in Italy and the Plio-Pleistocene Boundary. Giorn. Geol., (2), 41, 1-2: 61-79.

Azzaroli A., De Giuli C., Ficcarelli G. & D. Torre 1986. Mammal succession of the Plio-Pleistocene of Italy. Mem. Soc. Geol. It., 31: 213-218.

Barbieri F., Carraro F. & Petrucci F. 1974. Osservazioni micropaleontologiche e stratigrafiche sulla serie marina e glaciomarina della Valchiusella (Ivrea, prov. di Torino). Acta Nat. Ateneo Parmense, 10 (1): 5-14.

Basilici G. 1996. Sedimentologia.In F. Carraro (ed.). Revisione del Villafranchiano nell'area-tipo di Villafranca d'Asti. Il Quaternario, Italian J. Quat. Sci., 9 (1): 42-56.

Basilici G., Martinetto E., Pavia G. & Violanti D., 1997. Paleoenvironmental evolution in the Pliocene marine-coastal succession of Val Chiusella (Ivrea, NW Italy). Boll. Soc. Paleont. It.

Benthem van F., Clarke G. & Punt W. 1984. Fagaceae. The Nortwest European Pollen Flora, 33: 87-110.

Bertoldi R. 1990. Apporto della palinologia alla conoscenza dei giacimenti continentali pliocenici e pleistocenici inferiori dell'Italia centro-settentrionale. Studi Trent. Sc. Nat., Acta Biol. 66: 9-15.

Bertoldi R. 1995. Palinostratigrafia dei bacini intermontani dell'Appennino nord-occidentale. Il Quaternario, Italian J. Quat. Sci., 8 (1): 61-70.

Bertoldi R. 1996. Pollini. Il Complesso inferiore. In F. Carraro (ed.), Revisione del Villafranchiano nell'area-tipo di Villafranca d'Asti. Il Quaternario, Italian J. Quat. Sci., 9 (1): 79-85.

Bertoldi R. & E. Martinetto 1995. Ricerche paleobotaniche (palinologiche e paleocarpologiche) sulla successione "villafranchiana" del Rio di Ca' Viettone. Il Quaternario, Italian J. Quat. Sci., 8 (2): 403-421.

Bertoldi R., Binotti A., & F. Castello 1994. *Reevesia* and *Itea* in the pollen flora of the upper Neogene continental deposit at Sarzana (lower Magra Valley, northern Italy). Rev. Palaeobot. Palyn., 80 (1/2): 159-172.

Beug H.J. 1961. Leitfaden der Pollenbestimmung. 1. Fischer, Stuttgart. 63 pp.

Biino G. & Compagnoni R. (1989). The Canavese Zone between the Serra d'Ivrea and the Dora Baltea River (Western Alps). Eclogae geol. Hel., 82, 413-427.

Boriani G. C. & Sacchi R. 1973. Geology of the junction between the Ivrea-Verbano and Strona-Ceneri Zones (Southern Alps). Mem Ist. Geol. Miner. Univ. Padova, 28.

Boriani G. C. & Sacchi R. 1974. The Insubric and others tectonic lines in the Southern Alps (in Italy). Mem. Soc. Geol. It., 13 (1), 327-337.

Bortolami G. C., Carraro F. & Sacchi R. 1967. Note illustrative della Carta Geologica d'Italia alla scala 1:100000: Foglio 43: Biella. Servizio Geologico d'Italia, Roma.

Bortolami G. C., Carraro, Friz C., Govi M. & Sacchi R. 1966. Carta geologica d'Italia alla scala 1:100000: Foglio 43, Biella. II ed., Servizio Geologico d'Italia, Roma.

Brice J.C. 1983. "Planform properties of meandering rivers". In: Eliott M. (Ed.) River Meandering . Proc. Conf. "River 83. American Society of Civil Engineers, New York, 1-15.

Bruno L. 1877. I terreni costituenti l'anfiteatro allo sbocco della Dora Baltea. F.L. Curbis, Ivrea, 65 pp.

Caramiello R., Carraro F., Collo G., Gianotti F., Giardino M., Martinetto E., Perotto A., Siniscalco C. 1996. Revisione del significato dei depositi "Villafranchiani" in Piemonte. Il Quaternario, Italian J. Quat. Sci., 9 (1), 187-194.

Caratini C., Van Campo M. & Sivak J. 1972. Pollen de *Cathaya* (Abietaceae) au Tertiaire en France. Pollen et Spores, XIV (2): 169-172.

Carraro F. (ed.) 1996 (with contributions of: P. Ambrosetti, M. Angela-Franchini, A. Azzaroli, G. Basilici, G. Belluomini, R. Bertoldi, P. Boano, D. Bormioli, F. Campanino, R. Caramiello, F. Carraro, M. Cerasoli, A. Ciangherotti, R. Compagnoni, D. Esu, E. Ferrero, G. Ficcarelli, M.G. Forno, G. Genovese, M. Giardino, O. Girotti, E. Gliozzi, R. Lanza, D. Mai, L. Manfra, E. Martinetto, F. Masini, A. Moscariello, G. Pavia, A. Perotto, R. Polino, B. Sala, C. Siniscalco, D. Torre & D. Violanti). The Villafranchian in the Villafranca d'Asti type-area: A revision. Italian J. Quat. Sci., 9(1), 1996, 5-120.

Carraro F. 1992. La zona pedemontana da Ivrea ad Arona - Depositi Quaternari. In: Dal Piaz G.V. (ed): Le Alpi dal Monte Bianco al Lago Maggiore. Guide Geologiche Regionali. Soc. Geol. it. 186-209. BEMA. Milano

Carraro F. 1992. L'Anfiteatro Morenico d'Ivrea. In: Dal Piaz G.V. (eds) Le Alpi dal Monte Bianco al Lago Maggiore. Guide Geologiche Regionali. Soc. Geol. it. 188-191. BEMA. Milano

Carraro F., Medioli F. & Petrucci F. 1970. Significato della presenza di depositi glaciomarini nell'Anfiteatro morenico d'Ivrea riguardo al problema del limite Plio-Pleistocene. Acc. Naz. dei Lincei, Rend. Cl. Sc. FF. MM. NN., Ser. 8. 56/ 1-6. Roma .

Carraro F., Medioli F. & Petrucci F. 1974. Significato della presenza di depositi glaciomarini nell'Anfiteatro morenico d'Ivrea riguardo al problema del limite Plio-Pleistocene: Atti Acc. Naz. Lincei, Cl. SFMN., ser. VIII, 56 (3): 397-402.

Carraro F., Medioli F. & Petrucci F. 1975. Geomorphological study of the Morainic Amphitheatre of Ivrea, Northwest Italy". Bull. R. Soc. New Zealand. 13: 89-93. Wellington.

Carraro F., Lanza R., Perotto A. & Zanella E. 1991. L'evoluzione morfologica del Biellese occidentale durante il Pleistocene inferiore e medio, in relazione all'inizio della costruzione dell'Anfiteatro Morenico d'Ivrea. Boll. Museo Reg. Sc. Nat. Torino. 9(1): 99-117.

Cassulo R. 1999. Revisione della geologia del settore frontale-destro dell'Anfiteatro Morenico d'Ivrea. Unpubl. graduation thesis in Geol. Sci., Univ. Torino.

Cavalli C. & Vigna B. 1995. Il «Villafranchiano» nel sottosuolo della Pianura Cuneese. Ital. J. Quat. Sci. 8 (2): 423-434.

Cavallo O. & E. Martinetto 1996. Flore plioceniche del bacino del Tanaro. Alba Pompeia, 17 (1): 5-31.

Cavallo P. & E. Martinetto in press. Flore carpologiche del Pliocene di Castelletto Cervo (Biella). Boll. Mus. Reg. Sci. Nat. To.

Cerchio E. 1982. Studio palinologico dei depositi glaciomarini pliocenico-medi della Val Chiusella. Graduation thesis in Geological Sciences, University of Torino, unpublished.

Cerchio E., Coccolini G., Fornelli A., Fozzati L. & Tropeano D. 1990. Per un'archeologia forestale in Piemonte: il giacimento "Villafranchiano" della Stura di Lanzo (Villanova, Nole Canavese, Torino). Quad. Soprint. Archeol. Piem. 9: 6-25.

Charrier G. 1953. I legni silicizzati del Neogene Piemontese. Riv. Ital. Palaeont. Strat. 59 (1): 123-144.

Cita M.B. 1975. Studi sul Pliocene e sugli strati di passaggio dal Miocene al Pliocene. VIII. Planktonic foraminiferal biozonation of the Mediterranean Pliocene deep sea record. A revision. Riv. It. Paleont. Strat., 81 (4): 527-544.

Clarke G.C.S. 1980. Boraginaceae. The Northwest European Pollen Flora, 2. Elsevier, Amsterdam.

Clarke G.C.S., Punt W. & Hoen P.P. 1991. Ranunculaceae. The Northwest European Pollen Flora, 51, Elsevier, Amsterdam.

CNR (Consiglio Nazionale delle Ricerche) 1983. Neotectonic map of Italy. Quaderni de La Ricerca Scientifica. 4 , 114. L.A.C., Firenze.

Collinson M.E. 1983. Accumulation of fruits and seeds in three small sedimentary environments and their palaeoecological implications. Ann. Bot. 52: 583-592.

Cremaschi, M. & C. Ravazzi 1995. Nuovi dati stratigrafici e geocronologici sul Bacino di Leffe (Prealpi Lombarde, Bergamo). Il Quaternario, Italian J. Quat. Sci., 8 (1): 167-182.

De Beaulieu J.L. 1969. La végétation dans les Alpes meridionales et le Massif Central pendant le Tardiglaciaire et le Post-glaciaire. Bull. Ass. Franc. Et. Quat. Suppl. (INQUA, Etudes Franç. Quat.). 124-126.

De Giuli C., Ficcarelli G., Mazza P. & D. Torre 1983. Confronto fra successioni marine e continentali del Pliocene e Pleistocene inferiore in Italia e nell'area mediterranea. Boll. Soc. Paleont. Ital., 22 (3): 323-328.

Dode L.A. 1906. Contribution à l'étude du genre *Juglans*. Bull. Soc. Dendrol. France 2, 67 - 98.

Dode L.A. 1909. Contribution à l'étude du genre *Juglans*. Bull. Soc. Dendrol. France 11, 22 - 50; 13, 165 -215.

Emberger L. & Sabeti H. 1962 - Forets denses intertropicales et forets caspiennes humides. Naturalia Monspeliensia, Série Botanique, 14, 55-61.

ENEL (Ente Nazionale per l'Energia Elettrica) 1981. Elementi di Neotettonica del territorio italiano - Relazione. 95 pp. Grafiche Alma, Milano

Erdtman G. 1965. Pollen and Spore Morphology / Plant Taxonomy. Part III. Almqvist Wiksell, Stockolm.

Francavilla F. & L. Tomadin 1970. Contributo alle conoscenze paleobotaniche e sedimentologiche del Villafranchiano-Tipo. Giorn. Geol. (ser. 2), 45 (1): 65-76.

Franchi S., Mattirolo E., Novarese V., Stella A. 1912. Foglio 42, «Ivrea», della Carta Geologica d'Italia alla scala 1:100.000, I ed., R. Ufficio Geologico, Roma.

Gabert P. 1962. Les plaines occidentales du Po et leurs Piedmonts (Piémont, lombardie occidentale et centrale. Etude morphologique. Luis Jean, Gap, 531 pp.

Gee, C.T., Abraham, M. & Sander P.M., 1997, The occurrence of carpofloras in coarse sand fluvial deposits: comparison of fossil and recent case studies. Mededelingen Nederlands Instituut voor Toegepaste Geowetenschappen TNO, 58: 171-178.

Gianotti F. (1993). Ricostruzione dell'evoluzione geologica quaternaria del margine esterno del settore laterale sinistro dell'Anfiteatro Morenico d'Ivrea. Graduation thesis in Geological Sciences, University of Torino, unpublished.

Gianotti F. 1993. Studio geologico di un settore del tratto laterale sinistro dell'Anfiteatro morenico d'Ivrea. Degree Thesis in Geological Science. Università di Torino, unpublished.

Gianotti F. 1996. Bessa, paesaggio ed evoluzione geologica delle grandi aurifodine biellesi. Quaderni di Natura Biellese, 1. Eventi & Progetti Editore, 83 pp.

Giardino M. 1997. Geomorphology of the Ivrea Morainic Amphitheatre. In Ajassa R. & Biagini E. eds. "Guide to the excursion of the Fourth International Conference on Geomorphology - Italy 1997. Suppl. Geogr. Fis. Dinam. Quat, III, T2, 68-71.

Gregor, H.-J. 1986. Preliminary report about the macrofloral history of the Stirone River sequence (Zanclean-Piacenzian-"Calabrian"). Mem. Soc. Geol. It., 31: 219-227.

Gregor H.-J. 1990. Contribution to the Late Neogene and Early Quaternary floral history of the Mediterranean. Rev. Palaeobot. Palynol., 62: 309-338.

Günther T. & Gregor H.-J., 1989 - Computer-Analyse mitteleuropäischer Frucht- und Samenfloren Europas, Band 1. Documenta Naturae 50, 1: 1-180.

Hancock P. 1985. Brittle microtectonics: principles and practice. J. Struct. Geol., 7, 437-458.

Hills L.V., Klovan J.E. & Sweet A.R., 1974 - *Juglans eocinerea* n. sp., Beaufort Formation (Tertiary), southwestern Banks Island, Arctic Canada. Can. J. Bot. 52: 65 - 90.

Hou H.-Y. 1983. Vegetation of China with reference to its geographical distribution. Ann. Missouri Bot. Gard. 70: 509-548.

Huang T.-C. 1972. Pollen Flora of Taiwan. National Taiwan University, Botany Department Press.

Kennett J.P. & Srinivasan M.S. 1983 – Neogene Planktic Foraminifera, pp. 263, Hutchinson Ross Publ. Comp.

Krassilov V.A. 1974. Causal biostratigraphy. Lethaia, 7: 173-179.

Krutzsch W. 1988. Kritische Bemerkungen zur Palynologie und zur klimastratigraphischen Gliederung des Pliozäns bis tieferen Altpleistozäns in Süd-Südwest-Nordwest- und pro parte Mitteleuropa sowie dei Lage der Pliozän-Grenze in diesem Gebiet: Quartärpaläont., 7: 7-51.

Leeuwen van P., Punt W. & Hoen P.P. 1988. Polygonaceae. The Northwest European Pollen Flora, 43. Elsevier, Amsterdam.

Leroy S. & Seret G. 1992. Duration and vegetation dynamic of the Nogaret interglacial (-1.9 Ma) (S. of France) - tentative correlation with stage 75. In Kukla G. & Went E. (eds.): "Start of a glacial". Proc. of Mallorca NATO ARW, NATO ASI Series I, 3: 113-125. Springer Verlag, Heidelberg.

Leroy S. & Roiron P. 1996. Latest Pliocene pollen and leaf floras from Bernasso palaeolake (Escandorgue Massif, Hérault, France). Rev. Palaeobot. Palynol., 94: 295 - 328.

Lindsay E.H., Opdyke N.D. & Fejfar O. 1997. Correlation of selected late Cenozoic European mammal faunas with the magnetic polarity time scale. Palaeogeogr. Palaeoclimatol. Palaeoecol., 133: 205-226.

Lindsay E.H., Opdyke N.D. & Johnson N.M. 1980. Pliocene dispersal of the horse *Equus* and late Cenozoic mammalian dispersal events: Nature, 287: 135-138.

Liu Y.S., Zetter R. and Ferguson D.K. 1997. Fossil pollen grains of *Cathaya* (Pinaceae) in the Miocene of eastern China. Mededelingen Nederlands Instituut Toegepaste Geowtenschappen, 58: 227-235.

Lona F. & Bertoldi R. 1973. La storia del Plio-Pleistocene italiano in alcune sequenze vegetazionali lacustri e marine. Mem. Acc. Naz. Lincei, v. XI - Sez. III, pp. 1-35, Roma.

Mai D.H. 1964. Die Mastixioideen-Floren im Tertiär der Oberlausitz.Paläont. B, 2(1): 1-192.

Mai D.H. 1985. Entwicklung der Wasser und Sumpfplantzen-Gesellschaften Europas von der Kreide bis ins Quartär. Flora, 176: 449-511.

Mai D.H. 1994. Fossile Koniferenreste in der meridionalen Zone Europas. Feddes Repert., 105 (3-4): 207-227.

Mai D.H. 1995a. Tertiäre Vegetationsgeschichte Europas, 691 pp.. Gustav Fischer, Jena.

Mai D.H. 1995b. Palaeocarpological investigations in the Villafranchian (Pliocene) of Italy. Boll. Mus. Reg. Sci. Nat. Torino.

Mai D.H. & H. Walther 1978. Die Floren der Haselbacher Serie im Weisselster-Becken (Bezirk Leipzig, DDR). Abh. Staatl. Mus. Min. Geol. Dresden, 28: 1-200.

Mai D.H. & H. Walther 1988. Die pliozänen Floren von Thüringen, Deutsche Demokratische Republik. Quartärpaläont., 7: 55-297.

Manchester S.R. 1987. The fossil history of Juglandaceae. Ann. Missouri Bot. Gard., 21, 137 pp.

Manning W.E. 1978. The classification within the Juglandaceae. Ann. Missouri Bot. Gard. 65, 1058 - 1087.

Marasti R. & S. Raffi 1976. Osservazioni biostratigrafiche e paleoecologiche sulla malacofauna del Piacenziano di Majatico (Emilia occ., Parma). Boll. Soc. Paleont. Ital., 15/2: 189-214.

Martinetto E. 1993. Paleocarpological investigations in the Pliocene of Piedmont (Italy). In: Planderova E. *et al.* (ed.). "Paleofloristic and paleoclimatic changes during Cretaceous and Tertiary", pp. 187-190, Bratislava 1993.

Martinetto E. 1994a. Analisi palaeocarpologica dei depositi continentali pliocenici della Stura di Lanzo. Boll. Mus. Reg. Sci. Nat. Torino 12 (1): 137-172.

Martinetto E. 1994b. Palaeocarpology and the *"in situ"* ancient plant communities of a few Italian Pliocene fossil forests. In: Matteucci R., Carboni M.G. & Pignatti J.S. (eds.). Studies on Ecology and Palaeoecology of Benthic Communities. Boll. Soc. Palaeont. Ital. Spec. Vol. 2, pp. 189-196, Mucchi, Modena.

Martinetto E. 1995. Significato cronologico e palaeoambientale dei macrofossili vegetali nell'inquadramento stratigrafico del «Villafranchiano» in alcuni settori del Piemonte. Doctorate thesis, 149 pp.. Dipartimento di Scienze della Terra di Torino, Torino.

Martinetto E. 1996. Pliocene vegetation at the western margin of the Po Basin. Allionia, 34: 349-355.

Martinetto E. 1999. Chronological framing of Pliocene to Early Pleistocene plant macrofossil assemblages from northern Italy. Acta Palaeobot., Suppl. 2: 503-511.

Martinetto E. in press. The role of central Italy as a centre of refuge for thermophilous plants in the late Cenozoic. Acta Palaeobot.

Martinetto E. & D. H. Mai 1996. Macrofossili vegetali. In F. Carraro (ed.). Revisione del Villafranchiano nell'area-tipo di Villafranca d'Asti. Italian J. Quat. Sci., 9 (1): 73-79.

Martinetto E. & Ravazzi C. 1997.Plant biochronology of the Valle della Fornace succession (Varese) based on the Plio-Pleistocene record in northern Italy. Geologia Insubrica, 2 (1) (1997).

Martinetto E., Pavia G. & Bertoldi R., 1997. Fruit and seed floras rich in exotic and subtropical elements from two Lower Pliocene successions of Italy. Mededelingen Nederlands Instituut voor Toegepaste Geowetenschappen TNO, 58: 237-244.

Meijden van der R. 1987. A survey of the pollenmorphology of the Indo-Pacific species of *Symplocos* (Symplocaceae). Pollen et Spores, XII (4): 513-546.

Monegatti P. & Raffi S. 2001. Taxonomic diversity and stratigraphic distribution of Mediterranean Pliocene bivalves. Palaeogeogr. Palaeoclimatol. Palaeoecol., 165: 171-193.

North American Commission on Stratigraphic Nomenclature 1983. North American Stratigraphic Code. Amer. Ass. Petrol. Geol. Bull. 67(5): 841-875.

Numata M. (ed.) 1974. The flora and vegetation of Japan. Elsevier, Amsterdam, 294 pp.

Ollier C. D. (1981). Tectonics and landforms. Longman, London & New York, 324 pp.

Pavia G. 1970. Resti di *Anancus arvernensis* e flora ad affinità plioceniche nel Villafranchiano inferiore della cava di Arboschio (Villafranca d'Asti). Mem. Soc. Geol. It. 9: 157-176.

Pavia G., Chiambretto L. & G. Oreggia 1989. Paleocomunità a Molluschi nel Pliocene inferiore di Breolungi (Mondovì, Italia NW). Atti III Simp. Ecol. Paleoecol. Comunità Bentoniche: 521-569, Catania

Peola P. 1895. Flora fossile braidese. Tip. Racca, Bra (Cuneo), 134 pp.

Peola P. 1901. La vegetazione in Piemonte durante l'Era Terziaria. Riv. Fis. Mat. Sc. Nat. 1901: 1-45.

Punt W. & Blackmore S. 1976-1995. The Northwest European Pollen Flora, 1-7. Elsevier, Amsterdam.

Punt, W. & Malotaux, M. 1984. Cannabaceae, Moraceae and Urticaceae. The Northwest European Pollen Flora, 4.. Elsevier, Amsterdam.

Punt W., Bos J.A.A. & Hoen P.P. 1991. Oleaceae. The Northwest European Pollen Flora, 45. Elsevier, Amsterdam.

Punt, W., Reitsma, Tj. & Reuvers, A.A.M.L. 1976. Caprifoliaceae. The Nortwest European Pollen Flora 1: 5-29. Elsevier, Amsterdam.

Rabogliatti C. 1953. Studio dei lembi pliocenici dei dintorni di Ivrea. Pubbl. Ist. Geol. Univ. Torino, 2: 95-114.

Raffi S. & R. Marasti 1982.The Mediterranean from the Pliocene to the Recent: observations and hypotheses based on the evolution of the taxonomic diversity of Molluscs. In: Palaeontology, Essential of Historical Geology, pp. 158-176, S.T.E.M. Mucchi, Modena.

Raffi S. & Monegatti P. 1993. Bivalve taxonomic diversity throughout the Italian Pliocene as a tool for climatic-oceanographic and stratigraphic inferences. Ciencias da Terra (UNL), 12: 45-50.

Raffi S., Stanley, S.M. & Marasti R. 1985. Biogeographic patterns and Plio-Pleistocene extinction of Bivalvia in the Mediterranean and southern North Sea. Paleobiology, 11: 368-388.

Ramasco M. & Rossanigo P. (1988).Evoluzione morfologica dell'alveo del T. Cervo nel tratto di pianura e studio fotointerpretativo dell'inondazione verificatasi il 2-3 novembre 1968. Provincia di Vercelli (Settore Assetto Ambientale) - Regione Piemonte (Servizio Geologico) Technical Report. 28pp., 6 oversizes plates.

Ravazzi C. 1993. Variazioni ambientali e climatiche al margine meridionale delle Alpi nel Pleistocene inferiore: stratigrafia e analisi pollinica della serie di Leffe. Tesi di Dottorato di Ricerca. 269 pp. Dipartimento di Scienze della Terra. Università di Milano.

Ravazzi C. 1995.Paleobotany of the biogenic unit of the Leffe Formation (Early Pleisotcene, northern Italy): brief report on the state of the art. Italian Journal of Quaternary Sceinces, 8 (2): 435-442.

Ravazzi C. & Moscariello A. 1997. Sedimentation, palaeoenvironmental evolution and time duration of earliest Pleistocene climatic cycles in the 24 - 56 m FM-core interval (Leffe Basin, northern Italy). Mededelingen Nederlands Instituut Toegepaste Geowtenschappen, 59 (1998).

Ravazzi C. and Van der Burgh J. 1994.Coniferous woods in the Early Pleistocene brown coals of the Leffe Basin (Lombardy, Italy). Rivista Italiana di Paleontologia e Stratigrafia, vol. 100 (4): 597-620.

Ravazzi C. & Van der Burgh J. 1994. Coniferous woods in the Early Pleistocene brown coals of the Leffe Basin (Lombardy, Italy). Riv. Ital. Paleont. Strat., 100 (4): 597-620.

Ravazzi C. 1995. Paleobotany of the biogenic unit of the Leffe Formation (Early Pleistocene, N-Italy): brief report on the status of the art. Il Quaternario - Italian Journal of Quaternary Sciences, vol. 8 (2): 435-442.

Ravazzi C. 1993. Variazioni ambientali e climatiche al margine meridionale delle Alpi nel Pleistocene inferiore. Stratigrafia e analisi pollinica della serie di Leffe. Tesi di Dottorato di Ricerca in Scienze della Terra, A.A.

1991/1992, 269 pp. Università di Milano.

Reid C. & E.M. Reid 1915. The Pliocene floras of the Dutch- Prussian border. Meded. Rijksopsp. Delfst., 6: 1-178.

Reid E.M. 1920. Recherches sur quelques graines pliocénes du Pont-de-Gail (Cantal). Bull. Soc. Geol. France, ser. IV, 20: 48-87.

Reille M. 1992-1998. Pollen et spores d'Europe et d'Afrique du Nord. Volume I + suppl. 1 and 2. Laboratoire de Botanique historique et Palynologie, Marseille.

Rudolph K. 1935. Mikrofloristische Untersuchung tertiärer Ablagerungen im nördlichen Böhmen. Beih. z. Bot. Centralbl. 54 B: 244-328.

Rudolph K. 1936. Mikrofloristische Untersuchung tertiärer Ablagerungen im nördlichen Böhmen. Beih. z. Bot. Centralbl., 54 B: 244-328.

Satoo T. 1983. Temperate broad-leaved evergreen forests of Japan. In: Ovington D. (ed.). Temperate broad-leaved evergreen forests. Elsevier, Amsterdam, 241 pp.

Schneider R.E. 1978. Pollenanalytische Untersuchungen zur Kenntnis der Spat-und postglazialen Vegetationsgeschischte am Sudrand der Alpen zwischen Turin und Varese (Italien). Bot. Jahrb. Syst. 100(1): 26-109.

Sismonda E. 1859. Prodrome d'une flore tertiaire du Piémont. Mem. R. Acc. Sci. Torino ser. II 18: 519-547.

Sismonda E. 1865. Materiaux pour servir à la Paléontologie du terrain tertiaire du Piémont. Végétaux. Mem. R. Acc. Sci. Torino ser. II 22: 391-471.

SPI 1996. XIII Congresso della Società Paleontologica Italiana. Guida alle escursioni. Centro Grafico Univ. Parma, 69 pp.

Spicer R.A. & Wolfe J. A. 1987. Plant taphonomy of late Holocene deposits in Trinity (Clair Engle) Lake northern California. Palaeobiol. 13, (2): 227-245.

Stone D.E. & Broome C.R. 1975. Juglandaceae. In S. Nilsson (chief editor), World Pollen and Spore Flora. Almqvist and Wiksell, Stockholm 4: 1-31.

Stoppani A. (1880) In Negri G., Stoppani A. & Mercalli G. (1880). Geologia d'Italia: 3 parti. parte 2a: L'Era Neozoica. Vallardi, Milano.

Suc J.-P., Bertini A., Combourieu-Nebout N., Diniz F., Leroy S., Drivaliari A., Russo-Ermolli E., Zheng Z., Bessais E. & Ferrier J. 1995a. Structure of the West Mediterranean vegetation and climate since 5.3 Ma: Acta Zool. Cracov. 38(1): 3-16.

Suc J.-P., F., Diniz S. Leroy C., Poumot A., Bertini L., Dupont M., Clet E,. Bessais Z., Zheng S,. Fauquette J., Ferrier 1995b, Zanclean (~ Brunssumian) to Lower Piacenzian (~ Lower -Middle Reuverian) climate from 4° to 54° north latitude (West Africa, West Europe and West Mediterranean areas). Mededelingen Rijks Geologische Dienst, 52: 43-56.

Summerfield M.A. (1993). Global Geomorphology. Longman Scientific & Technical, 537pp.

Takhtajan A. 1980. Outline of the classification of flowering plants (Magnoliophyta). Bot. Rev., 46: 225-359.

Thomasson J.R. 1991. Sediment-borne "seeds" from Sand Creek northwestern Kansas: taphonomic significance and palaeoecological and palaeoenvironmental implications. Palaeogeogr. Palaeoclimatol. Palaeoecol. 85: 213-225.

Thunnel R., Williams D., Tappa E., Rio D. & I. Raffi 1990. Plio-Pleistocene Stable Isotope Record for Ocean Drilling Program Site 653, Tyrrenian Basin: Implications for the paleoenvironmental history of the Mediterranean Sea. In Kastens K. A. et al. (eds.). «Proc. of the O.D.P., Scient. Res., 107: 387-399.

Torri P., Accorsi C.A., Bandini Mazzanti M. & Forlani L. 1990. Flora Palinologica italiana: *Ostrya carpinifolia* Scop., *Carpinus betulus* L., *Carpinus orientalis* Miller: schede palinologiche e chiave specifica. Giorn. Bot. It., 124, (1), 182.

Turner S.C. & Blackmore S. 1984. Plumbaginaceae. The Northwest European Pollen Flora, 4, Elsevier.

Uggeri A., Felber M., Bini A., Bignasca C. & Ravazzi C. 1994. La successione della Val Fornace. I depositi Plio-Quaternari e l'evoluzione del territorio varesino. Guida alle escursioni Riunione autunnale Gruppom Nazionale Geografia Fisica e Geomorfologia CNR, Varese: 63-92.

Uggeri A., Felber M., Bini A., Ravazzi C., Bignasca C. e Heller F. 1995. Pliocene-Pleistocene environmental evolution in the Varese region (NW Lombardia, Northern Italy): evidence of a Pliocene glaciation. Abstracts XIV International Congress INQUA, Berlin 1995, Terra Nostra 2/95: 280.

Van Der Burgh J. 1974. Wood-remains from the Lower Pleistocene of Tegelen (The Netherlands). Scripta Geol. 25, 1 - 35.

Van Der Burgh J. 1983. Allochthonous seed and fruit floras from the Pliocene of the Lower Rhine Basin. Rev. Palaeobot. Palyn., 40: 33-90.

Van der Hammen T. 1951. A contribution to the paleobotany of the Tiglian. Geol. Mijnb., 7: 242.

Venturini G. 1995. Geology, Geochemistry and Geochronology of the inner central Sesia Zone (Western Alps, Italy). Mém. Géol. (Lausanne), 25, 148 pp.

Voshage H., Hofmann A.W., Mazzucchelli M., Rivalenti G., Sinigoi S., Raczek I. & Demarchi G. (1990) -Isotopic evidence from the Ivrea Zone for a hybrid lower crust formed by magmatic underplating. Nature, 347 (6295), 731-736.

Wiemann M.C., Manchester S. R., Dilcher D.L., Hinojosa L.F. & Wheeler E. A. 1998. Estimation of temperature and precipitation from morphological characters of Dicotyledonous leaves. *Amer. Jour. Bot.:* 85 (12): 1796-1802.

Wing S.L. & Greenwood D.R., 1993. Fossils and fossil climate: the case for equable continental interiors in the Eocene. *Phil. Trans. R. Soc. Lond. B.*; 341: 243-252.

Wang C.-W. 1961. The forests of China with a survey of grassland and desert vegetation, 313 pp.. Maria Moores Cabot Foundation Publ., ser. 5, Havard Univ., Cambridge-Massachussets.

Wolfe J.A. 1971. Tertiary climatic fluctuations and methods of analysis of tertiary floras. Palaeogeogr. Palaeoclimatol. Palaeoecol., 9: 27-57.

Wolfe J.A., 1979. Temperature parameters of humid to mesic forests of eastern Asia and relation to forests of other regions of the northern hemisphere and Australia. *U. S. Geological Survey Prof. Paper* No.1106.

Ying T.S. 1983. The floristic relationships of the temperate forest regions of China and the United States. Ann. Missouri Bot. Gard., 70: 597-604.

Ying T., Zhang Y. and Boufford D.E. 1993. The endemic genera of seed plants of China. Science Press, Beijing.

Zagwijn W.H. 1960. Aspects of the Pliocene and Early Pleistocene vegetation in the Netherlands. Meded. Geol. Sticht., III (1) 5: 3-78.

Zagwijn W.H. 1963. Pollen-analytic investigations in the Tiglian of the Netherlands. Meded. Geol. Sticht. 16, 49-72.

Zagwijn W.H. 1974, The Pliocene-Pleistocene boundary in western and southern Europe. Boreas, 3: 75-97.

Zagwijn W.H. 1990. Subtropical relicts in the Pliocene flora of Brunssum (The Netherlands). Geol. Mijnbouw, 6: 219-225.

Zagwijn W.H. 1992. The beginning of the Ice Age in Europe and its major subdivisions. Quat. Sci. Rev., 11: 583-591.

Zheng Z. 1990. Végétations et climats néogènes des Alpes maritimes franco-italiennes d'après les données de l'analyse palynologique. Paléobiol. cont., 17: 217-244.

Zienert A. 1973. Das moränen-Amphitheater von Ivrea (Dora Baltea). Heidelberger Geogr. Arb. 38, 141-157.

Zubakov V.A. & Borzenkova I.I. 1990. Global Paleoclimate of the Late Cenozoic. Elsevier, Amsterdam, 453 pp.

Appendix 1. Systematic list of fruit and seed taxa found in the Pliocene floras of the Piemonte region, with plates in CD-ROM - by E. MARTINETTO.

The occurrences are indicated by an abbreviation of the fossil site name, as reported in Fig. 1.2. Some abbreviations are followed by numbers which indicate different layers. The list has not been updated since 1996, but the nomenclature has been revised. Systematic order of families according to Takhtajan (1980).

More or less one third of the species listed below have been figured in several publications (Cavallo & Martinetto, 1996; Cavallo & Martinetto, in press; Mai, 1995; Martinetto, 1994a, 1994b, 1998; Ravazzi & Martinetto, 1997) All the plates published in such works, accompanied by an updated English description, are enclosed as digital files in the CD-ROM attached to this volume. The CD-ROM also contains five plates by Pavia (1970), which show the most common fossil leaves found in the Arboschio succession (Key-site 8).

Pteridophyta

SELAGINELLACEAE

Selaginella borysthenica DOROFEEV & WELICZKIEVICZ 1971
- GA1.

Selaginella jeanettae KNOBLOCH 1986
- BG2, BG3, BA, GA1, RB.

Selaginella kunovicensis KNOBLOCH 1986
- BG2, BG3, CV, FR, GA1, MO2, STU, RI.

Selaginella magnae KNOBLOCH 1986
- BG3, FR, MO4.

Selaginella cf. *malesovicensis* KNOBLOCH 1986
- MO2, STU.

Selaginella moravica KNOBLOCH 1986
- BA, BE, BG2, BG3, BR, CH, CV, MO4, MO2, RB.

Selaginella aff. *selaginoides* (L.) LINK
- CH.

SALVINIACEAE

Salvinia miocenica DOROFEEV 1968
- BE, CT.

Salvinia tuberculata NIKITIN 1948
- BO, FR, GA2, RDB6, STU.

AZOLLACEAE

Azolla cf. *pyrenaica* FLORSCHUETZ & MENENDEZ AMOR 1960
- BE, CT.

Azolla tegeliensis FLORSCHUETZ 1938
- BO, BU, FR, GA1.

Coniferophyta

PINACEAE

Abies spp. (leaves e squame)
- MO2 (squame); CV, CH, BG2, MZ1, BG3, STU.

Cathaya van-der-burghii GOSSMANN in MAI 1994
- BE, BL, CH, CV, LC, TC.

cf. *Cathaya* (leaves)
- BA, BG2, BG3, BO, CT, CV, MO2.

Picea florschuetzii VAN DER HAMMEN 1951
- GA1

Picea spp. (leaves)
- GA1, MO2, MZ, STU.

Pinus aff. *bungeana* ZUCCARINI
- MO2.

Pinus hampeana (UNGER 1847) HEER 1855
- BE, BL, CV, TC.

Pinus massalongi SISMONDA 1865
- CV.

Pinus peuce GRISEBACH
- BL, CV, MO2.

Pinus cf. *salinarum* (PARTSCH 1847) ZABLOKI 1928
- BL, TC.

Pinus cf. *spinosa* HERBST 1844 emend. MAI 1965
- CV.

Pinus sylvestris L. subsp. *pliocenica* KINKELIN 1908
- GA1.

Pinus spp. (leaves)
- BE, BG2, BG3, BG7, BR, CT, CV, MZ.

Pseudolarix schmidtgenii KRAEUSEL 1925
- BG2, BG7, FR, GA5, MZ.

Tsuga sp.
- MZ.

Pinaceae gen et sp. indet.

TAXODIACEAE

Taiwania sp.
- CV, MO4.

Cryptomeria
- BA, BE, CV, MO2, MZ.

Cryptomeria rhenana KILPPER 1968
- BE, BL, BR, CH, CV, MO2, MO4, MZ, STU.

Glyptostrobus europaeus (BRONGNIART 1833) UNGER 1850
- BA, BG2, BL, FN, FR, LC, MO2, RDB10, STU.

Sequoia abietina (BRONGNIART 1822) KNOBLOCH 1964
- BE, CH, CV, ?GA1, MO2, MO4, STU.

Taxodium dubium (STERNBERG 1823) HEER 1855
RDB1.

CUPRESSACEAE

Chamaecyparis sp.
- BA, BE, BG7, BU2, CH, CV, GA1, MO2, MZ.

Libocedrus (s.l.) sp.
- BG2.

Tetraclinis salicornioides (UNGER 1941) KVACEK 1986 (=*Tetraclinis wandae* ZABLOCKI)
- BG2, BG3, BR, CV, MZ.

Thuja sp.
- BR, MZ.

CEPHALOTAXACEAE

Cephalotaxus rhenana GREGOR 1979
- GA1.

TAXACEAE

Taxus sp.
- BG2.

Magnoliophyta

MAGNOLIACEAE

Liriodendron geminata KIRCHHEIMER 1957
- BA, BG3, BU2, CV, GA1, MO2, MZ, RDB1, STU.

Magnolia allasoniae MARTINETTO 1995
- BE, BG2, BL, BR, CH, CV, MZ, PO, RB, RI.

Magnolia cor LUDWIG 1857
- ?BO, BU2, FR, GA1, RDB1, STU.

Magnolia lignita (UNGER 1861) MAI 1975
- BE, BL, CH, CV, TC.

LAURACEAE

Cinnamomum costatum (MAI 1960) PINGEN, FERGUSON & COLLINSON 1994
- BG2, BG3, CV, MO4, STU.

cf. *Lindera*
- BE, CV, RI.

"Litsea" sonntagii GREGOR 1978
- BE, BL, BR, CH, CV, MZ, RB, TC.

Ocotea sp. A
- ?BL, CH, CV, ?TC.

Phoebe sp.
- CV.

Sassafras ludwigii MAI 1971
- RDB1.

Lauraceae gen. et sp. indet.
- BG2, GA1, PO.

CABOMBACEAE

Brasenia victoria (CASPARY 1857) WEBERBAUER 1893
- BE, BO, CT, MO4, STU.

NYMPHAEACEAE

Nuphar canaliculatum C. & E. M. REID 1915
- BO, BU2, CV3, FN, FR, GA1, LC, RDB1, STU.

Nymphaea sp.
- BE.

Pseudoeuryale limburgensis (C. & E. M. REID 1908) DOROFEEV 1972
- BO, GA1.

CERATOPHYLLACEAE

Ceratophyllum demersum L.
- BO, FR, GA1.

Ceratophyllum submersum L.
- BE, BO, LC.

SARGENTODOXACEAE

Sargentodoxa lusatica (MAI 1985) MAI 2001
- BC, RB.

MENISPERMACEAE

Cyclea palatinati-bavariae GREGOR 1977
- BR, CV, MZ.

Sinomenium cantalense (E. M. REID 1920) DOROFEEV 1963
- BA, BG7, BO, BR, CV, FR, GA1, RB, RDB1.

BERBERIDACEAE

Mahonia staphyleaeformis MAI & WALTHER 1988
- BG2, BG7, CV, MO2, RI.

RANUNCULACEAE

Ranunculus cf. *tanaiticus* DOROFEEV 1974
- CV3.

Ranunculus ex gr. *aquatilis* L.
- RDB1, RDB6, STU.

Ranunculus pseudoflammula DOROFEEV 1974
- FN, FR, GA1, STU.

Ranunculus reidii SZAFER 1947
- ?BG7, STU.

Ranunculus sceleratus L.
- BG7, BO, FR, GA1, RDB1, STU.

Thalictrum minimum (SZAFER 1947) MARTINETTO 2001
- CH, GA1, MO2, STU.

Thalictrum sp.
- FR, LC, MO2.

HAMAMELIDACEAE

?Distylium aff. *protogaeum* MAI 1991
- BG2, CV.

Hamamelidoideae gen. et spp.
- BG2, CV.

Hamamelis sp.
- CV.

Liquidambar magniloculata CZECZOTT & SKIRGIELLO 1959
- BE, BG7, BL, BR, CH, CV, TC.

Parrotia reidiana KIRCHHEIMER 1957
- GA1, MO4, RDB1, STU.

?DAPHNIPHYLLACEAE

cf. *Daphniphyllum*
- CV.

ULMACEAE

Zelkova ungeri KOVATS 1851
- GA1, RDB1.

MORACEAE

Ficus cf. *carica* L.
- BO, FR, GA1, MO2, MZ, STU.

Ficus potentilloides MAI 1964
- BE, BG2, BG3, CV, MZ, RB, RDB1.

Morus sibirica DOROFEEV 1963
- GA1, MO2, STU.

URTICACEAE

Boehmeria lithuanica DOROFEEV 1982
- BG7, BO, CH, CV, FN, FR, GA1, LC, MO2, RDB1, RDB6, STU.

Pilea bashkirica DOROFEEV 1982
- BO, RB.

Urtica cf. *dioica* L.
- FR, GA2.

Urtica sp.
- MO2.

FAGACEAE

Fagus decurrens C. & E. M. REID 1915
- BR, FN, GA1, LC, MO2, STU.

Fagus sp. indet.
- BA, BE, BO, BL, CH, CV, MZ, PO, TC.

Quercus cf. *robur*
- BG3, ?BL, BR, GA1, TC.

Quercus ex sect. *Cerris* OERSTEDT
- BL, GA1, TC.

Quercus sp. A
- BG2.

Quercus sp. B
- BG2.

Trigonobalanopsis exacantha (MAI 1970) KVACEK & WALTHER 1989
- BE, BG2, BL, BR, CH, CV, MZ, RB, TC.

BETULACEAE

Alnus sp. (spp. ?)
- BA, BG2, BG3, BG7, BO, BU2, CV, FN, FR, GA1, LC, MO2, MO4, MZ, RDB1, RDB6, STU.

Betula sp.
- BG3, FR, MO.

Carpinus betulus L.
- BG7, BO, BR, CH, CV, MO2, MZ, PO, STU, TC.

Carpinus cf. *europaea* NEGRU 1968
- BE, BG3, CH, CV, FR, MO2, PO, STU.

Corylus avellana L.
- MO2, RDB6, STU.

Ostrya sp.
- BG2, BO.

?Tubela sp.
- CV.

MYRICACEAE

Myrica sp. A
- CH.

JUGLANDACEAE

Carya globosa (LUDWIG 1857) MAEDLER 1939
- GA1.

Carya sp.
- GA1, STU.

Cyclocarya nucifera (LUDWIG 1857) MAI 1973
- GA1.

Juglans bergomensis (BALSAMO-CRIVELLI 1840) MASSALONGO 1852
- BU2, CV, GA1.

Palaeocarya macroptera (BRONGNIART 1828) JAEHNICHEN *et al.* 1977
- BG2, CV.

Pterocarya limburgensis C. & E. M. REID 1915
- BG2, BL, BR, BU2, CV, GA1, PO, STU.

PHYTOLACCACEAE

Phytolacca salsoloides MARTINETTO 1995
- BU2, CV, RB, RI.

CARYOPHYLLACEAE

Caryophyllaceae gen. et sp. indet.
- MO2, RDB1.

CHENOPODIACEAE

Chenopodium sp.
- BG2.

POLYGONACEAE

Polygonum hydropiper L.
- FR.

Polygonum spp.
- CV, FR, GA1, MO2, STU.

cf. *Rumex* sp.
- STU.

THEACEAE

Eurya stigmosa (LUDWIG 1860) MAI 1960
- BA, BE, BG2, BG3, BG7, BO, BL, BR, CH, CT, CV, MO2, MZ, PO, RB, RI.

Hartia quinqueangularis (MENZEL 1913) MAI 1975
- BE, CV.

Stewartia beckerana (LUDWIG 1857) KIRCHHEIMER 1957
- GA1, MO2.

Ternstroemia reniformis (CHANDLER 1957) MAI 1971
- CV, STU.

Visnea germanica MENZEL 1913
- BG2, BR, CH, CV, MZ, PO, RB, TC.

GUTTIFERAE

Hypericum sp. A
- CV, FR, MO4, MZ, RDB1, STU.

Hypericum sp. B
- RDB1, RDB6.

Hypericum sp. C
- CV.

Hypericum sp. D
- CV.

Hypericum cf. *tetrapterum* FRIES
- BG3, BO, BU2, CT, CV, FN, FR, GA1, MO2, STU.

VIOLACEAE

Viola bergaensis MAI & WALTHER 1988
- BO, FR, MO2, RDB1, RDB6, STU.
Viola neogenica MAI & WALTHER 1988
- BU2, MO2, RDB6, STU.
Viola sp. A
- BU2, MO2, STU.

CUCURBITACEAE

Trichosanthes fragilis E. M. REID 1920
- FR.

?CAPPARIDACEAE

? Capparidaceae gen. et sp. indet.
- CV.

SALICACEAE

Salix sp.
- MZ.

ACTINIDIACEAE

Actinidia faveolata C. & E. M. REID 1915
- CV3, FR, GA1, MO2, RDB6, STU.
Actinidia sp.
- CV.

?EPACRIDACEAE

cf. *Staphelia*
- BE, BG2, BL, CV.

ERICACEAE

Erica aff. *carnea* L.
- BA, BG3, BR, CH, CV, MZ.
Erica aff. *tetralix*
- CV, MO4.
Erica sp. A
- CV, MO2, STU.
Erica vel *Enkianthus* sp.
- MO2.
Leucothoe aff. *narbonnensis* (SAPORTA 1865) MAI 1960
- BE, BR, CH, CV, MZ.
Leucothoe sp. A
- BE, CV.
Rhododendron sp
- CV.

STYRACACEAE

Halesia crassa (C. & E. M. REID 1915) KIRCHHEIMER 1943
- GA1.
Rehderodendron ehrenbergii (KIRCHHEIMER 1935) MAI 1970
- BE, BL, CH, CV, TC.
Styrax maximus (WEBER 1852) KIRCHHEIMER 1949
- GA1, MO2, RDB6, STU.

SYMPLOCACEAE

cf. *Sphenoteca*
- CV.
Symplocos casparyi LUDWIG 1857
- BG2, BG7, BO, CV, TC.
Symplocos gothanii KIRCHHEIMER 1935
- BG2, BL, CV, TC.
Symplocos lignitarum (QUENSTEDT 1967) KIRCHHEIMER 1950
- BE, BG2, BO, BL, BR, CV, (GA1), MO2, PO, RB, TC.
Symplocos minutula (STERNBERG 1825) KIRCHHEIMER 1949
- BE.
Symplocos aff. *paniculata* WALL.
- BU2.
Symplocos salzhausensis (LUDWIG 1860) KIRCHHEIMER 1936
- BE, BG2, BO, CH, CV, RB, RI.
Symplocos schereri KIRCHHEIMER 1935
- BE, BG2, BG7, BO, CV, PO.
Symplocos sp.
- BG2, BG7, CV.

PRIMULACEAE

Lysimachia cf. *vulgaris* L.
- CH, FR, GA1, MO2.

TILIACEAE

Craigia bronnii (UNGER 1845) KVACEK, BUZEK & MANCHESTER 1991
- CV3.
Tilia sp.
- FR.

EUPHORBIACEAE

Euphorbia sp.
- BU2
Mallotus maii MARTINETTO 2001 (*M. tuberculatus* MAI 2001?)
- CH, CV, MZ, PO.
Mercurialis cf. *annua* L.
- MO2.

THYMELEACEAE

Wikstroemia thomasii GEISSERT & GREGOR 1981
- MO4, STU.

HYDRANGEACEAE

Itea europaea MAI 1985
- FN, FR, STU.
Schizophragma polonica MAI 1985
- STU.

DROSERACEAE

Aldrovanda sp.
- GA2.

ROSACEAE

Cotoneaster gailensis (E. M. REID 1923) MAI & WALTHER 1988
- LC, STU.
Crategus sp.
- BL.
Fragaria sp.
- STU.
Malus sp.
- STU.
Potentilla sp. A
- MO2.
Potentilla supina L.
- BO, FR, GA1, MO2, STU.
Prunus (*Padus*) sp. A
- BO, LC, MO2, RDB1, RDB6, STU.
Prunus (*Prunus*) aff. *spinosa* L.
- MO2.
Pyracantha acuticarpa (C. & E. M. REID 1915) SZAFER 1961
- MO2, RT.
Rubus laticostatus KIRCHHEIMER 1942
- CV, MO2, RI, STU.
Rubus microspermus C. & E. M. REID 1910
- BA, BE, BG3, BG7, BO, ?BR, CV, FN, ?FR, GA1, ?LC, MO2, ?MZ, RB, RDB1, ?RDB6, STU.
Rubus semirotundatus LANCUCKA-SRODONIOWA 1979
- CV, GA1, RI1.
Rubus sp.
- BG2.
Sorbus herzogenrathensis (MENZEL 1913) GREGOR 1978
- BG2, BL, CV, RT, TC.
Spiraea sp.
- BO.
Rosaceae gen. et sp. indet.
- CV.

LYTHRACEAE

Decodon globosus (E. M. REID 1920) NIKITIN 1929
- BE, FR.

MYRTACEAE

Myrtus palaeocommunis FRIIS 1985
- BG2, CV.

ONAGRACEAE

Ludwigia sp.
- BE, CV, FR, MO4, STU.

TRAPACEAE

Trapa cf. *heeri* FRITSCH 1885
- BO, FR.

HALORAGACEAE

Myriophyllum sp.
- BG3.
Proserpinaca reticulata C. & E. M. REID 1915
- BE, BO, CV, RDB1, STU.

RUTACEAE

Phellodendron elegans (C. & E. M. REID 1907) C. & E. M. REID 1915
- BU2, FR, STU.
Phellodendron cf. *elegans* (C. & E. M. REID 1907) C. & E. M. REID 1915
- BR, CV, MZ, RB.
Phellodendron sp.
- CV.
Toddalia latisiliquata (LUDWIG 1860) GREGOR 1975
- BE, CH, CV, RB.
Toddalia naviculaeformis (E. M. REID 1923) GREGOR
- RDB1.
Toddalia rhenana GREGOR 1979
- BE, BG2, ?BO, CH, ?CT, CV, MO2, ?MZ, RB, RDB1, STU.
Zanthoxylum ailanthiforme (GREGOR 1975) GREGOR 1978
- BE, CH, CV, PO.
Zanthoxylum mueller-stollii GREGOR 1984
- BE, CV, RB.
Zanthoxylum cf. *tiffneyi*
- CV.

STAPHYLEACEAE

Turpinia cf. *ettingshausenii* (ENGELHARDT 1870) MAI 1964
- ?BG2, CV.

ACERACEAE
Acer (?sect. *Rubra* (PAX) POJARKOVA) sp. A
- LC, RDB1.
Acer sp. B
- BR, MZ.
Acer (sect. *Platanoidea* PAX) sp. C
- BA, BG2, BL, CV, LC, PO, STU.

?SAPINDACEAE
Sapindoidea margaritifera (LUDWIG 1860) KIRCHHEIMER 1936
- BE, BG2, BL, CV, PO, TC.

SABIACEAE
Meliosma miessleri MAI 1964
- MO4.
Meliosma canavesana MARTINETTO 2001
- BR, CH, CV, RB.
Meliosma wetteraviensis (LUDWIG 1857) MAI 1973
- CV, FN, LC, RDB1, RDB6, STU.
Sabia europaea CZECZOTT & SKIRGIELLO 1959
- STU.

OXALIDACEAE
Oxalis europaea JORDAN
- MO2.

NYSSACEAE
Nyssa disseminata (LUDWIG 1857) KIRCHHEIMER 1937
- BG2, BO, CV3, FR, RDB1, STU.
Nyssa sibirica DOROFEEV 1963
- BG2, BG3, BO, BR, CV, FR.

ALANGIACEAE
Alangium sp.
- BE, BG2, RB.

CORNACEAE
Swida discimontana MAI 1982
- BR, CV, MZ.
Swida gorbunovii (DOROFEEV 1955) NEGRU 1972
CV3, RT.
Swida kraeuselii GEISSERT, GREGOR & MAI 1990
- GA1, MO2.
Swida sp.
- BO, CV, GA1.
?Cornaceae indet.
- BG2, BG7, CH, CV.

ARALIACEAE
Aralia sp.
- CV, GA1, MO2.
Araliaceae indet.
- FR.

APIACEAE
Oenanthe cf. *aquatica* L.
- GA1.
Oenanthe sp. A
- CV3, FN, ?MO2, RDB1, RDB6, STU.
Peucedanum moebii (KINKELIN 1908) MAEDLER 1939
- MO2, RDB6.
Apiaceae gen. et spp. indet.
- BA, BG7, FR, RDB1, STU.

AQUIFOLIACEAE
Ilex cantalensis E. M. REID 1923
- ?BG2, ?CV, STU.
Ilex fortunensis VAN DER BURGH 1978
- ?CV, BG2, BR, CV3, STU.
Ilex saxonica MAI 1964
- BG2, BG3, CV.
Ilex thuringiaca MAI
- BE, BG2, CH, CV.
Ilex spp.
- BA, BG2, BO, CV, MO2.

RHAMNACEAE
Frangula alnus MILLER
- STU.
Frangula cf. *solitaria* GREGOR 1977
- CV3, FR.

VITACEAE
Ampelopsis malvaeformis (SCHLOTHEIM 1822) MAI in MAI & GREGOR 1982
- BE, BG2, BR, CH, CV, FN, GA1, MO2, MZ, PO, RB, RI, STU.
Tetrastigma sp.
- BC, BG2, CV.
Vitis parasylvestris KIRCHHEIMER 1940 sensu KIRCHHEIMER 1957
- BG2, BU2, CH, CV, FR, GA1, PO, RB, RDB1, RDB6, STU.
Vitis teutonica A. BRAUN 1854
- BE, BG2, BG7, BR, CH, CV, MZ1, PO, RB, ?RI.
Vitis aff. *rotundifolia* MICHAUX
- GA1.

RUBIACEAE
Cephalanthus kireevskianus (DOROFEEV 1960) RANIECKA-BOBROWSKA in DOROFEEV 1963
- BO, FR, PO.

ASCLEPIADACEAE
Asclepiadacaeae gen. et sp. indet.
- RT.

CAPRIFOLIACEAE
Sambucus bashkirica DOROFEEV 1977
GA1, MO2.
Sambucus pulchella C. & E. M. REID 1915
- ?BA, BR, BU2, CH, CV, FR, GA1, MO2, MZ, RDB6, STU.
Viburnum cf. *hercynicum* MAI & WALTHER 1988
- FR.

DIPSACACEAE
Scabiosa sp.
- MO2.

BORAGINACEAE
Ehretia sp.
- BG2, CH, CV, PO.

LAMIACEAE
Ajuga antiqua C. & E. M. REID 1915
- CV, RDB6, STU.
Lycopus europaeus L.
- BA, BG3, CV, LC, RDB1, RDB6, STU.
Melissa elegans E. M. REID 1920
- RDB1, RDB6, STU.
Melissa cf. *elegans* E. M. REID 1920
- GA1.
Melissa sp. A
- CH, CV, MZ.
Mentha aff. *aquatica* L.
- RDB1, STU.
Mentha spp. indet.
- BA, CV, FN, GA1.
Origanum cf. *vulgare* L.
- BA, GA1, MO2.
Stachys sp.
- GA1.
Teucrium sp. A
- BG3.
Teucrium tatjanae NIKITIN in DOROFEEV 1955
- FR, MO2.
Lamiaceae gen. et sp. B
- FN, RDB1.
Lamiaceae gen. et sp. C
- CV, GA1, MZ, RB.
Lamiaceae gen. et spp. indet.
- BA, BR, GA1, MO2, MZ, RB.

CALLITRICHACEAE
Callitriche sp.
- RDB1.

LOBELIACEAE
Lobelia pliocenica (DOROFEEV 1960) MAI 2001
- FR.

SOLANACEAE
Hyosciamus cf. *niger* L.
- BU2.
Solanum cf. *dulcamara* L.
- CV3, MO2.

BIGNONIACEAE
Paulownia cantalensis (E. M. REID 1923) MAI in MARTINETTO 1995
- BA, BG3, BG7, CT, CV, MO4, STU.

ASTERACEAE
Cirsium sp.
- RDB6.
Eupatorium cannabinum L.
- GA1.
cf. *Lactuca*
- MO2.
Xanthium sp.
- GA5.

ALISMATACEAE
Alisma sp.
- ?BG2, BG3, BG7, BO, CV3, FR, GA1, LC, MO2, RDB1, STU.
Luronium natans (L.) RAFINISQUE
- MO2.
Sagittaria sp. A
- BE3, BO, CT, FR.
Sagittaria sp. B
RT.
HYDROCHARITACEAE
Stratiotes intermedius (HARTZ 1909) CHANDLER 1923
- BU3.

POTAMOGETONACEAE
Potamogeton cf. *polymorphus* DOROFEEV 1959
- BO, CV3, FR, RDB1, STU.
Potamogeton cf. *trichoides* CHAM. & SCHLECT.
- GA1, MO2.
Potamogeton sp. A
- LC.
Potamogeton sp. B
BO, STU.

RUPPIACEAE
Ruppia maritima L.
- GA1.
?Ruppiaceae gen. et sp. indet.
- BR, CH, MZ.

CYMODOCEACEAE
Cymodocea sp.
- BL, CH.

NAJADACEAE
Najas cf. *irtyshensis* DOROFEEV 1963
- GA1.
Najas lanceolata C. & E. M. REID 1915
- FR.

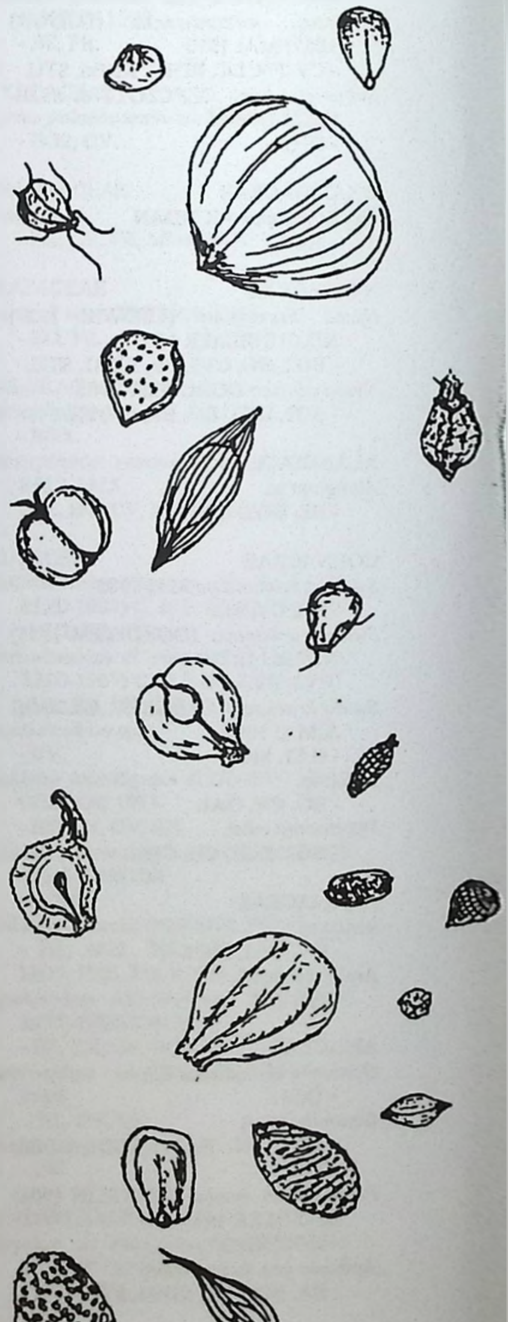
JUNCACEAE
Juncus sp.
- GA1, MO2, STU.
CYPERACEAE
Carex cf. *aquatilis* WALENBG.
- BO, CV, FN, GA1, LC, MO2, RDB1, RDB6, STU.
Carex aff. *atrofusca* SCHKUHR
- FR, MO2, RDB1, RDB6, STU.
Carex brizoides L.
- FN, STU.
Carex flagellata C. & E. M. REID 1915
- BO, FR, MO2, RDB6, STU.
Carex flavaeformis LANCUCKA-SRODONIOWA 1979
- MO2.
Carex aff. *fusca* ALLIONI (ex sp. 2)
- BG3, CV3, MO4, STU.
Carex cf. *laevigata* SMITH
- RDB1, RDB6.
Carex cf. *loliacea* L.
- CV3, FN, RDB1, STU.
Carex aff. *pallescens* L.
- RDB1.
Carex cf. *panicea* L.
- BU2, GA1.
Carex paucifloroides WELICZKIEWICZ 1975
- CV, FN, FR, MO2.
Carex aff. *pendula* HUDSON (ex sp. 4)
- RDB6, STU.
Carex plicata LANCUCKA-SRODONIOWA 1979
- MZ, RI.
Carex pseudocyperus L.
- CV3, FN, FR, MO2, RDB1, STU.
Carex cf. *punctata* GAUDIN
- MO2.
Carex aff. *remota* L. (ex sp. 1)
- MO2, RDB1, RDB6, STU.
Carex rostrata STOKES
- STU.
Carex szaferi MAI & WALTHER 1988
- BO, FR, RDB1.
Carex (?) sp. (ex sp. 7)
- CV3, RDB6, STU.
Carex spp.
- BA, BO, CH, CV, GA1, LC, MO2.
Cladium paleomariscus DOROFEEV 1969
- CV, BE, CT.
Cladium sp. indet.
- BE, BR, CT, RB, RI, STU.
Cyperus cf. *longus* L.
- BU.
Cyperus sp. indet.
- BG3, BU2.
cf. *Cyperus*
- MZ.
Dichostylis cf. *hamulosa* (M. B.) NEES
- GA1.
Dulichium arundinaceum (L.) BRITTON
- BG7, BO, CV3, FN, STU.
Dulichium vespiforme C. & E. M. REID 1908
- RT1.
Eleocharis aff. *obtusa* (WILLDENOW) SHULTES
- MO2.
Eleocharis aff. *prolifera* TORREY
- MO2.
Eleocharis ovata (ROTH) ROSTKOFF & SCHMIDT
- FR, MO2, STU.
Eleocharis sp. indet.
- GA1.
Scirpus cf. lacustris L.
- BU2.
Scirpus cf. tabernaemontani GMELIN
- CT, GA1.
Scirpus isolepioides MAI & WALTHER 1988
- BA, BE, BO, STU.
Scirpus cf. *isolepioides* MAI & WALTHER 1988
- GA1.
Scirpus mucronatus L.
- FR, GA1, MO2, STU.
Scirpus radicans SCHKUHR
- BO, FR, MO2, STU.
Scirpus sp. indet.
- CV, MO2.
Scirpus supinus L.
- BE, GA1.
Scirpus sylvaticus L.
- BC, LC, STU.

TYPHACEAE
Sparganium neglectum BEEBY (incl. *Sparganium ovale* E. M. REID 1920)
- BE, BO, BU2, FR, GA1, RDB1.
Sparganium nanum DOROFEEV in KOLAKOVSKIJ 1958
- BA, BE, BG2, BG3, BG7, BO, BR, CH, CT, CV, RDB1, RI, STU.
Sparganium sp. indet.
- BG7, BO, CH.
Typha sp.
- CT, GA1, MO2, STU.

ZANNICHELLIACEAE
Zannichellia sp.
- GA1.

ARACEAE
Epipremnites reniculus (LUDWIG 1857) GREGOR & BOGNER 1989
- BC, STU.
Scindapsites crassus (C. & E. M. REID 1915) GREGOR & BOGNER 1983
- BO, FR, STU.

INCERTAE SEDIS
Carpolithes cucurbitinus MARTINETTO 1995
- BA, CH, CV, GA1, MO2, MZ, RDB6, STU.
Carpolithes gratioloides MARTINETTO 1995
- BA, BR, CH, CV, MZ, STU.
Carpolithes montioides MARTINETTO 1995
- BR, CH, CV, MZ, RB, STU.
Spirellea sp.
- BG2, CH, CV, MO4, MZ, RB.



Explanation of plates enclosed in the cd-rom attached to the volume: Pliocene plants, environment and climate of northwestern Italy. Fl. Tertiaria Medit., V.8 (2001).

These plates are enclosed as a preliminary documentation of the Pliocene floras of NW Italy. The explanation has been copied and pasted (with minor changes) from the original papers in English or translated and shortened from those papers written in Italian. The nomenclature of taxa is taken from the original papers without revision, which can be found in the systematic list published in the attached volume.

REFERENCES FOR PLATES:

BASILICI, G., MARTINETTO, E., PAVIA, G. & VIOLANTI, D., 1997. Paleoenvironmental evolution in the Pliocene marine-coastal succession of Val Chiusella (Ivrea, NW Italy). Boll. Soc. Paleont. It., 36 (1-2): 23-52.

BERTOLDI, R. & MARTINETTO, E., 1995: Ricerche paleobotaniche (palinologiche e paleocarpologiche) sulla successione villafranchiana del Rio Ca' Viettone. Il Quaternario, 8 (2): 403-422

CAVALLO, O. & MARTINETTO, E., 1996. Flore plioceniche del bacino del Tanaro. Alba Pompeia, 17 (1): 5-31.

CAVALLO, P. & MARTINETTO, E., in press. Flore carpologiche del Pliocene di Castelletto Cervo (Biella). Boll. Mus. Reg. Sci. Nat. To., 47 pp.

MARTINETTO E. & RAVAZZI, C., 1997. Plant biochronology of the Valle della Fornace succession (Varese) based on the Plio-Pleistocene record in northern Italy. Geologia Insubrica, 2 (2): 81-98.

MARTINETTO, E. , 1994a. Analisi paleocarpologica dei depositi continentali pliocenici della Stura di Lanzo - Boll. Mus. Reg. Sci. Nat. Torino, 12 (1): 137-172.

MARTINETTO, E., 1994b. Paleocarpology and the in situ ancient plant communities of a few Italian Pliocene fossil forests. In: MATTEUCCI, R. et al. (a cura di), Studies on Ecology and Paleoecology of Benthic Communities - Boll. Soc. Paleont. Ital., Spec. Vol. 2, pp. 189-196, Mucchi, Modena.

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, Università di Torino, Dipartimento di Scienze della Terra, 149 pp.

MARTINETTO, E., 1998. “East Asian elements in the Plio-Pleistocene floras of Italy”. In: Aoluo, Z. & Sugong, W. (eds.): Proc. Int. Symp. Floristic Charact. Diversity East Asian Plants. Springer-Verlag: 71-87.

MARTINETTO, E., 2001. Studies on some exotic elements of the Pliocene floras of Italy. Palaeontographica Abt. B, 259: 149-166.

PAVIA, G., 1970 - Resti di *Anancus arvernensis* e flora ad affinità plioceniche nel Villafranchiano inferiore della cava di Arboschio (Villafranca d'Asti). Mem. Soc. Geol. It., IX: 157-176.

EXPLANATIONS

BA&A97-1 (BASILICI *ET AL.* 1997, PLATE 1)

Selected fruits and seeds from the Sento succession, Early Pliocene of NW Italy: Taxodiaceae-Myricaceae. Scale bar 1 mm.

Fig. 1 - *Cryptomeria rhenana* Kilpper 1968. Seed, layer S7.

Fig. 2 - *Taiwania* cf. *paracryptomerioides* Kilpper 1968. Cone, layer S7.

Figs 3-6 - *Tetraclinis salicornioides* (Unger 1841) Kvacek 1986.
3- 5: cones, layer S6. 3: lateral-apical view. 4: lateral view. 5: apical view showing the four cone scales. 6a: fragment of articulated vegetative shoot, layer S5. 6b: detail with stomata.

Fig. 7 - *Magnolia lignita* (Unger 1861) Mai 1975. Seed, external side, layer S6.

Fig. 8 - *Cinnamomum costatum* (Mai 1960) Pingen, Ferguson & Collinson 1994. Endocarp, layer S5.

Figs 9-11 - *Ocotea* sp. A. Layer S6.
9: fruit enclosed in a cupula with damaged lobes.10: cupulate fruit. 11: cupula.

Fig. 12- *Sinomenium cantalense* (E. M. Reid 1920) Dorofeev 1963. Seed, layer S7a.

Fig. 13 - *Mahonia staphyleaeformis* Mai & Walther 1988. Seed, layer S1b.

Fig. 14 - *Liquidambar magniloculata* Czeczott & Skirgiello 1959. Fruiting head, layer S9.

Fig. 15 - ?*Gironniera* cf. *carinata* Mai 1970. Endocarp in apical (15a), lateral (15b) and frontal view (15c). The systematic position of this taxon is not clear; it could also belong to the Lauraceae. Layer S6.

Figs 16, 17 - *Trigonobalanopsis exacantha* (Mai 1970) Kvacek & Walther 1989. Layer S6.
16: cupula. 17: cupula with the three lobes apically opened to show the trigonous nut inside.

Figs 18, 19 - *Myrica* sp. A. Endocarps from layer S1b.
18: external side with small wax pellets, often found on *Myrica* fossil endocarps. 19: internal side of a splitted specimen.


1
2
3
4
5
6a
6b
7
8
9
10
11
12
13
14
15a
15b
15c
16
17
18
19

BA&A97-2 (BASILICI *ET AL.* 1997, PLATE 2)

Selected fruits and seeds from the Sento succession, Early Pliocene of NW Italy: Phytolaccaceae-Rutaceae. Scale bar 1 mm.

Fig. 1 - *Phytolacca salsoloides* Martinetto 1995. Damaged seed in lateral view, layer S5. The hilum is still visible towards the top.

Figs 2, 3 - *Eurya stigmosa* (Ludwig 1860) Mai 1960. Seeds, layer S7.
2: external side. 3: internal side of a splitted specimen,.

Fig. 4 - *Visnea germanica* Menzel 1913. Fruit, layer S4.

Figs 5, 6 - *Symplocos casparyi* Ludwig 1857. Endocarps from layer S5.
5: lateral view. 6: apical view of a laterally compressed specimen.

Fig. 7 - *Symplocos gothanii* Kirchheimer 1935. Endocarp, apical view, layer S5.

Figs 8, 9 - *Symplocos lignitarum* (Quenstedt 1867) Kirchheimer 1950. Endocarps in lateral view, layer S5.

Fig. 10 - *Symplocos minutula* (Sternberg 1825) Kirchheimer 1949. Endocarp, lateral view, layer S5.

Figs 11-13 - *Symplocos salzhausensis* (Ludwig 1860) Kirchheimer 1936. Endocarps from layer S5.
11: lateral view. 12: basal view. 13: apical view.

Fig. 14 - *Symplocos schereri* Kirchheimer 1935. Endocarp, lateral view, layer S7.

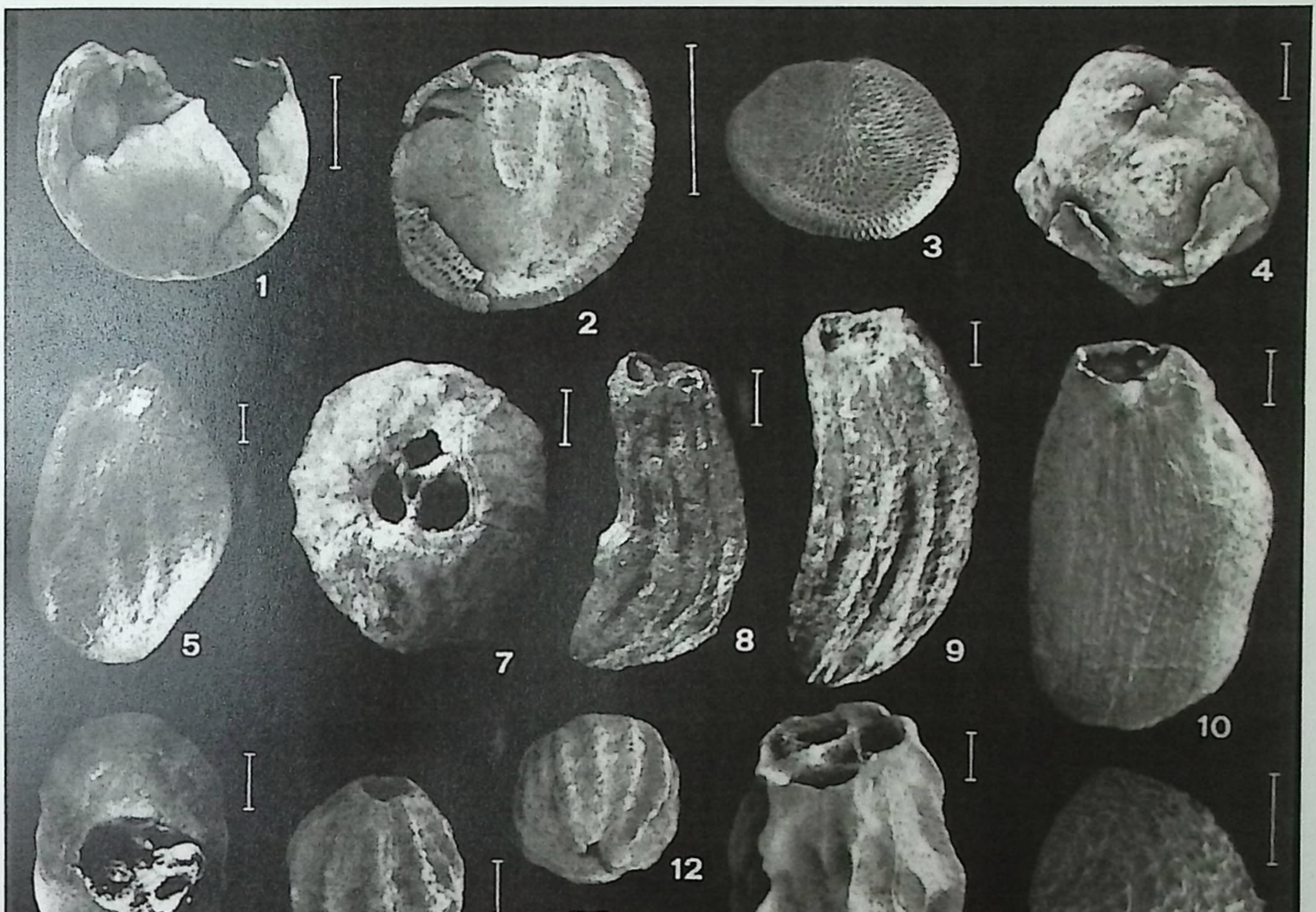
Fig. 15 - *Mallotus* sp.. A quarter of a seed in external lateral view, layer S7. A complete specimen from the nearby Ca' Viettone fossil site is figured by Bertoldi & Martinetto (1995).

Figs 16, 17 - *Toddalia latisiliquata* (Ludwig 1860) Gregor 1975. Seeds from layer S5.
16: lateral view of a broken specimen showing the embrional chamber. 17: lateral view.

Fig. 18 - *Toddalia naviculaeformis* (E. M. Reid 1923) Gregor 1978. Seed, lateral view, layer S6.

Figs 19, 20 - *Toddalia rhenana* Gregor 1979. Layer S6.
19: seed in lateral view. 20: ventral view of a seed.

Fig. 21 - *Zanthoxylum mueller-stollii* Gregor 1984. Seed in lateral view, layer S1b.


1
2
3
4
5
7
8
9
10
6
11
12
13
14
15
16
17
19
18
21
20

BA&A97-3 (BASILICI *ET AL.* 1997, PLATE 3)

Selected fruits and seeds from the Sento succession, Early Pliocene of NW Italy: Rutaceae - Poaceae. Scale bar 1 mm.

Figs 1, 2 - *Zanthoxylum ailanthiforme* (Gregor 1975) Gregor 1978.
1: seed from layer S1b in ventral view. 2: seed from layer S7 in lateral view.

Figs 3, 4 - *Turpinia ettingshausenii* (Engelhardt 1870) Mai 1964. Seeds in lateral view, layer S5.

Figs 5, 6 - *Sapindoidea margaritifera* (Ludwig 1860) Kirchheimer 1936. Layer S4.
5: lateral-apical view. Fig. 6: basal view of a holed specimen, showing the characteristic inner ridges.

Fig. 7 - *Meliosma miessleri* Mai 1964. Endocarp, layer S6.

Fig. 8 - *Meliosma* aff. *reticulata* (Reid) Chandler 1950. Endocarp in lateral view, layer S1b.

Figs 9, 10 - *Nyssa* cf. *disseminata* (Ludwig 1857) Kirchheimer 1937. Endocarps showing dehiscence valve in the upper half, layer S4.

Fig. 11 - *Alangium* sp.. Endocarp, layer S5.

Fig. 12 - *Ilex saxonica* Mai 1964. Seed, layer S5.

Fig. 13. *Tetrastigma* sp.. Seed with holed chalaza, layer S5.

Fig. 14 - *Cymodocea* sp. Endocarp from layer S2.

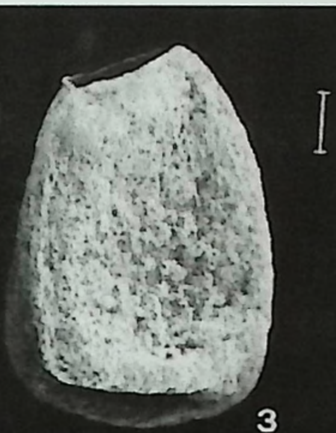
Fig. 15 - *Dulichium arundinaceum* (L.) Britton. Nutlet with partly preserved setae, layer S7.

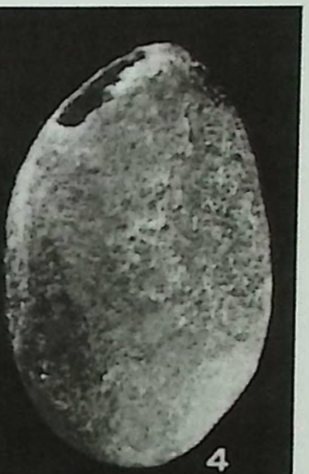
Figs 16, 17 - *Scirpus* cf. *tabernaemontani* Gmelin. Nutlets.
16: nutlet bearing scanty remains of perigonal setae. 17: nutlet broken in the upper part, layer S8.

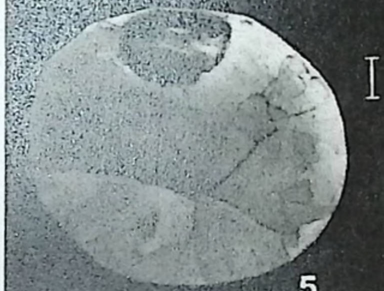
Figs 18, 19 - Poaceae gen. et sp. indet. Fragments of segmented stems, layer S8.

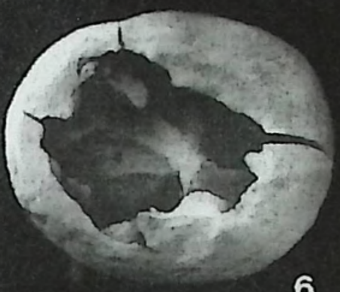

1


2


3


4


5

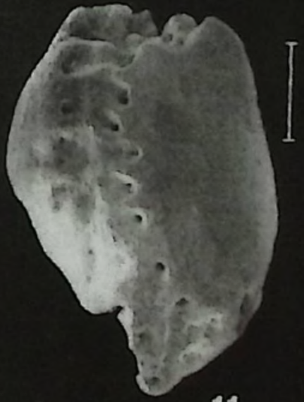

6


7


8

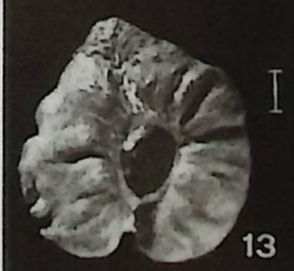

9


10


11

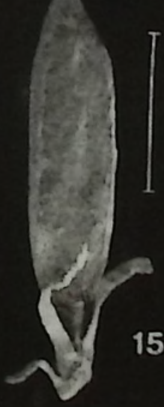

14

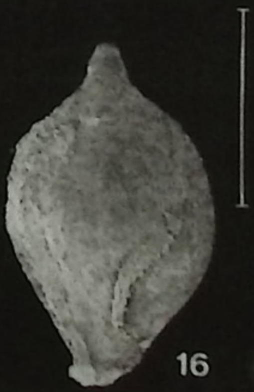

12


13


18


19


15


16


17

BE-MA95-1 (BERTOLDI & MARTINETTO 1995, PLATE 1)

Selected fruits and seeds from the Ca' Viettone succession, Early Pliocene of NW Italy.

Fig. 1: *Cathaya van-der-burghii* GOSSMANN in MAI 1994. Female cone, x2.

Fig. 2, 3: *Cryptomeria rhenana* KILPPER 1968. Fig. 2: Fragmentary cone, x6. Fig. 3: seed picked up from the overlaying cone, x8.

Fig. 4: *Tetraclinis salicornioides* (UNGER 1941) KVACEK 1986 (=*Tetraclinis wandae* ZABLOKI). Female cone, x10.

Fig. 5-7: *Magnolia allasoniae* MARTINETTO 1995. Fig. 5: holotype, external side, x5.5. Fig. 6: seed, x4.5. Fig. 7: inner side of a seed valve, x5.5.

Fig. 8, 9: *Magnolia lignita* (UNGER 1861) MAI 1975. Seeds, external side. x4.5.

Fig. 10: *Cinnamomum costatum* (MAI 1960) PINGEN, FERGUSON & COLLINSON 1994. Endocarp, 5.5x.

Fig. 11, 12: *Ocotea* sp. A. Fig. 11: Cupula with damaged lobes, x1.6. Fig. 12: Cupulate fruit, x2.3.

Fig. 13: *Sinomenium cantalense* (E. M. REID 1920) DOROFEEV 1963. Seed. x7.5.

Fig. 14: ?*Gironniera* cf. *carinata* MAI 1970. Endocarp in lateral-ventral view, x7.5.

Fig. 15: *Trigonobalanopsis exacantha* (MAI 1970) KVACEK & WALTHER 1989. Cupula, x 5.5.

Fig. 16, 17: *Palaeocarya macroptera* (BRONGNIART 1828) JAEHNICHEN *et al.* 1977. Fig. 16: inner side of endocarp valve, x7,5. Fig. 17: endocarp in external view, x7.5.

Fig. 18, 19: *Phytolacca salsoloides* MARTINETTO 1995. Fig. 18: seed, x12. Fig. 19: holotype, seed, x14.

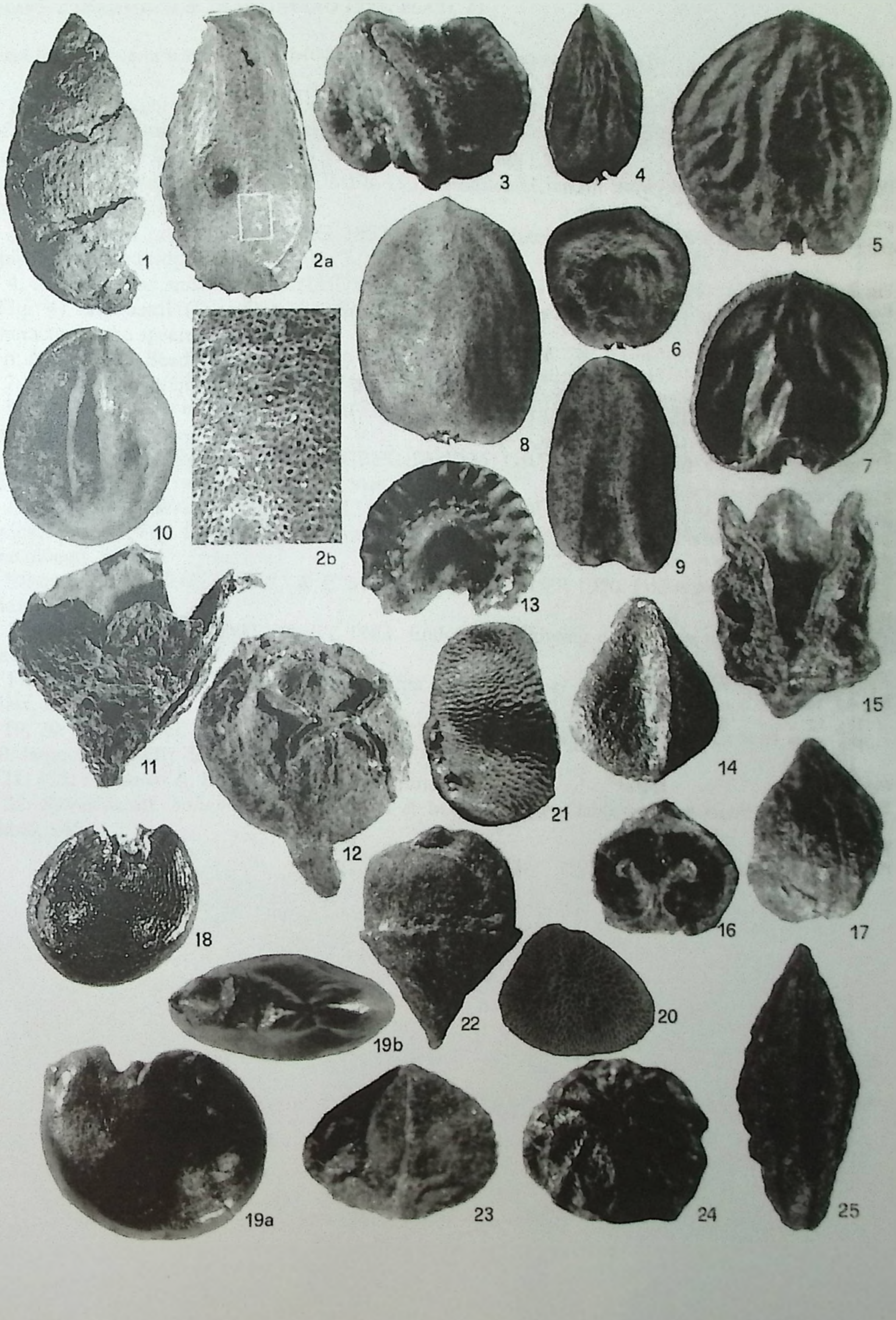
Fig. 20: *Eurya stigmosa* (LUDWIG 1860) MAI 1960. Seed, SEM photo, x16.

Fig. 21: *Ternstroemia reniformis* (CHANDLER 1957) MAI 1971. Seed, x8.

Fig. 22: *Visnea germanica* MENZEL 1913. Fruit, x12.

Fig. 23, 24: *Arctostaphyloides* cf. *menzelii* KIRCHHEIMER 1936. Fig. 23: fruit in lateral-basal view, x10. Fig. 24: longitudinally dissected fruit, x10.

Fig. 25: *Rehderodendron ehrenbergii* (KIRCHHEIMER 1935) MAI 1970. Endocarp, x 1.6.


1
2a
3
4
5
6
8
7
10
2b
9
13
11
15
12
21
14
16
17
18
22
20
19b
19a
23
24
25

BE-MA95-2 (BERTOLDI & MARTINETTO 1995, PLATE 2)

Selected fruits and seeds from the Ca' Viettone succession, Early Pliocene of NW Italy.

Fig. 1: *Symplocos gothanii* KIRCHHEIMER 1935. Endocarp, apical view. Distingushing features of this species are: globose shape, smooth or slightly costate surface and diameter of the emergence of seed locules lesser than half endocarp width, x7.

Fig. 2: *Symplocos schereri* KIRCHHEIMER 1935. Endocarp, lateral view. Strong interrupted and anastomosed ridges are typical, x4.

Fig. 3: *Symplocos casparyi* LUDWIG 1857. Endocarp, lateral view. Noteworthy are the thin spirally arranged ridges, x7.

Fig. 4, 5: *Symplocos salzhausensis* (LUDWIG 1860) KIRCHHEIMER 1936. Endocarps in apical (Fig. 4) and basal (Fig. 5) view. Small size, evident straight ridges, and globose shape characterize the species, x7.

Fig. 6: *Mallotus* sp. Seed, lateral view, x10.

Fig. 7: *Toddalia latisiliquata* (LUDWIG 1860) GREGOR 1975. Seed, x6.

Fig. 8, 9: *Zanthoxylum mueller-stollii* GREGOR 1984. Seed in lateral (Fig. 8) and ventral (Fig. 9) view, x8.

Fig. 10, 11: *Zanthoxylum ailanthiforme* (GREGOR 1975) GREGOR 1978. Fig. 10: seed in ventral view, x10.5. Fig. 11: seed in left lateral view, x9.

Fig. 12, 13: *Sapindoidea margaritifera* (LUDWIG 1860) KIRCHHEIMER 1936. Fig. 12: lateral-apical view, x7. Fig. 13: fragment showing the characteristic inner structure with branched ridges and alveols, x7.

Fig. 14: *Meliosma* aff. *reticulata* (C. & E. M. REID) CHANDLER 1950. Endocarp in lateral-ventral view, x6.5.

Fig. 15, 16: *Nyssa sibirica* DOROFEEV 1963. Endocarps showing dehiscence valve in the upper half, x7.

Fig. 17, 18: *Ilex saxonica* MAI 1964. Endocarps in lateral (Fig. 17) and lateral-ventral (Fig. 18) view, x8.5.

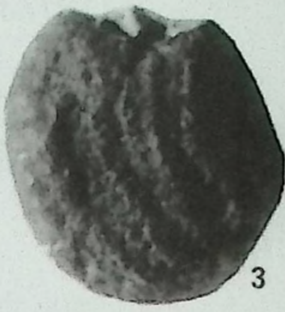
Fig. 19, 20: *Frangula* cf. *solitaria* GREGOR 1977. Fig. 19: endocarp containing the seed, 10x. Fig. 20: large-sized partly damaged seed, 10x.

Fig. 21: *Vitis teutonica* A. BRAUN 1854. Seed, dorsal side, 10x.

Fig. 22: *Spirellea* aff. *bohemica* KNOBLOCH & MAI 1984. Probable seed in lateral view, SEM photo, x45.


1


2

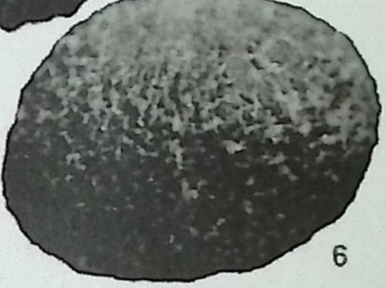

3


8


4


5

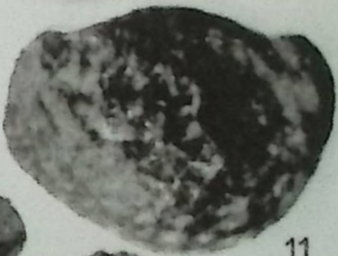

9


6


10


12


7


11


14


13


17


18


21


19


20


15


16


22

Ca-ma02-1 (Cavallo & Martinetto 2002, plate 1)

Pliocene carpofloras of Castelletto Cervo I and II.

Note: The position of layers CB1, CB2 and CA3 is indicated at p. 32, Fig. 5.3 of the attached volume; for other information see Cavallo & Martinetto (2002). Scale bar 1 mm, apart fig. 1 (1 cm).

Fig. 1: *Picea florschuetzii.* Female cone. CB2

Fig. 2: *Pseudolarix schmidtgenii.* Scale of a female cone. CB1

Figs 3, 4: *Xanthium* sp. CB2 A7P

Fig. 5: *Corylus avellana*. CB2 A7P

Figs 6, 7: *Eucommia europaea*. CB2

Fig. 8: *Fagus decurrens*. Cupula, CA3 A0M

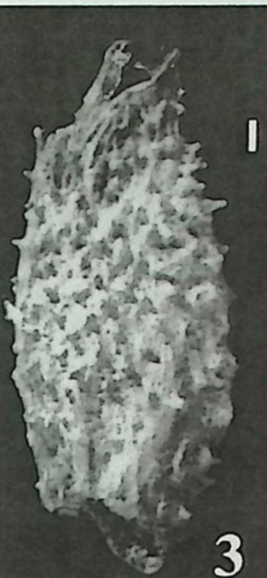
Fig. 9: *Parrotia* sp. Capsule, CA4 A5L

Figs 10a, b: *Carya globosa*. Endocarp: external view and internal view of one of the two valves. CA3

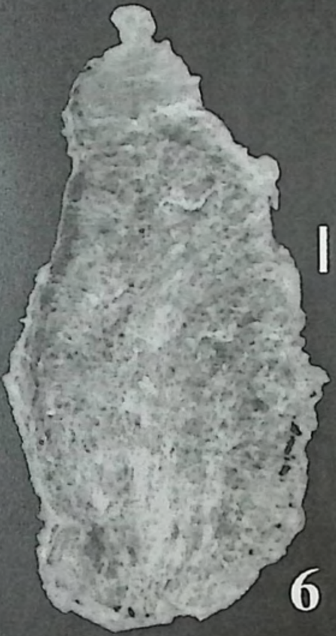
Fig. 11: *Carya globosa*. CA3


1


2


3

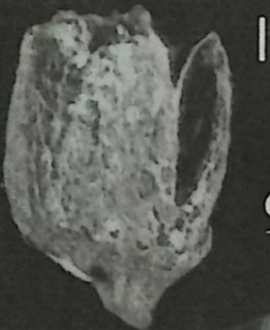

4


6

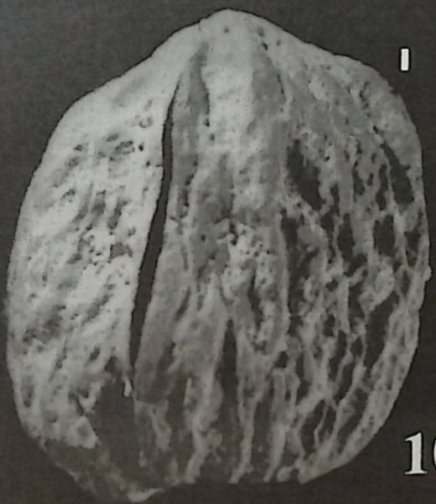

7


8


5


9


11


10a


10b

CA-MA02-2 (CAVALLO & MARTINETTO 2002, PLATE 2)

Pliocene carpofloras of Castelletto Cervo I and II.

Note: The position of layers CB1, CB2 and CA3 is indicated at p. 32, Fig. 5.3 of the attached volume; for other information see Cavallo & Martinetto (2002). Scale bar 1 mm, apart figs 3 and 4 (1 cm).

Figs 1, 2: *Cyclocarya nucifera.* Endocarps, CA3, external and internal view.

Figs 3, 4: *Juglans bergomensis.* External and internal view. CA3

Figs 5, 6: *Sassafras ludwigii.* Cupule of an immature fruit and endocarp. CB2 A5N

Figs 7-10: *Magnolia cor.* Variabilty of seed shapes. Fig. 7: CB1 A7X, others CB2

Fig. 11: *Magnolia cor.* This broad seed represents the «*Magnolia ultima*» morphotype by Kirchheimer 1957. CB2 a6q

Fig. 12: *Menispermum* cf. *reidii.* Endocarp, lateral view. CB2 a4l

Figs 13a, b: *Sinomenium cantalense.* Endocarp, lateral (a) and front view (b), CA3

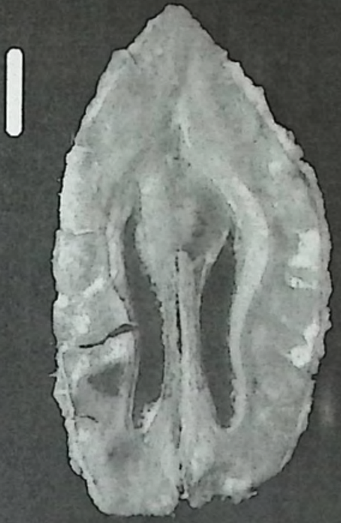

1


2

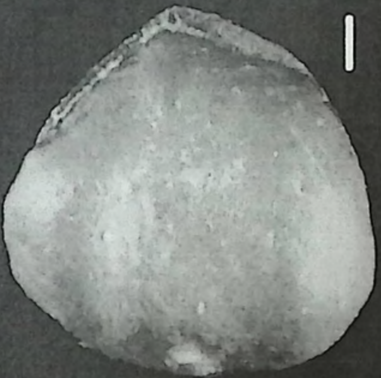

5

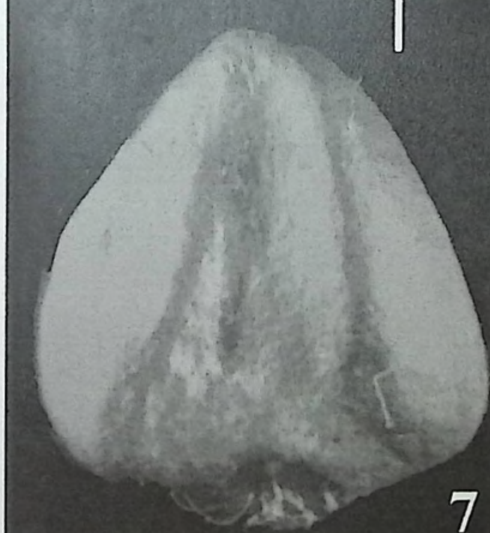

6

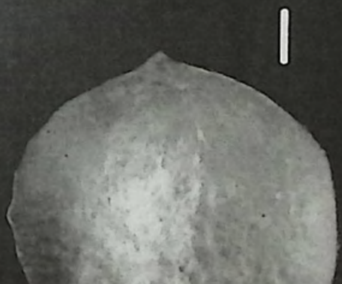

3

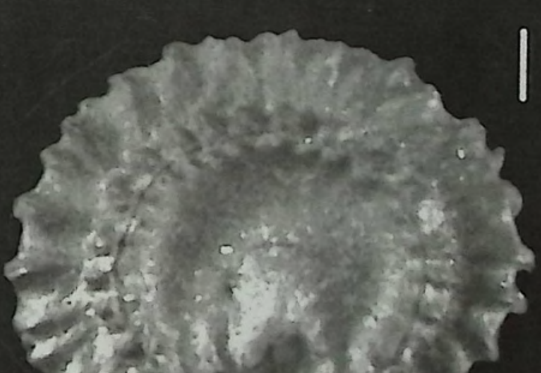

4

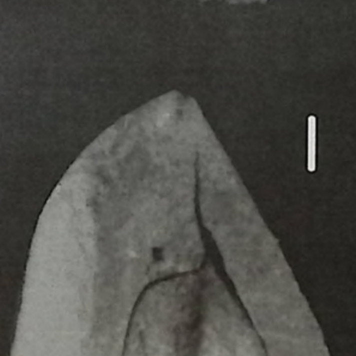

11


8

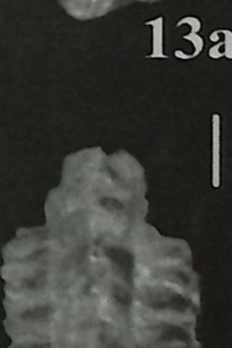

7


9


13a


10


12


13b

Ca-ma02-3 (Cavallo & Martinetto 2002, plate 3)

Pliocene carpofloras of Castelletto Cervo I and II.

Note: The position of layers CB1, CB2 and CA3 is indicated at p. 32, Fig. 5.3 of the attached volume; for other information see Cavallo & Martinetto (2002). Scale bar 1 mm.

Fig. 1: *Prunus insititia* var. *pliocaenica*. CB1

Fig. 2: *Phellodendron elegans*. CB1 A7M

Fig. 3: *Styrax maximus*. CA2

Figs 4, 5: *Symplocos* aff. *paniculata*. Endocarps. CB2 A5N

Figs 6, 7: *Stewartia beckerana*. Capsule. CA4 a5l

Figs 8-11: *Vitis parasilvestris.* Seeds in dorsal view (figs 9, 10) e ventral (figs 8, 11). CB2

Fig. 12: *Vitis* cf. *parasilvestris.* Seed in dorsal view, similar to *Vitis teutonica,* but probably a variant of *Vitis parasilvestris*, very common in this bed. CB1 A7M

Fig. 13: *Iris*. Seed. CB1 A7L.


1
2
3
4
5
6
7
8
9
10
11
12
13

CA-MA02-4 (CAVALLO & MARTINETTO 2002, PLATE 4)

Pliocene carpofloras of Castelletto Cervo I and II.

Note: The position of layers CB1, CB2 and CA3 is indicated at p. 32, Fig. 5.3 of the attached volume; for other information see Cavallo & Martinetto (2002). Scale bar 1 mm, apart figs 8, 11-14 (0,1 mm).

Fig. 1: *Acer* sp. 1. Endocarp, CB2 A7G

Fig. 2: *Acer* sp. 1. Endocarp, CB2 A7G

Figs 3a, b: *Ilex aquifolium*. Seed in ventral and dorsal view, CB2 A5N

Figs 4, 5: *Carpinus betulus*. Fruits, CB1 A7M

Figs 6, 7: *Ce~~t~~ratophyllum demersum*. Fruits, CB2 a4l

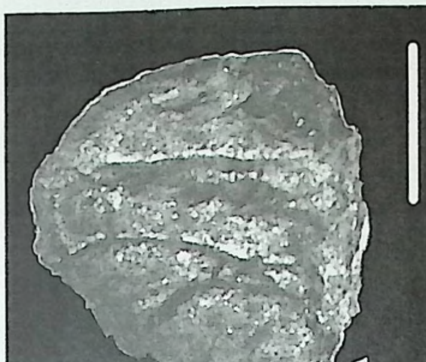
Fig. 8: *Chenopodium hybridum*. CB1 A7H

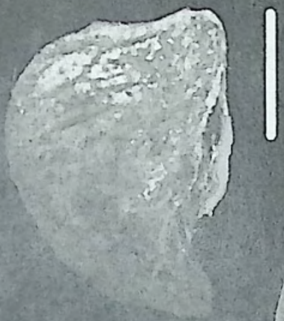
Figs 9, 10: *Ajuga antiqua*. CB2

Fig. 11: *Mentha* cf. *aquatica*. Achene, CB2 A7G.

Fig. 12: *Hypericum* sp. 3. Seed, CB1 A7L

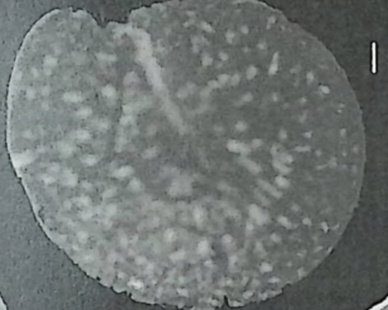
Figs 13, 14: *Hypericum* sp. 4. Seeds, CB1 A7L


1

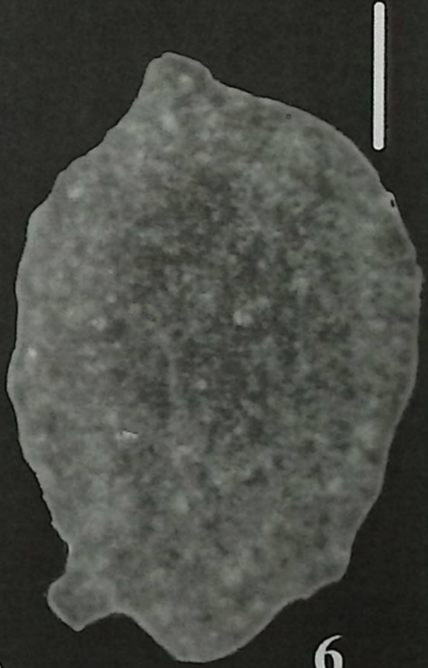

2

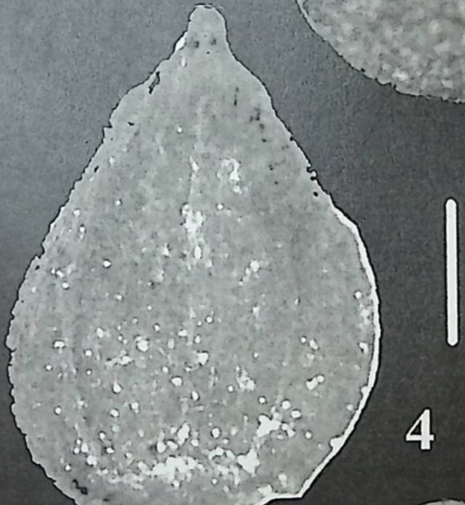

3a


3b


8

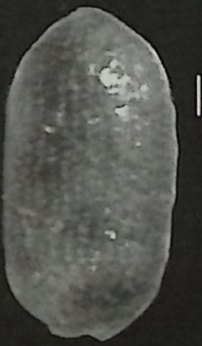

12


6

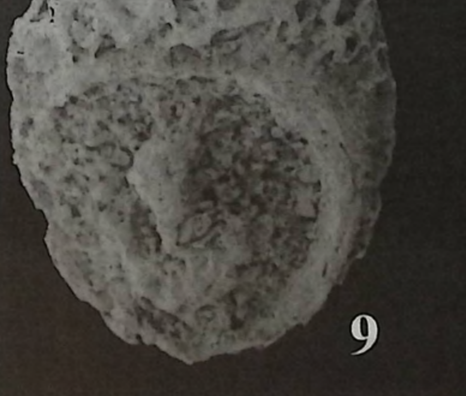

4

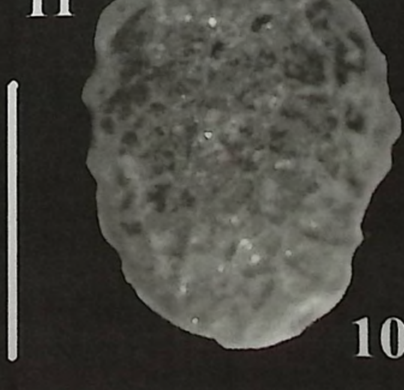

5


11


13


7


9


10


14

CA-MA02-5 (CAVALLO & MARTINETTO 2002, PLATE 5)

Pliocene carpofloras of Castelletto Cervo I and II.

Note: The position of layers CB1, CB2 and CA3 is indicated at p. 32, Fig. 5.3 of the attached volume; for other information see Cavallo & Martinetto (2002). Scale bar 1 mm, apart figs 4, 13 e 17-19 (0,1 mm).

Figs 1-3: *Liriodendron geminata*. Pair of seeds. CA1 A7X, fig. 3 from CA4 a5l

Fig. 4: *Morus germanica.* CA4 a5l

Figs 5, 6: *Nuphar* cf. *canaliculatum.* Seeds in apical and basal view. CB1 A7M

Figs 7, 8: *Polygonum* sp. Fruits, CB1 A7M

Figs 9, 10: *Thalictrum minimum*. Fruits, CA4 a5l

Figs 11, 12: *Cotoneaster* cf. *gailensis*. CA4 a5l

Figs 13, 14: *Rubus microspermus*. Endocarps, CA4 a5l

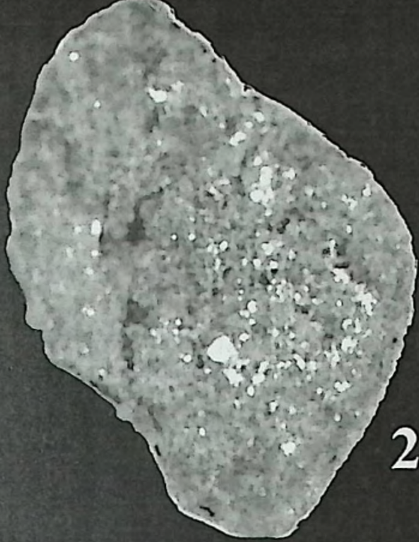
Fig. 15: *Physalis alkekengi*. Seed, CB2 A7V

Fig. 16: *Zelkova* sp. Fruit. CA5 A7Y

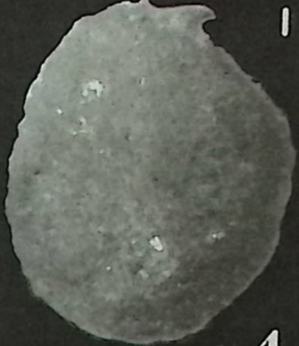
Fig. 17: *Pilea bashkirica.* Fruit. CB1 A7L

Figs 18, 19: *Pilea cantalensis.* Fruits. CB2.


1

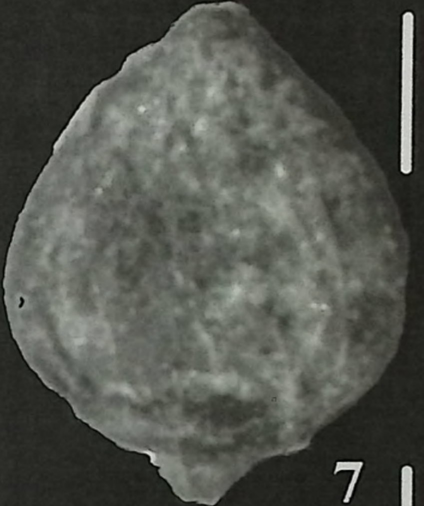

2


3

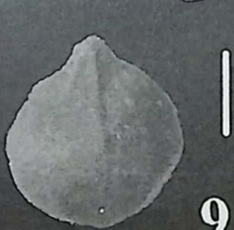

4


5


6


7

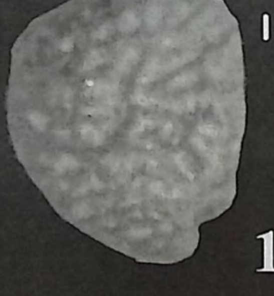

8

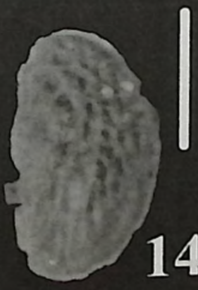

9

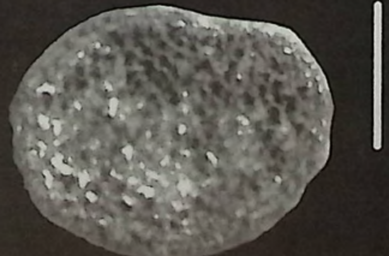

10


11

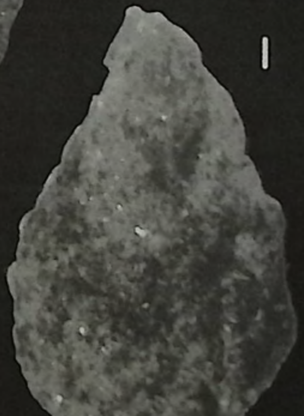

12

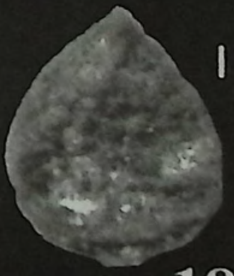

13

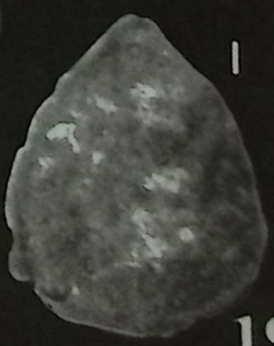

14


15


16


17


18


19

CA-MA02-6 (CAVALLO & MARTINETTO 2002, PLATE 6)

Pliocene carpofloras of Castelletto Cervo I and II.

Note: The position of layers CB1, CB2 and CA3 is indicated at p. 32, Fig. 5.3 of the attached volume; for other information see Cavallo & Martinetto (2002). Scale bar 1 mm, apart figs 1, 2, 18 e 19 (0,1 mm).

Figs 1, 2: *Boehmeria lithuanica.* Fruits. CB2 A5N

Figs 3, 4: *Viola neogenica.* Seeds. CB2 A5N

Fig. 5: *Ampelopsis malvaeformis.* Seed. CA5 A7R

Fig. 6: *Carex* aff. *atrofusca.* Achene. CB2 A7G

Figs 7-11: *Carex carpophora.* Achenes, those of figs 8, 9 with utricle remains. CB2 A6L, A6L, A7W, A5N and two specimens from A7W.

Figs 12, 13: *Carex szaferi.* Achenes. CB1 A7M e CB2 A7W

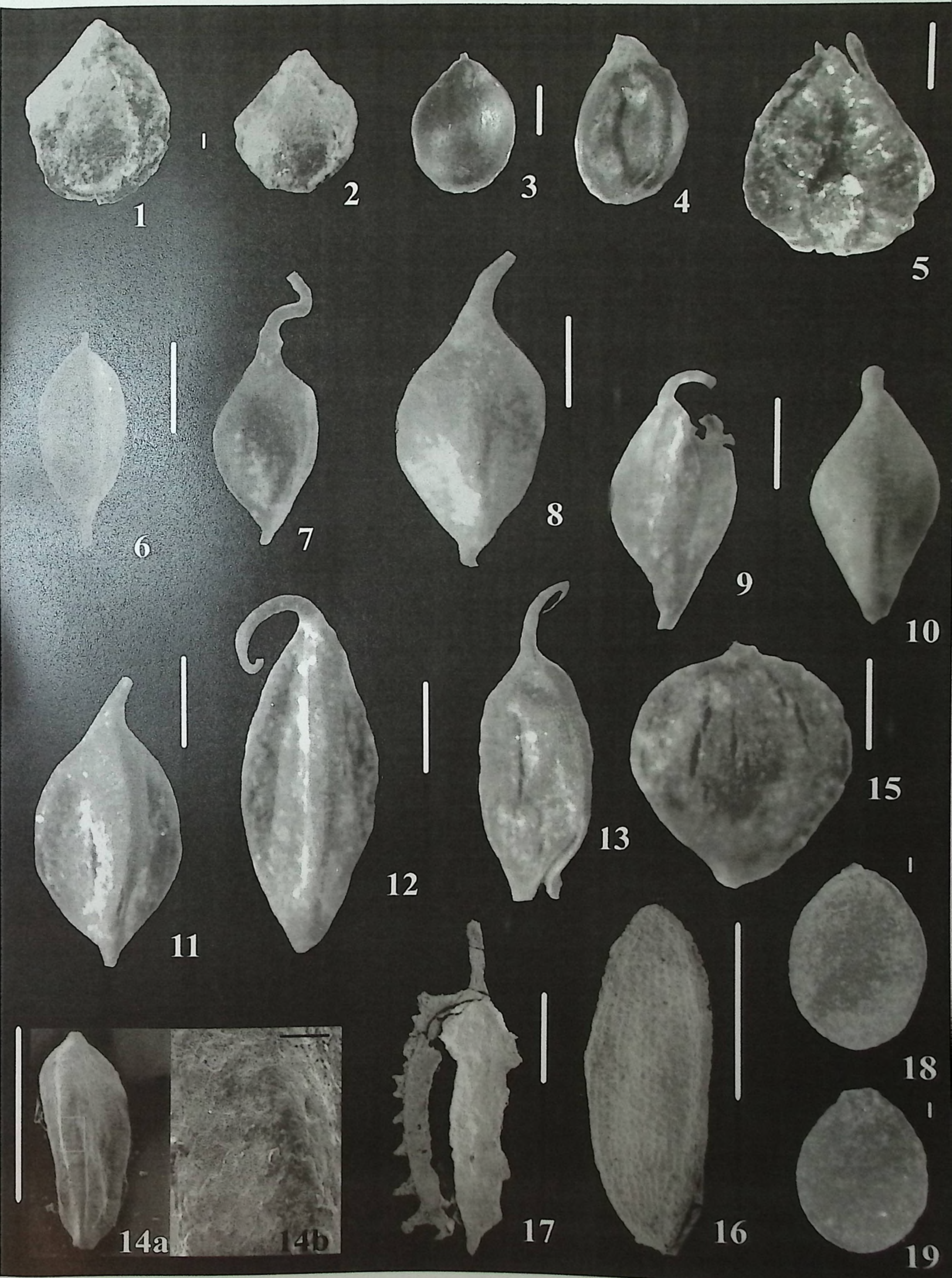
Fig. 14: *Cyperus* cf. *glaber.* Achene and detail x 8. CB2 A7G

Fig. 15: *Scirpus* cf. *isolepioides.* Achene. CA2 A8A

Fig. 16: *Najas* cf. *irtyshensis*. Seed. CA2 A1G

Fig. 17: *Zannichellia pedicellata.* CA2 A1G

Figs 18, 19: *Carpolithes cucurbitinus.* CA4 a5l.


1
2
3
4
5
6
7
8
9
10
11
12
13
15
18
14a
14b
17
16
19

CA-MA02-7 (CAVALLO & MARTINETTO 2002, PLATE 7)

Pliocene carpofloras of Castelletto Cervo I and II.
Note: The position of layers CB1, CB2 and CA3 is indicated at p. 32, Fig. 5.3 of the attached volume; for other information see Cavallo & Martinetto (2002). White scale bar 0.01 mm, black one 0.1 mm.

Fig. 1: *Chamaecyparis* sp. Seed and detail of seed wall. CA5 A7Y

Fig. 2: *Myosoton* cf. *aquaticum.* Seed and detail of seed wall. CB2 A6L

Fig. 3: *Euphorbia* sp. Seed. CB2 a6q

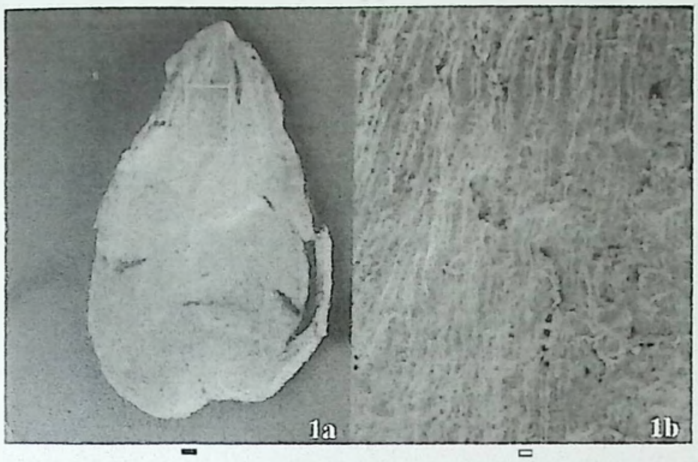
Fig. 4: *Stachys* sp. Seed and detail of seed wall. CB2 A7G

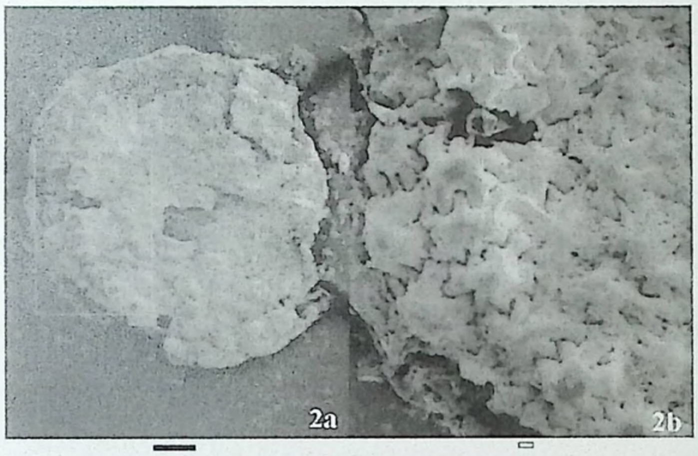
Fig. 5: *Ranunculus* cf. *sceleratoides.* Seed and detail of seed wall. CB2 A7G

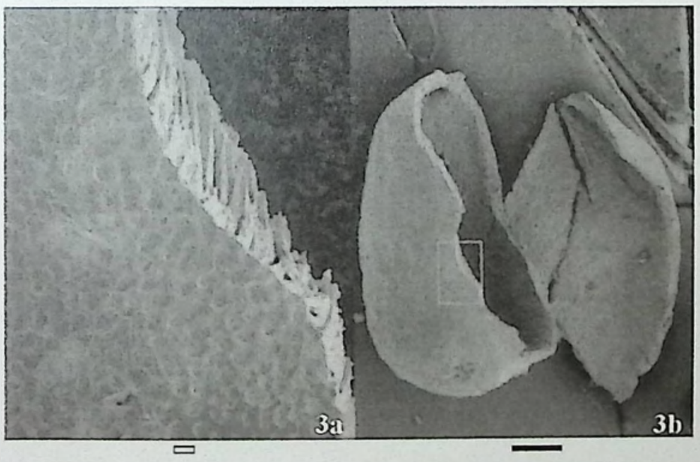
Fig. 6: *Ranunculus reidii.* Seed and detail of seed wall. CB2 A5N

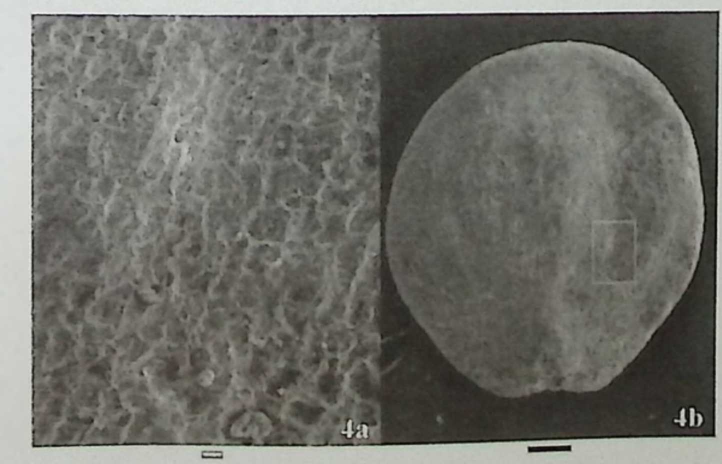
Fig. 7: *Najas* cf. *irtyshensis*. Seed and detail of seed wall. CA2 A1G

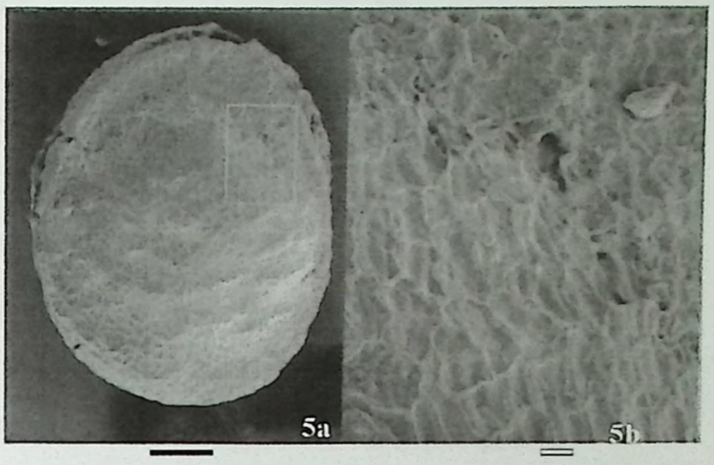
Fig. 8: *Ruppia* cf. *maritima*. Fruit and detail. CA2 A1G.

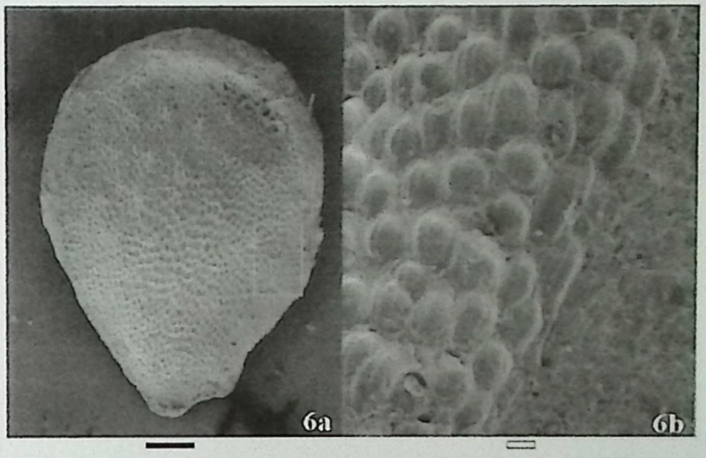

1a
1b

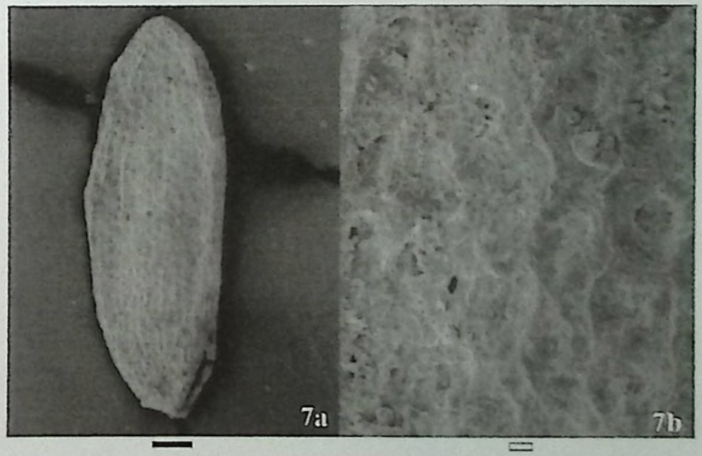

2a
2b

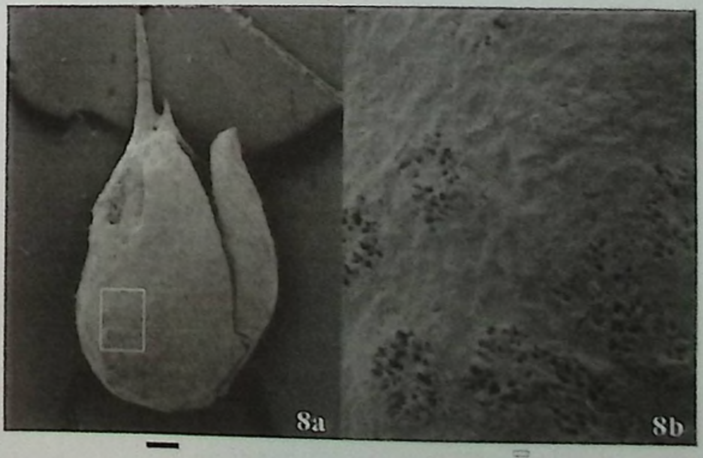

3a
3b


4a
4b


5a
5b


6a
6b


7a
7b


8a
8b

CA-MA96-1 (Cavallo & Martinetto 1996, plate 1)

Early Pliocene flora of Pocapaglia and few other sites, southern Piedmont.

Fig. 1. *Cryptomeria rhenana* Kilpper 1968 (TAXODIACEAE). Seed.

Fig. 2. *Chamaecyparis* sp. (CUPRESSACEAE). Shoot.

Fig. 3. *Tetraclinis salicornioides* (Unger 1841) Kvacek 1986 (CUPRESSACEAE). Shoot scale.

Fig. 4. *Liriodendron geminata* Kirchheimer 1957 (MAGNOLIACEAE). Pair of seeds.

Figs 5, 6. *Sinomenium cantalense* (E. M. Reid 1920) Dorofeev 1963 (MENISPERMACEAE).

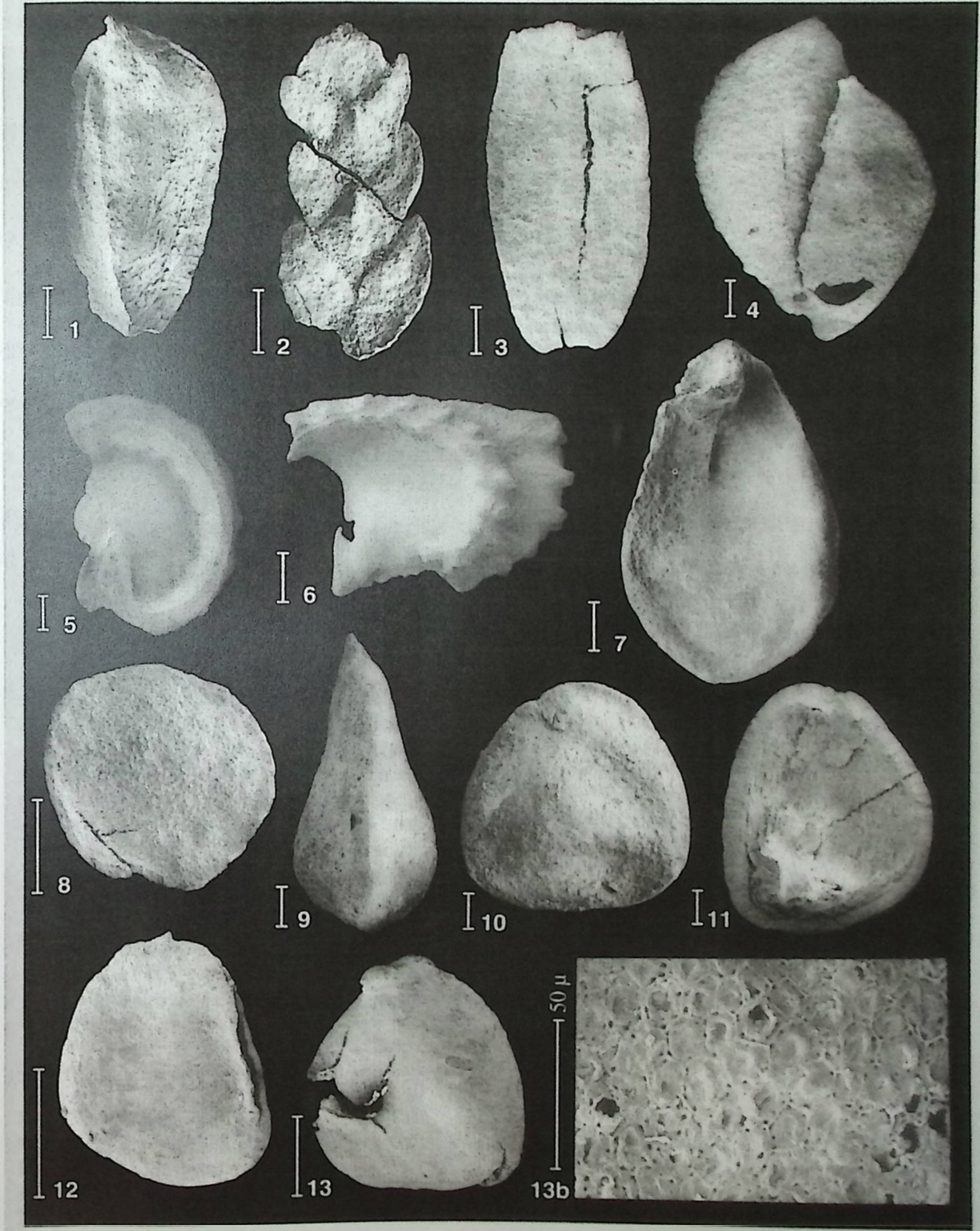
Fig. 7. *Mahonia staphyleaeformis* Mai & Walther 1988 (BERBERIDACEAE). Seed.

Fig. 8. *Ranunculus* cf. *reidii* Szafer 1947 (RANUNCULACEAE).

Figs 9-11. *?Gironniera* cf. *carinata* Mai 1970 (?ULMACEAE).

Fig. 12. *Ficus potentilloides* Mai 1964 (MORACEAE). Endocarp.

Fig. 13. *Morus sibirica* Dorofeev 1963 (MORACEAE). Endocarp with detail of external sculpture (13b).


1
2
3
4
5
6
7
8
9
10
11
12
13
50 µ
13b

CA-MA96-2 (CAVALLO & MARTINETTO 1996, PLATE 2)

Early Pliocene flora of Pocapaglia and few other sites, southern Piedmont.

Fig. 1. *Eurya stigmosa* (Ludwig 1860) Mai 1960 (THEACEAE). Seed.

Fig. 2. *Arctostaphyloides* cf. *menzelii* Kirchheimer 1936 (ERICACEAE).

Figs 3-5. *Symplocos schereri* Kirchheimer 1935 (SYMPLOCACEAE).

Fig. 6. *Rubus microspermus C.* & E. M. Reid 1910 (ROSACEAE). Endocarp.

Fig. 7. *Phellodendron* cf. *elegans* (C. & E. M. Reid 1907) C. & E. M. Reid 1915 (RUTACEAE).

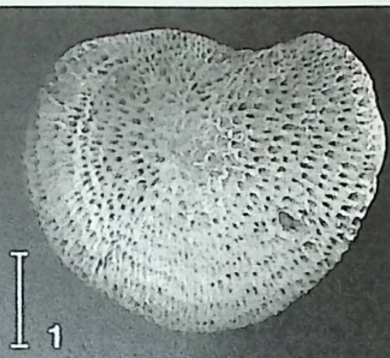
Figs 8, 9. *Coriaria* sp. (CORIARIACEAE).

Fig,. 10. *Aralia* sp. (ARALIACEAE).

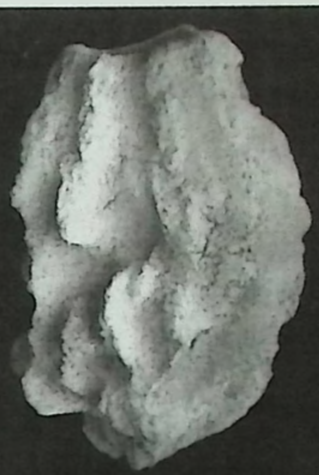
Fig. 11. *Ilex fortunensis* Van der Burgh 1978 (AQUIFOLIACEAE). Seed from Cherasco.

Fig. 12. *Ilex* sp. (AQUIFOLIACEAE).

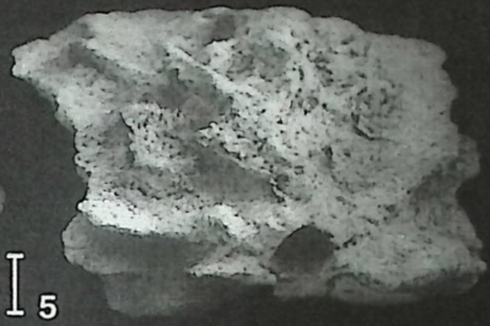
Fig. 13. *Cephalanthus kireevskianus* (Dorofeev 1960) Raniecka-Bobrowska in Dorofeev 1963 (RUBIACEAE). Endocarp.


1

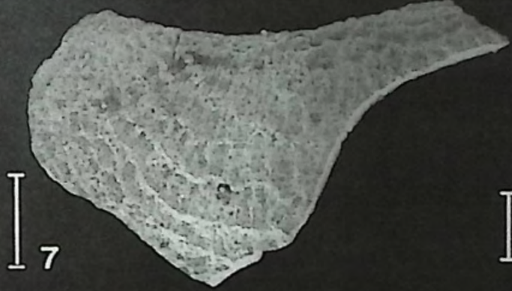

2

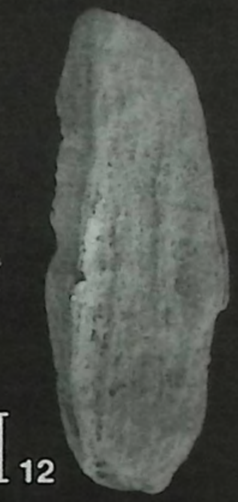

3


4

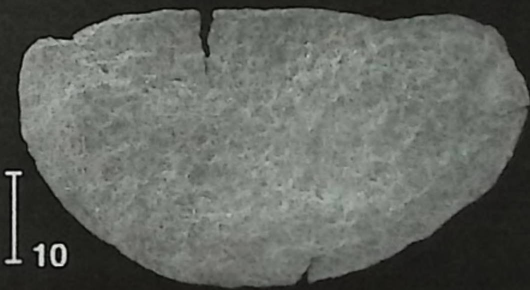

5


6


7

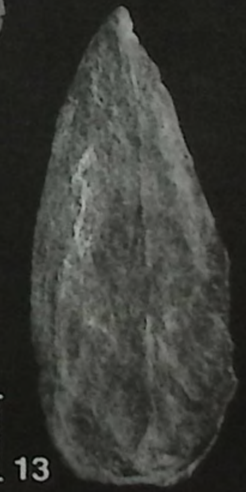

12


8


10


9


11


13

CA-MA96-3 (CAVALLO & MARTINETTO 1996, PLATE 3)

Early Pliocene flora of Pocapaglia and few other sites, southern Piedmont.

Fig. 1. *Sambucus pulchella C.* & E. M. Reid 1915 (CAPRIFOLIACEAE).

Figs 2,3. *Ehretia* sp. (BORAGINACEAE). Endocarps in dorsal and ventral view.

Fig. 4. *Paulownia cantalensis* (E. M. Reid 1923) Mai in Martinetto 1995 (BIGNONIACEAE).

Figs 5, 6. *Cladium* sp. (CYPERACEAE).

Fig. 7. *Sparganium nanum* Dorofeev in Kolakovskij 1958 (TYPHACEAE).

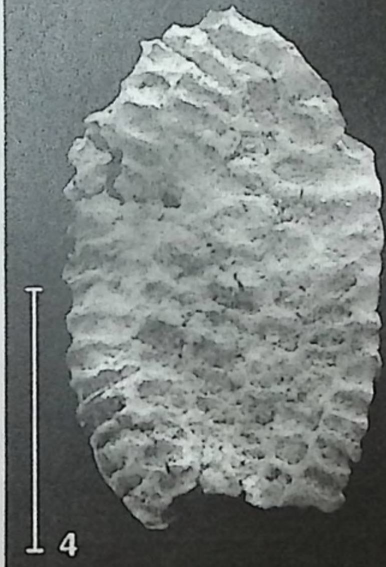
Fig. 8. *Carpolithes cucurbitinus* Martinetto 1995 (INCERTAE SEDIS). Seed or achene.

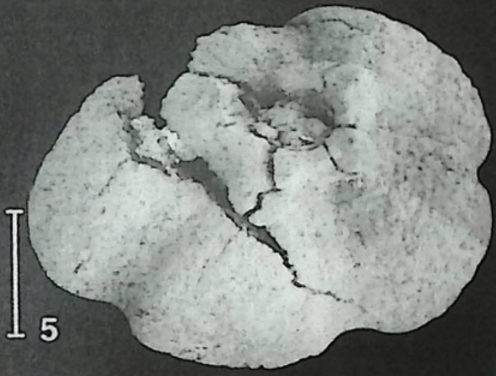
Fig. 9. *Spirellea* aff. *bohemica* Knobloch & Mai 1984 (INCERTAE SEDIS).

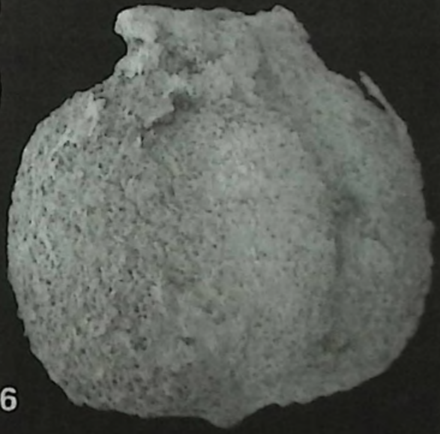

1


2


3


4


5


6


7


8


9

CA-MA96-4 (CAVALLO & MARTINETTO 1996, PLATE 4)

Early Pliocene flora of Pocapaglia and few other sites, southern Piedmont.

Fig. 1. *Abies* sp. (PINACEAE). Leaf fragment.

Fig. 2. *Glyptostrobus europaeus* (Brongniart 1833) Unger 1850 (TAXODIACEAE). Cone.

Fig. 3. *Chamaecyparis* sp. (CUPRESSACEAE). Cone.

Fig. 4. *Thuja* sp. (CUPRESSACEAE). Shoots.

Figs 5, 6. *Magnolia allasoniae* Martinetto 1995 (MAGNOLIACEAE).

Fig. 7. *Ocotea* sp. A (LAURACEAE). Fragment of a cupula with a portion of fruit.

Fig. 8. *Sassafras ludwigii* Mai 1971 (LAURACEAE). Fruit with cupula.

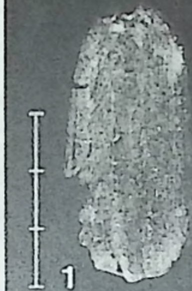
Fig. 9. *Liquidambar magniloculata* Czeczott & Skirgiello 1959 (HAMAMELIDACEAE).

Fig. 10. *Fagus* sp. indet. (FAGACEAE). Cupula.

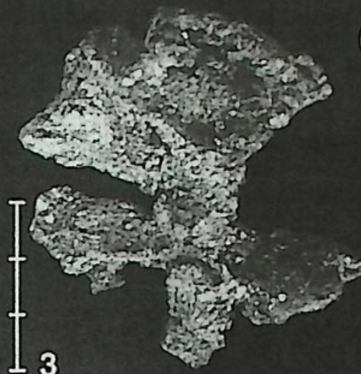
Fig. 11. *Quercus* sp. indet. (FAGACEAE). Pair of immature achorns.

Fig. 12. *Trigonobalanopsis exacantha* (Mai 1970) Kvacek & Walther 1989 (FAGACEAE). Cupula.

Figs 13-16. *Pterocarya limburgensis* C. & E. M. Reid 1915 (JUGLANDACEAE).


1


2


3

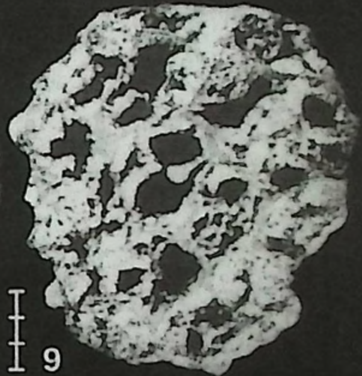

4

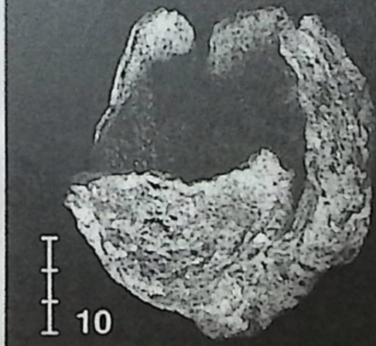

5


6

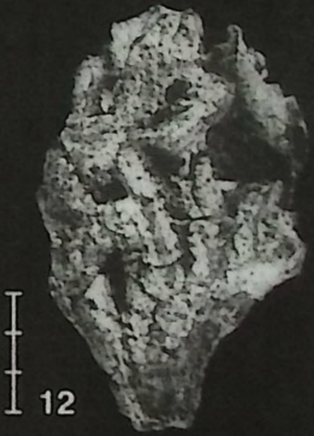

7


8

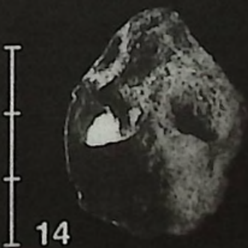

9


10

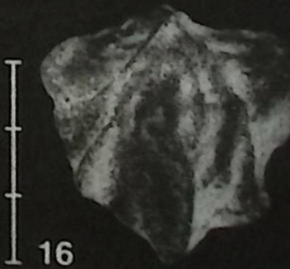

11


12


13


14


15


16

CA-MA96-5 (CAVALLO & MARTINETTO 1996, PLATE 5)

Early Pliocene flora of Pocapaglia and few other sites, southern Piedmont.

Fig. 1. *Carpinus* cf. *europaea* Negru 1968 (BETULACEAE).

Fig. 2. *Carpinus betulus* L. (BETULACEAE).

Fig. 3. *Corylus avellana* L. (BETULACEAE).

Fig. 4. *Visnea germanica* Menzel 1913 (THEACEAE).

Fig. 5. *Salix* sp. (SALICACEAE). Fruit from Cherasco.

Fig. 6. *Leucothoe* aff. *narbonnensis* (Saporta 1865) Mai 1960 (ERICACEAE). Capsule.

Fig. 7. *Rehderodendron ehrenbergii* (Kirchheimer 1935) Mai 1970 (STYRACACEAE). Endocarp.

Fig. 8. *Styrax maximus* (Weber 1852) Kirchheimer 1949 (STYRACACEAE).

Fig. 9. *Symplocos lignitarum* (Quenstedt 1867) Kirchheimer 1950 (SYMPLOCACEAE).

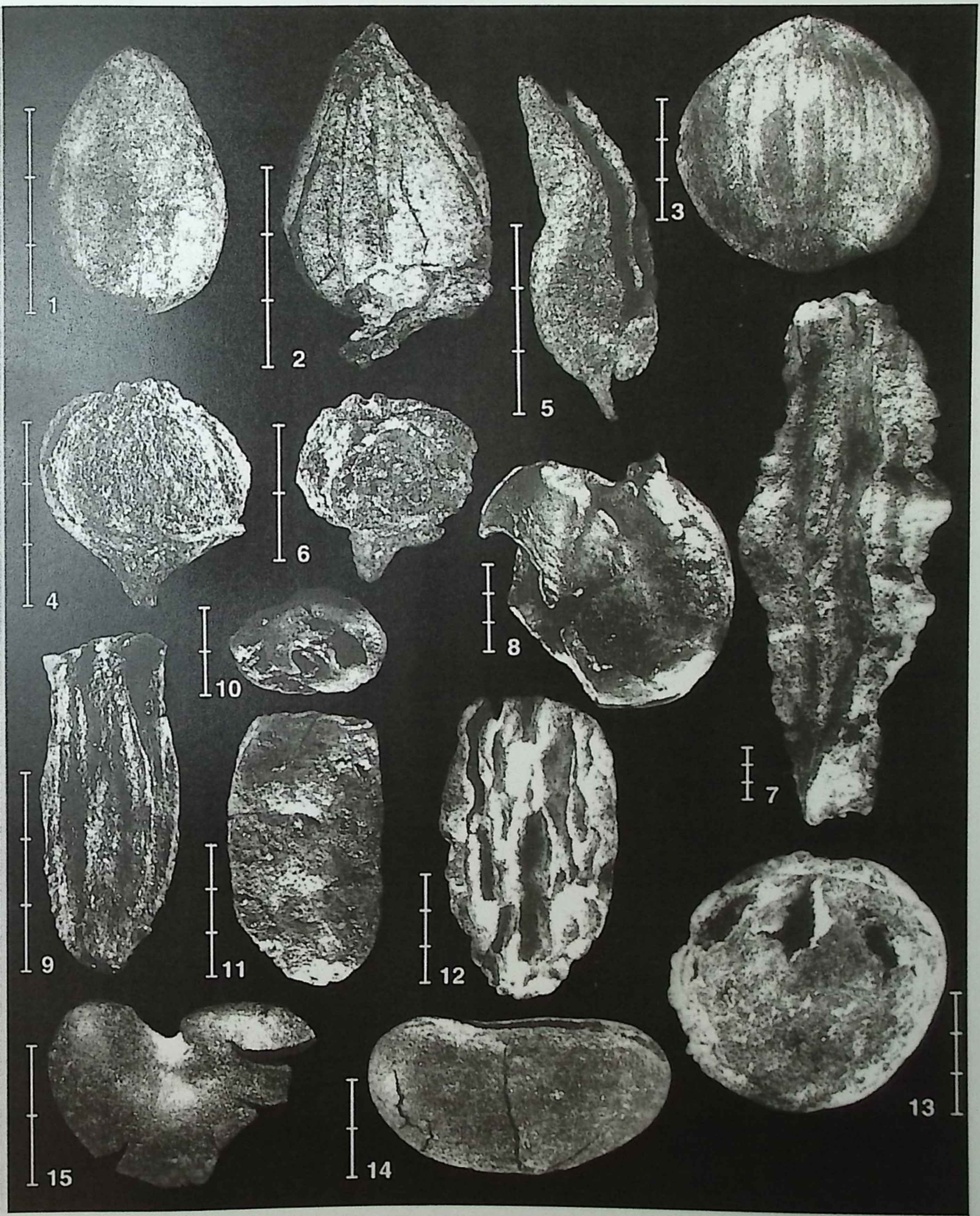
Figs 10,11. *Symplocos minutula* (Stemberg 1825) Kirchheimer 1949 (SYMPLOCACEAE).

Fig. 12. *Symplocos schereri* Kirchheimer 1935 (SYMPLOCACEAE).

Fig. 13. *Sorbus herzogenrathensis* (Menzel 1913) Gregor 1978 (ROSACEAE).

Fig. 14. *Toddalia latisiliquata* (Ludwig 1860) Gregor 1975 (RUTACEAE).

Fig. 15. *Toddalia rhenana* Gregor 1979 (RUTACEAE).


1
2
5
3
4
6
8
7
10
9
11
12
13
15
14

CA-MA96-6 (CAVALLO & MARTINETTO 1996, PLATE 6)

Early Pliocene flora of Pocapaglia and few other sites, southern Piedmont.

Fig. 1. *Zanthoxylum ailanthiforme* (Gregor 1975) Gregor 1978 (RUTACEAE).

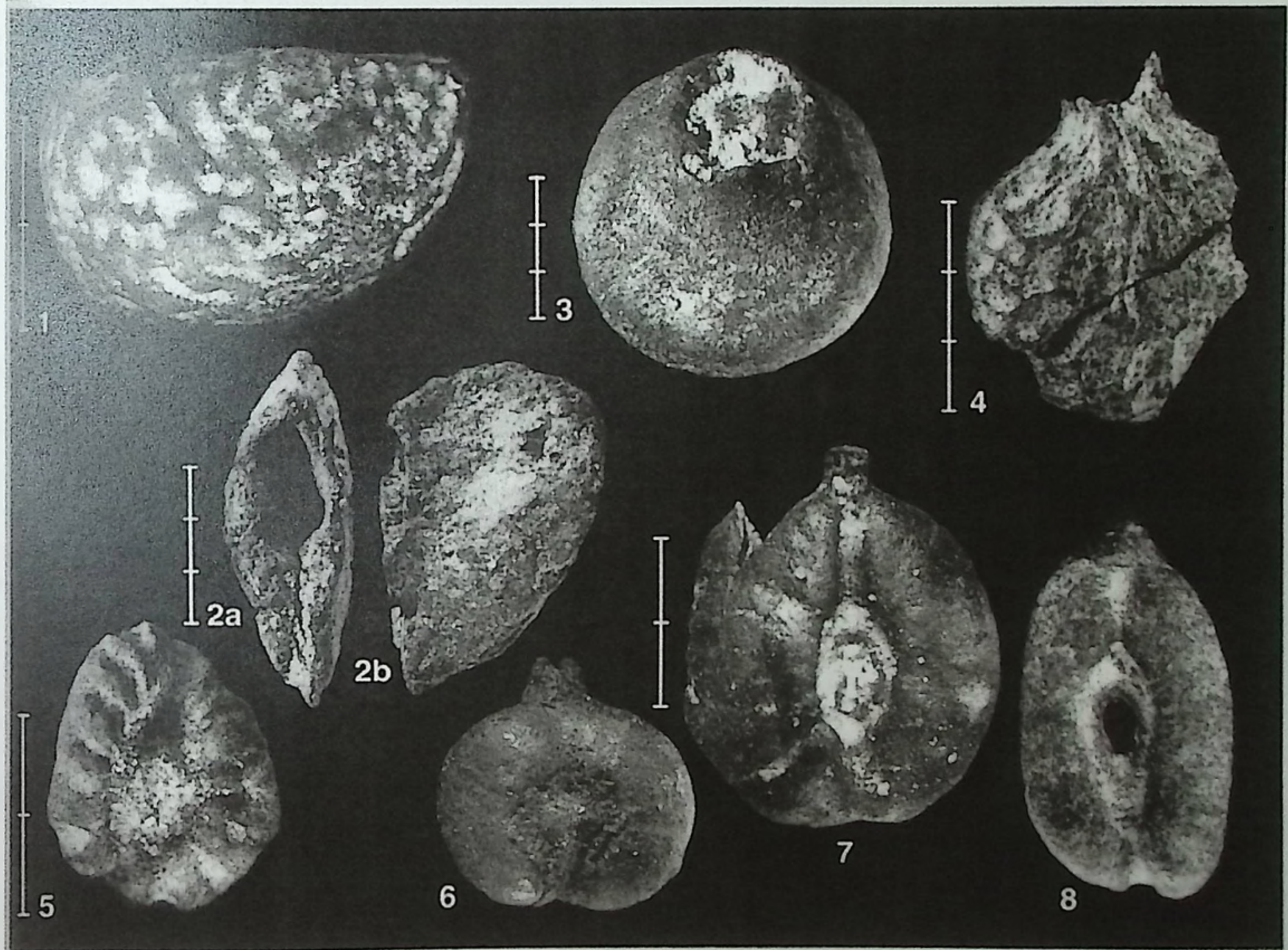
Fig. 2. *Acer* sp. indet. (ACERACEAE). Endocarp in ventral (a) and lateral view (b).

Fig. 3. *Sapindoidea margaritifera* (Ludwig 1860) Kirchheimer 1936 (?SAPINDACEAE).

Fig. 4. *Sabia europaea* Czeczott & Skirgiello 1959 (SABIACEAE).

Fig. 5. *Ampelopsis malvaeformis* (Schlotheim 1822) Mai in Mai & Gregor 1982 (VITACEAE).

Figs 6-8. *Vitis teutonica* A. Braun 1854 (VITACEAE).


1
3
4
2a
2b
5
6
7
8

MA01-1 (MARTINETTO 2001, PLATE 1)

Carpological remains from various Pliocene sites of Piedmont.

Fig. 1. *Cephalotaxus rhenana* GREGOR, seed from the "GA1 bed" bed of Castelletto Cervo (Middle Pliocene); MGPUT-P 00424 (x 3).

Fig. 2. *Cephalotaxus rhenana* GREGOR, seed from the " GA5 bed" of the same site (?Late Pliocene, ?Early Pleistocene) ; MGPUT-P 00425 (x 3).

Fig. 3. *Cathaya "vanderburghii"* GOSSMANN (*nomen nudum*), cone from the Candelo fossil site; MGPUT-P 00426 (x 2.3).

Fig. 4. *Pseudolarix schmidtgenii* KRÄUSEL, winged seed associated to a cone scale from the "*Pseudolarix* bed" of Castelletto Cervo; MGPUT-P 00429 (x 1.4).

Figs 5, 6. *Pseudolarix schmidtgenii* KRÄUSEL, internal and external view of cone scales from the same bed; MGPUT-P 00427 and 00428 (x 1.4).

Fig. 7a, b. *Mallotus maii* MARTINETTO 2001, half seed in external and internal view. Ca' Viettone, Early Pliocene; paratype MGPUT-P 00394 (x 8).

Fig. 8a, b. *Cyclea palatinati-bavariae* GREGOR, endocarp in external and internal view, Ca' Viettone, Early Pliocene; MGPUT-P 00430 (x 9.3).

Fig. 9. *Cyclea palatinati-bavariae* GREGOR, endocarp from Crava di Morozzo I, Early Pliocene; MGPUT-P 00431 (x 9.3).

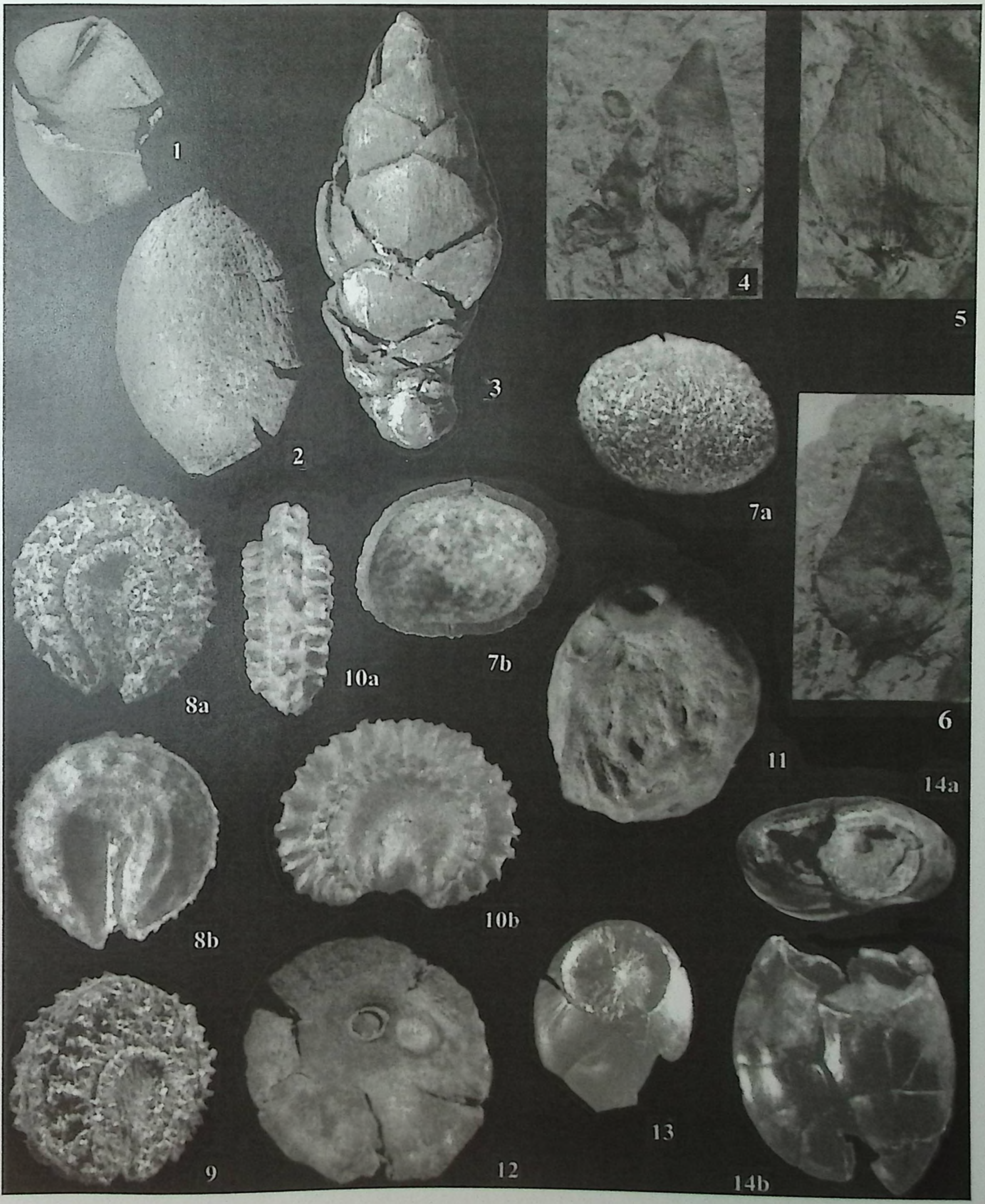
Fig. 10a, b. *Sinomenium cantalense* (E. M. REID) DOROFEEV, endocarp from the "GA1 bed" bed of Castelletto Cervo (Middle Pliocene); MGPUT-P 00432 (x 8).

Fig. 11. *Euryale nodulosa* C. & E. M. REID , seed in lateral view from the "*Trapa* bed" of Buronzo (?Late Pliocene, ?Early Pleistocene); MGPUT-P 00433 (x 3.5).

Fig. 12. *Euryale nodulosa* C. & E. M. REID , apical view of depressed seed with hilum and embryotega, same bed; MGPUT-P 00434 (x 4.3).

Fig. 13. *Sargentodoxa gossmannii* (GEISSERT, GREGOR & MAI) MARTINETTO 2001, fragmentary seed in oblique apical view, Ronco Biellese, Early Pliocene; MGPUT-P 00435 (x 7).

Fig. 14a, b. *Sargentodoxa gossmannii* (GEISSERT, GREGOR & MAI) MARTINETTO 2001, seed in apical and lateral view, Ronco Biellese, Early Pliocene; MGPUT-P 00436 (x 7).


1
2
3
4
5
6
7a
7b
8a
8b
9
10a
10b
11
12
13
14a
14b

MA01-2 (MARTINETTO 2001, PLATE 2)

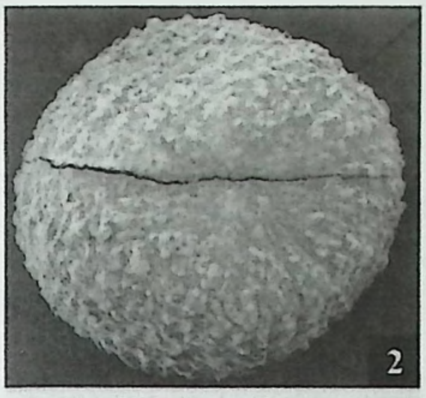
Carpological remains from various Pliocene sites of Piedmont.

Figs 1-9. *Mallotus maii* MARTINETTO 2001, Ca' Viettone, Early Pliocene.
1. Seed in apical view. Ca' Viettone, Early Pliocene. Holotype, MGPUT-P 00415 (x 11).
2. Seed in basal view. Ca' Viettone, Early Pliocene. Paratype, MGPUT-P 00416 (x 11).
3. Half a seed in internal view. Paratype, MGPUT-P 00417 (x 11).
4a,b. Detail of the internal ornamentation and wall structure and of MGPUT-P 00417 (x 26, x 107).
5. Detail of the internal ornamentation and wall structure of MGPUT-P 00417 (x 105).
6. External ornamentation of MGPUT-P 00415 (x 41).
7a,b. External surface of MGPUT-P 00415 (x 160) with detail of sclereids (x 1300).
8. Sclereids forming the wall of MGPUT-P 00417 (x 290).
9. Detail of the internal areolate ornamentation of MGPUT-P 00417 (x 235).

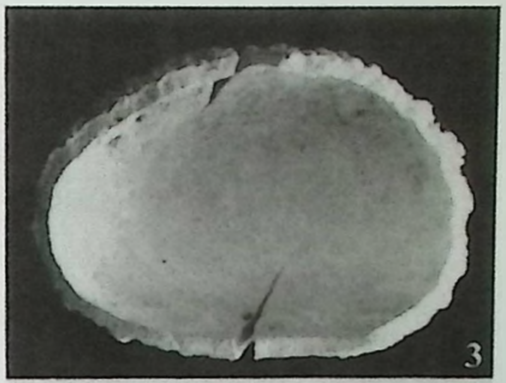
Fig. 10. *Melissa elegans* E. M. REID, nutlet in ventral view, Stura, Middle Pliocene; MGPUT-P 00437 (x 56).

Fig. 11-12. *Melissa elegans* E. M. REID, Castle Eden, England, Pliocene. Natural History Museum of London, REID collection. Courtesy of Mrs. Tiffany Foster.
11. nutlet in ventral view, V.37552 specimen 1 (x 75).
12. detail of the ornamentation on the dorsal side of another nutlet, V.37552 specimen 2 (x 450).

1

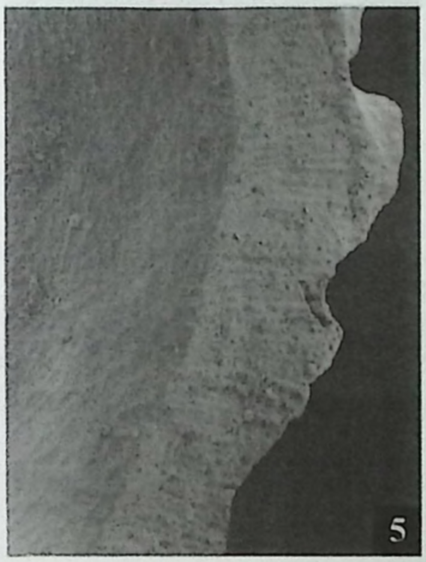


2

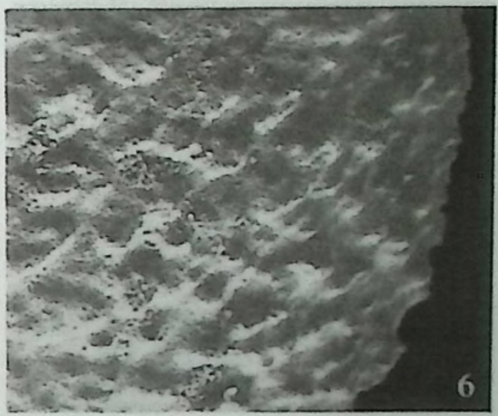


3

4a



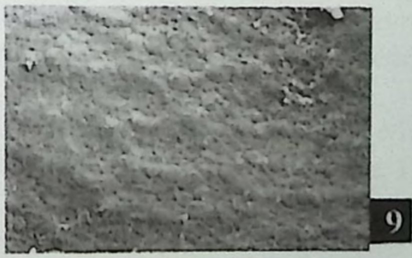
5



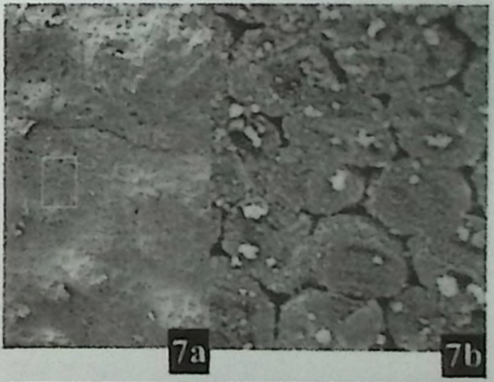
6

4b

8



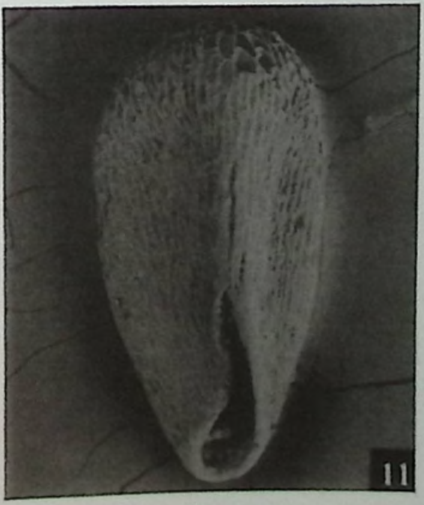
9



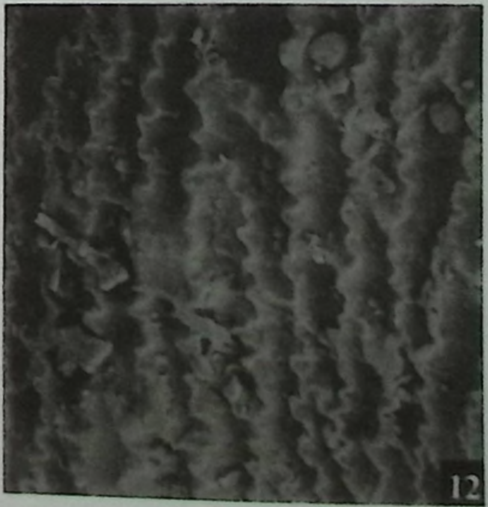
7a

7b

10



11



12

MA01-3 (MARTINETTO 2001, PLATE 3)

Carpological remains from various Pliocene sites of Piedmont.

Fig. 1a, b. *Meliosma wetteraviensis* (LUDWIG) MAI, endocarp in ventral and dorsal view. Stura, Middle Pliocene; MGPUT-P 00438 (x 7.8).

Fig. 2. *Meliosma wetteraviensis* (LUDWIG) MAI, endocarp in ventral view, Stura; MGPUT-P 00439 (x 7.8).

Fig. 3. *Meliosma wetteraviensis* (LUDWIG) MAI, inner view of half an endocarp, Stura; MGPUT-P 00440 (x 7.8).

Fig. 4a, b. *Meliosma veitchiorum* HEMSL., modern endocarp in ventral and basal view, carpological collection of the SZAFER Institute of Botany of Krakow (x 7.8).

Fig. 5a, b. *Meliosma veitchiorum* HEMSL., modern endocarp in ventral and dorsal view, carpological collection of the SZAFER Institute of Botany of Krakow (x 7.8).

Fig. 6a, b. *Meliosma canavesana* MARTINETTO 2001, paratype MGPUT-P 00418, endocarp in ventral and anterior view. Ca' Viettone, Early Pliocene (x 7.8).

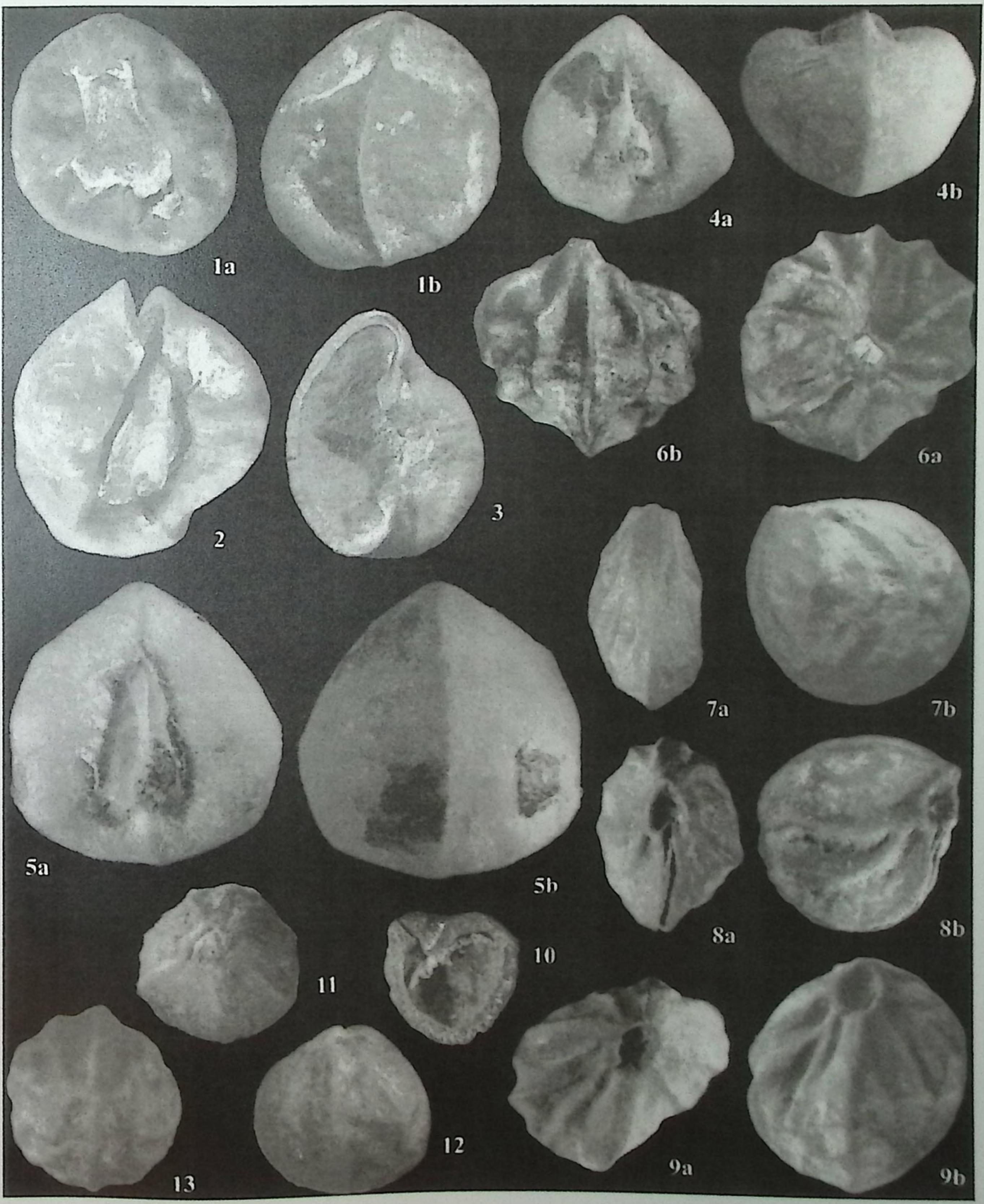
Fig. 7a, b. *Meliosma canavesana* MARTINETTO 2001, paratype MGPUT-P 00419, endocarp in anterior and lateral view. Ca' Viettone, Early Pliocene (x 7.8).

Fig. 8a, b. *Meliosma canavesana* MARTINETTO 2001, paratype MGPUT-P 00420, endocarp in ventral and lateral view. Ca' Viettone, Early Pliocene (x 7).

Fig. 9a, b. *Meliosma canavesana* MARTINETTO 2001, holotype, MGPUT-P 00421, endocarp in ventral and ventral-posterior view. Ca' Viettone, Early Pliocene (x 7).

Fig. 10. *Meliosma canavesana* MARTINETTO 2001, paratype MGPUT-P 00422, internal view of a split endocarp showing curved marginal canal. Ca' Viettone, Early Pliocene (x 7.8).

Fig. 11-13. *Meliosma myriantha* SIEBOLD & ZUCCARINI, modern endocarps in ventral, lateral and dorsal view. From Kyoto B. G., carpological collection of the SZAFER Institute of Botany of Krakow (x 7.8).


1a
1b
4a
4b
6b
6a
2
3
7a
7b
5a
5b
8a
8b
11
10
9a
9b
13
12

Ma01-4 (Martinetto 2001, plate 4)

Carpological remains from various Pliocene sites of Piedmont.

Fig. 1a, b. *Meliosma wetteraviensis* (Ludwig) Mai, inner view of half an endocarp, showing the ventral pore under the prominent plug and a detail of the thin wall, Stura, Middle Pliocene. SEM; MGPUT-P 00441 (x 9.4, x 75).

Fig. 2a, b. *Meliosma wetteraviensis* (Ludwig) Mai, endocarp in ventral view, with detail of the external ornamentation. Stura, Middle Pliocene. SEM; MGPUT-P 00442 (x 7.6, x 61).

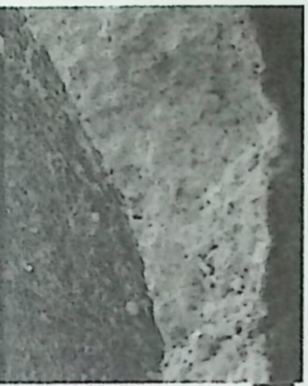
Fig. 3a, b. *Meliosma veitchiorum* Hemsl., same view as fig. 2, notice the definitely coarser ornamentation. Modern, carpological collection of the Szafer Institute of Botany of Krakow. SEM (x 7.6, x 61).

Fig. 4a, b. *Meliosma canavesana* Martinetto 2001, paratype, inner view of half an endocarp showing the thick wall and the granulate inner surface, SEM. Ca' Viettone, Early Pliocene; MGPUT-P 00423 (x 13.5, x 108).

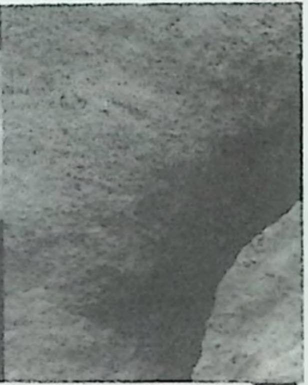
Figs 5-13. *Meliosma wetteraviensis* (Ludwig) Mai, size and shape variation in endocarps from Stura, Middle Pliocene; MGPUT-P 00443 (x 5).

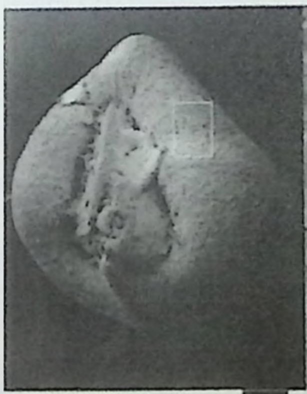
Fig. 14. *Craigia bronnii* (Unger) Kvacek, Buzek & Manchester, fruit compression from Ca' Viettone, Early Pliocene; MGPUT-P 00444 (x 6.5).

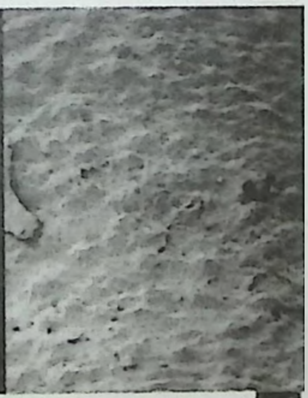

1a


1b

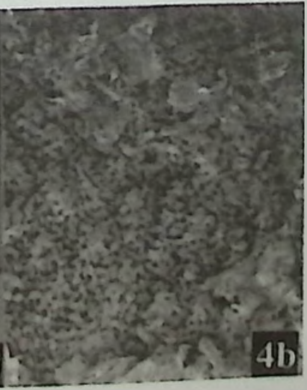

2a

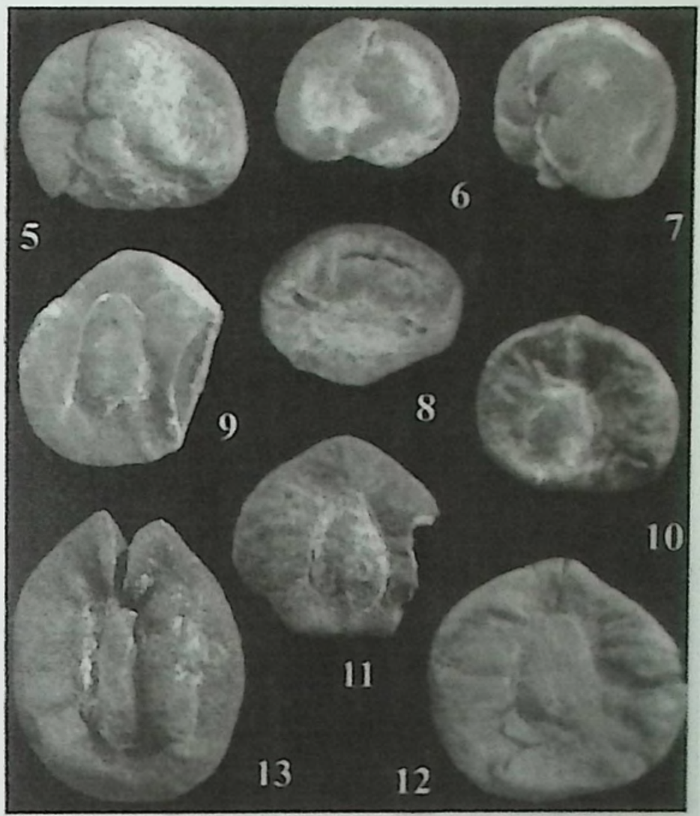

2b


3a


3b


4a


4b




14

MA01-5 (MARTINETTO 2001, PLATE 5)

Carpological remains from various Pliocene sites of Piedmont.

Fig. 1-3. *Sargentodoxa gossmannii* (GEISSERT, GREGOR & MAI) MARTINETTO 2001, fragment of seed. Ronco Biellese, Early Pliocene; MGPUT-P 00445.
1. detail of the wall structure in cross-section (x 200).
2. detail of the wall and internal surface (x 100).
3. detail of the external surface at two different magnifications (x 67, x 535).

Fig. 4a, b. *Thalictrum minimum* (SZAFER 1947) MARTINETTO 2001, endocarp with detail of the external cell structure; Stura, Middle Pliocene; MGPUT-P 00446 (x 27, x 213).

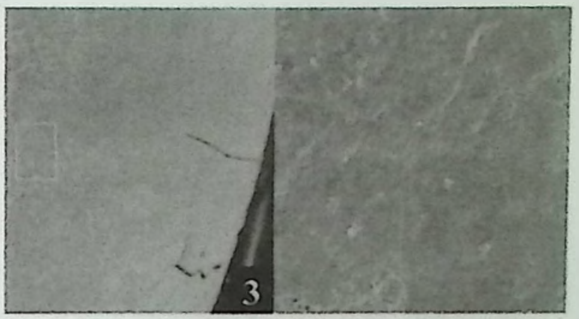
Fig. 5. *Thalictrum minimum* (SZAFER 1947) MARTINETTO 2001, endocarp with remains of the pedicle; Stura, Middle Pliocene; MGPUT-P 00447 (x 33).

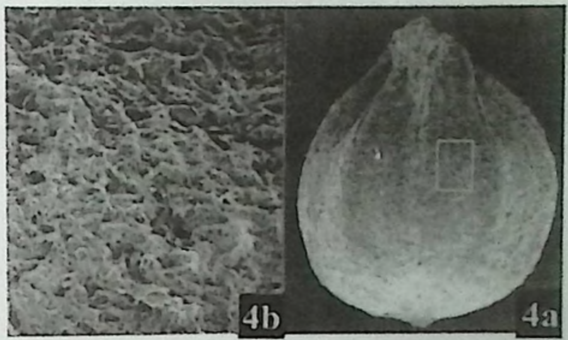
Fig. 6-10. *Thalictrum* sp., modern specimens from Jiouzhaigou, W-Sichuan, China.
6. endocarp with remains of the pedicle.
7. detail of the external cell structure of the foregoing specimen (x 134).
8. detail of internal cell structure at the bottom of the seed chamber, same specimen of fig. 10 (x 75).
9. complete fruit with pedicle and style (x 17).
10a, b. cross-section of a fruit with detail of the wall structure (x 20, x 100).

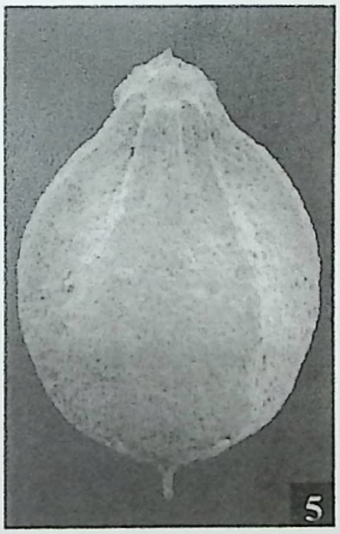
Fig. 11-12. *Thalictrum minimum* (SZAFER 1947) MARTINETTO 2001, endocarps from Stura (Middle Pliocene) in cross-section, with details of the internal cell structure at the bottom of the seed chamber (11b) and wall structure (12b); MGPUT-P 00448 (x 38, x 193) and 00449 (x 29, x 205).

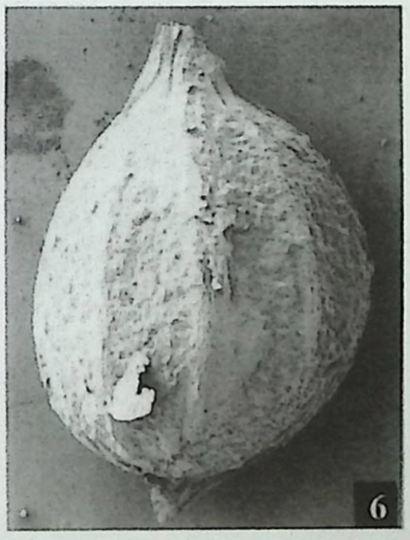

1


2

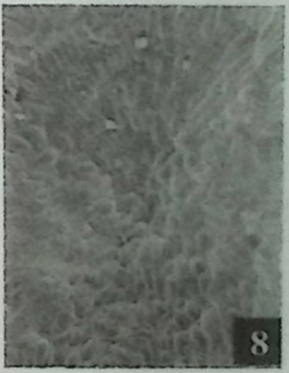

3

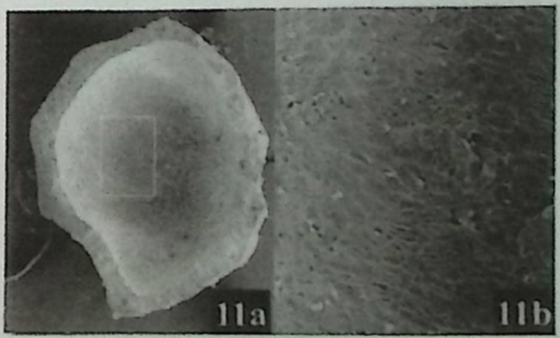

4b
4a


5

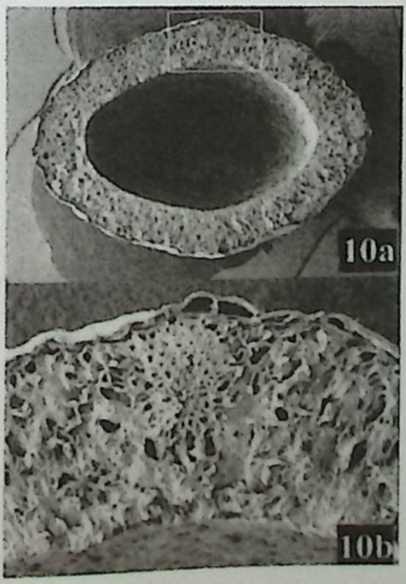

6

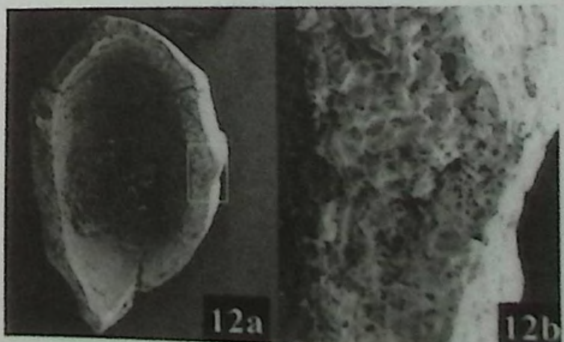

7


8


11a
11b


9


10a
10b


12a
12b

MA94A-1 (MARTINETTO 1994A, PLATE 1)

Carpological remains from Stura (Stura di Lanzo, Nole Canavese); Middle Pliocene of NW Italy.

Fig. 1, 2 - *Glyptostrobus europaeus* (Brongniart) Unger. 1: cone, 4.4x. 2: winged seed, 7.6x.

Fig. 3, 4 - *Alnus* sp. 3; female catkin, 3.7x. 4: fruit, 18.9x.

Fig. 5 - *Lycopus europaeus* Linné. Achene, ventral view, 22x.

Fig. 6 – *Epipremnites reniculus* (Ludwig) Mai. Seed, lateral view, 13.5x.

Fig. 7 - *Carex* cf. *loliacea* Linné. Utricle with achene, 22.3 x.

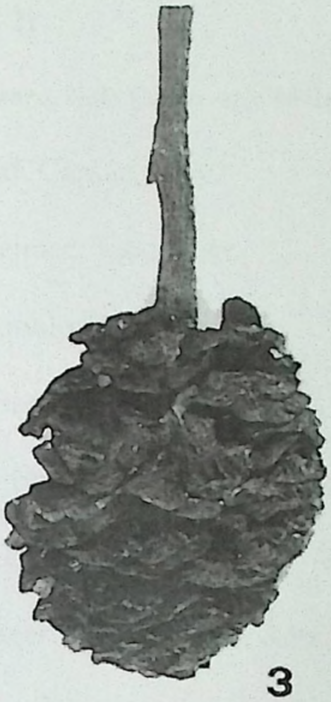
Fig. 8 - *Carex* gr. *caespitosa* Linné. Achene with utricle remains, 19.5x.

Fig. 9, 10 - *Carex flagellata* C. & E. M. Reid. 9: Achene, 12.3x. 10: Utricle, 9.3x.

Fig. 11 - *Dulichium arundinaceum* (Linné) Britton. Achene, 14.6x.

Fig. 12 - *Scirpus* cf. *mucronatus* Linné. Achene, 18.5x.


1


3


6


5


7


2


4


11


12


8


9


10

Ma94a-2 (Martinetto 1994a, plate 2)

Carpological remains from Stura (Stura di Lanzo, Nole Canavese); Middle Pliocene of NW Italy.

Fig. 1 - *Fagus decurrens* C. & E. M. Reid. Cupula, 2.9x.

Fig. 2 - *Styrax maximus* (Weber) Kirchheimer. Seed, 3.4x.

Fig. 3 - *Sequoia abietina* (Brongniart) Knobloch. Cone, 2.5x.

Fig. 4 - *Parrotia reidiana* Kirchheimer. Seed, 8.4x.

Fig. 5 - *Ampelopsis malvaeformis* (Schlothheim) Mai. Seed, 6.5x.

Fig. 6 - *Actinidia faveolata* C. & E. M. Reid. Seed, 9.5x.

Fig. 7 - *Liriodendron geminata* Kirchheimer. Pair of seeds, 8.9x.

Fig. 8 - *Magnolia cor* Ludwig. Seed, 5.6x.

Fig. 9 – *Toddalia* cf. *rhenana* Gregor. Seed, 11.7x.

Fig. 10 - *Phellodendron elegans* C. & E. M. Reid. Seed, 7.4x.

Fig. 11 - *Wikstroemia thomasii* Geissert & Gregor. Seed, 8.7x

Fig. 12 - *Meliosma wetteraviensis* (Ludwig) Mai. Endocarp, 4.6x.

Fig. 13 - *Sabia europaea* Czeczott & Skirgiello. Endocarp, lateral view. 6.4x.


1


2

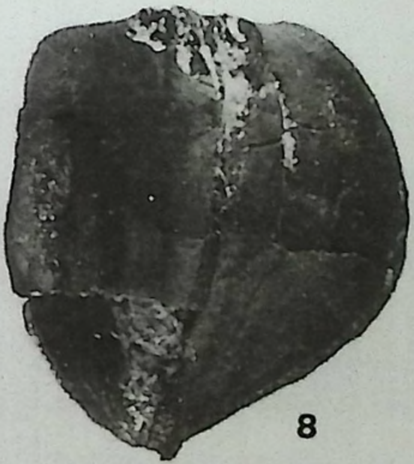

3


4


5


6


7


8


12


9


11


13


10

Ma94a-3 (Martinetto 1994a, plate 3)

Carpological remains from Stura (Stura di Lanzo, Nole Canavese); Middle Pliocene of NW Italy.

Fig. 1 - *Selaginella pliocenica* Dorofeev. Megaspore, 63x.

Fig. 2 - *Salvinia tuberculata* Nikitin. Megaspore, 100x

Fig. 3 - *Potentilla supina* Linné. Achene, 66.7x.

Fig. 4 - *Nuphar canaliculatum* C. & E. M. Reid. Seed, 16x.

Fig. 5 - *Ranunculus reidii* Szafer. Achene, 30.4x.

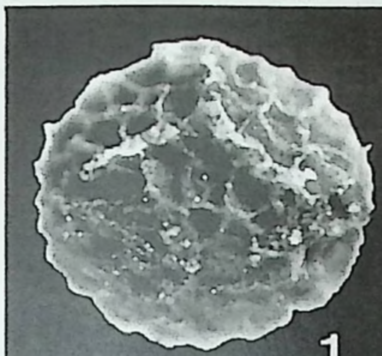
Fig. 6 - *Ranunculus pseudoflammula* Dorofeev. Achene, 40x.

Fig. 7 - *Potamogeton* cf. *polymorphus* Dorofeev. Endocarp. 16.0x.

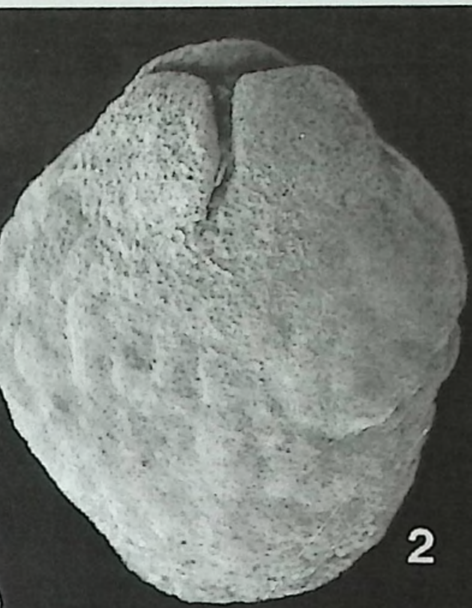
Fig. 8 - *Ludwigia* cf. *palustris* (Linné) Elliot. Seed, 107x.

Fig. 9 - *Proserpinaca reticulata* C. & E. M. Reid. Fruit, 18.7x.

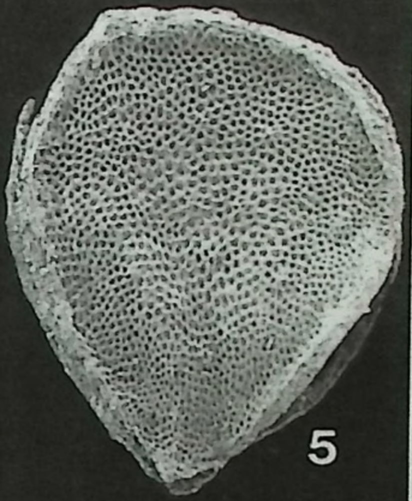
Fig. 10 - *Melissa elegans* E. M. Reid. Achene, ventral view, 66.7x



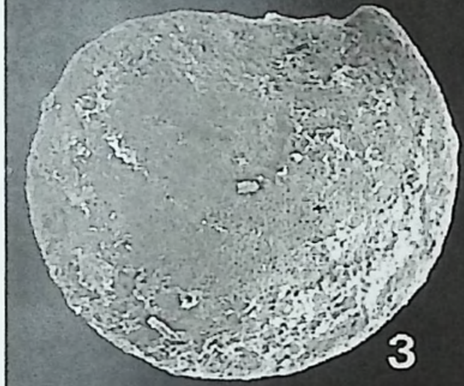
1



2



5



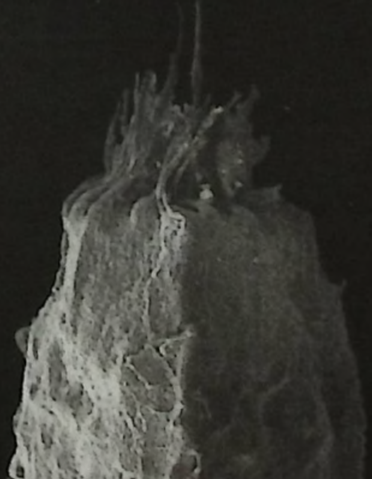
3

4

6

7

8



9

10

MA94B-1 (MARTINETTO 1994B, PLATE 1)

Fig. 1-4 - *Glyptostrobus europaeus*" (Brongniart) Heer. 1) cone, sample LC1, x 6; 2) seed with perfectly preserved wing, sample Stura di Lanzo near Nole Canavese, x 9; 3) seed from Dunarobba, Pliocene of central Italy, x 11; 4) cone scale from La Cassa, Pliocene of NW Italy, x 6.

Fig. 5 - *Alnus* sp., fruit lacking outer fruit coat and wings, from Barbania, Pliocene of NW Italy, x 36.

Fig. 6 - *Meliosma* cf. *pliocaenica* (Szafer) Gregor, laterally compressed endocarp from Dunarobba, Pliocene of central Italy, x 12.

Fig. 7 - *Meliosma wetteraviensis* (Ludwig) Mai, endocarp, Stura di Lanzo near Nole Canavese, x 9.

Fig. 8, 9 - *Swida gorbunovii* (Dorofeev) Negru from Dunarobba, Pliocene of central Italy. 8) heart-shaped endocarp, sample DU10, x 12; 8a) external view; 8b) broken side showing the wall dividing the two seed chambers; 9) extremely elongated endocarp, sample DU10, x 14.


1


2


4


5


6


3


7


9


8a


8b

MA94B-2 (MARTINETTO 1994B, PLATE 2)

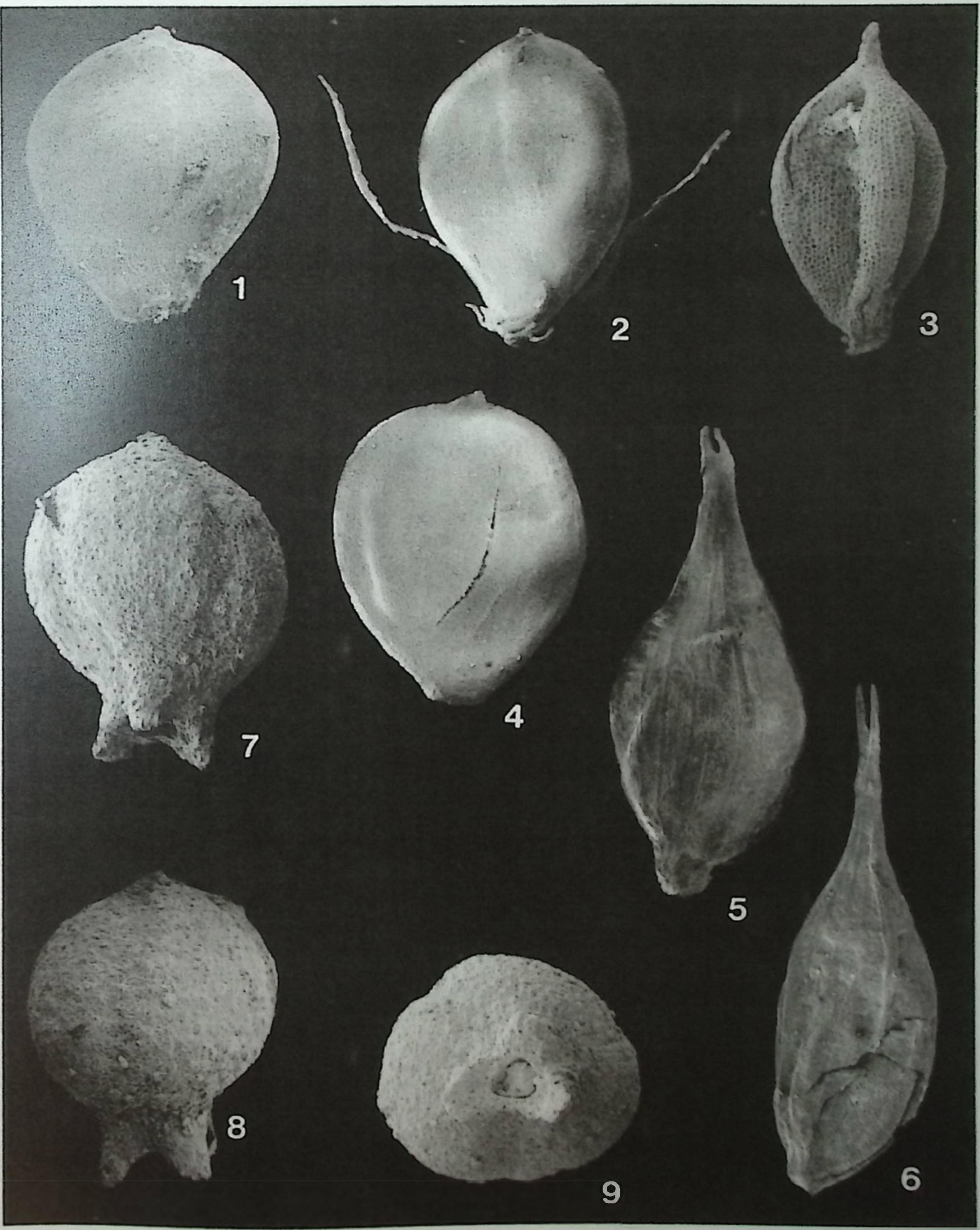
Fig. 1, 2 – *Scirpus* (*Schoenoplectus*) *isolepioides* Mai & Walther from Dunarobba, Pliocene of central Italy. 1) fruit, convex side; 2) fruit with two complete setae, x 42.

Fig. 3 - *Carex plicata* Lanckucka-Srodoniowa, nutlet from La Cassa, Pliocene of NW Italy, x 46.

Fig. 4 - *Carex* gr. *caespitosa* Linné, nutlet, sample FN3, x 46.

Fig. 5, 6 - *Carex pseudocyperus* Linné from Dunarobba, Pliocene of central Italy, 5) complete utricle, x 24; 6) utricle partly broken at the base to show the nutlet, x 25.

Fig. 7-9 - *Cladium paleomariscus* Dorofeev from Dunarobba, Pliocene of central Italy. 7) endocarp in lateral view showing the three basal appendixes; 8) endocarp; 9) endocarp, basal view with hilar pit and appendixes, x 46.


1
2
3
4
5
6
7
8
9

MA95-1 (MARTINETTO 1995, PLATE 1)

Typical assemblage of the Ca' Viettone Floristic Complex, Early (-Middle?) Pliocene of NW Italy.

Fig. 1: *Cathaya van-der-burghii* GOSSMANN in MAI 1994
Female cone. Ca' Viettone near Levone Canavese, x2.
Fig. 2: *Cryptomeria rhenana* KILPPER 1968
Fig. 2a: Seed. Ca' Viettone near Levone Canavese, x17.5. Fig. 2b: detail of the seed surface, x140.
Fig. 3: *Tetraclinis salicornioides* (UNGER 1941) KVACEK 1986 (= *Tetraclinis wandae* ZABLOKI). Female cone, Ca' Viettone near Levone Canavese, x10.
Fig. 4-7: *Magnolia allasoniae* MARTINETTO 1995
Fig. 4, 6: seeds with different shapes. Ca' Viettone near Levone Canavese, x4.5.
Fig. 5: holotype, external side. Ca' Viettone near Levone Canavese, x5.5.
Fig. 7: internal side of a seed valve. Ca' Viettone near Levone Canavese, x5.5.
Fig. 8, 9: *Magnolia lignita* (UNGER 1861) MAI 1975
Seeds, external side. Ca' Viettone near Levone Canavese, x4.5.
Fig. 10: *Cinnamomum costatum* (MAI 1960) PINGEN, FERGUSON & COLLINSON 1994
Endocarp. Ca' Viettone near Levone Canavese, 5.5x.
Fig. 11, 12: *Ocotea* sp. A
Fig. 11: Cupula with damaged lobes. Ca' Viettone near Levone Canavese, x1.6.
Fig. 12: Cupula containing the fruit. Ca' Viettone near Levone Canavese, x2.3.
Fig. 13: *Sinomenium cantalense* (E. M. REID 1920) DOROFEEV 1963
Seed. Ca' Viettone near Levone Canavese, x7.5.
Fig. 14: ?*Gironniera* cf. *carinata* MAI 1970
Fig. 14: endocarp lateral-ventral view. Ca' Viettone near Levone Canavese, x7.
Fig. 15: *Trigonobalanopsis exacantha* (MAI 1970) KVACEK & WALTHER 1989
Cupula, Ca' Viettone near Levone Canavese, x 5.5.
Fig. 16, 17: *Palaeocarya macroptera* (BRONGNIART 1828) JAEHNICHEN *et al.* 1977
Fig. 16: internal side of a split endocarp. Ca' Viettone near Levone Canavese, x7.5.
Fig. 17: endocarp in external view. Ca' Viettone near Levone Canavese, x7.5.
Fig. 18, 19: *Phytolacca salsoloides* MARTINETTO 1995
18: seed in lateral view. Ca' Viettone near Levone Canavese, x12.
Fig. 19a: holotype, seed in lateral view; 19b: the same in ventral view. Ca' Viettone near Levone Canavese, x14.
Fig. 20: *Eurya stigmosa* (LUDWIG 1860) MAI 1960
Seed, SEM. Ca' Viettone near Levone Canavese, x16.
Fig. 21: *Ternstroemia reniformis* (CHANDLER 1957) MAI 1971
Seed, Ca' Viettone near Levone Canavese, x8.
Fig. 22: *Visnea germanica* MENZEL 1913
Fruit. Ca' Viettone near Levone Canavese, x12.
Fig. 23, 24: *Arctostaphyloides* cf. *menzelii* KIRCHHEIMER 1936
Fig. 23: fragmentary fruit in lateral view. Sento, bed S5, x10.
Fig. 24: fruit in basal view; Sento, bed S5, x10.
Fig. 25: *Rehderodendron ehrenbergii* (KIRCHHEIMER 1935) MAI 1970
Endocarp. Ca' Viettone near Levone Canavese, x 1.8.


1
2
4
5
8
6
7
10
3
9
13
15
11
12
21
14
18
16
17
20
22
19
23
24
25

MA95-2 (MARTINETTO 1995, PLATE 2)

Typical assemblage of the Ca' Viettone Floristic Complex, Early (-Middle?) Pliocene of NW Italy.

Fig. 1: *Symplocos schereri* KIRCHHEIMER 1935
Endocarp, lateral view. Ca’ Viettone near Levone Canavese, x5.5.

Fig. 2: *Symplocos gothanii* KIRCHHEIMER 1935
Endocarp, apical view. Sento, bed S5, x7.

Fig. 3: *Symplocos casparyi* LUDWIG 1857
Endocarp, lateral view. Boschi di Barbania, x7.

Fig. 4, 5: *Symplocos salzhausensis* (LUDWIG 1860) KIRCHHEIMER 1936
Endocarps in basal (Fig. 4) and apical view (Fig. 5). Ca’ Viettone near Levone Canavese, x7.

Fig. 6: *Mallotus* sp. A
Seed from Ca’ Viettone near Levone Canavese, x10.

Fig. 7: *Toddalia latisiliquata* (LUDWIG 1860) GREGOR 1975
Seed. Ca’ Viettone near Levone Canavese, x5.5.

Fig. 8, 9: *Zanthoxylum mueller-stollii* GREGOR 1984
Seeds in lateral (Fig. 8) and ventral view (Fig. 9). Ca’ Viettone near Levone Canavese, x8.

Fig. 10, 11: *Zanthoxylum ailanthiforme* (GREGOR 1975) GREGOR 1978
Fig. 10: seed in ventral view. Ca’ Viettone near Levone Canavese, x10.5.
Fig. 11: seed in lateral view. Ca’ Viettone near Levone Canavese, x9.

Fig. 12, 13: *Sapindoidea margaritifera* (LUDWIG 1860) KIRCHHEIMER 1936
Fig. 12: lateral-apical view. Ca’ Viettone near Levone Canavese, x7.
Fig. 13: inner view of a fragmentary specimen showing the typical internal structure. Ca’ Viettone near Levone Canavese, x5.5.

Fig. 14: *Meliosma* aff. *reticulata* (C. & E. M. REID) CHANDLER 1950
Endocarp in lateral-ventral view. Ca’ Viettone near Levone Canavese, x6.

Fig. 15, 16: *Nyssa sibirica* DOROFEEV 1963
Endocarps, Ca’ Viettone near Levone Canavese, x7.

Fig. 17, 18: *Ilex saxonica* MAI 1964
Endocarps in lateral (Fig. 17) and lateral-ventral view (Fig. 18). Ca’ Viettone near Levone Canavese, x 8.5.

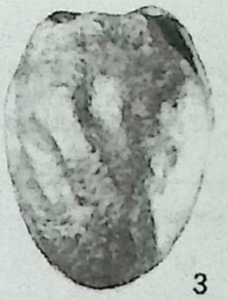
Fig. 19, 20 : *Frangula* cf. *solitaria* GREGOR 1977
Fig. 19: endocarp containing the seed. Ca’ Viettone near Levone Canavese, 10x.
Fig. 20: large seed. Ca’ Viettone near Levone Canavese, 10x.

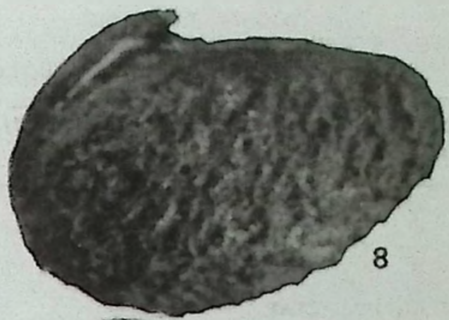
Fig. 21: *Vitis teutonica* A. BRAUN 1854
Seed, dorsal side. Ca’ Viettone near Levone Canavese, 10x.

Fig. 22: *Spirellea* aff. *bohemica* KNOBLOCH & MAI 1984
Probable seed in lateral view. Ca’ Viettone near Levone Canavese, SEM, x45.


1


2

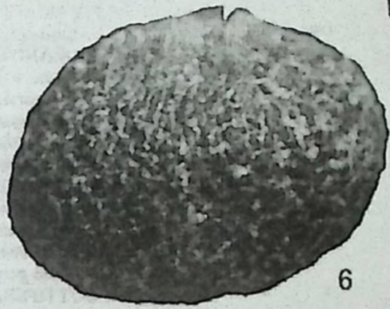

3


8


9


4

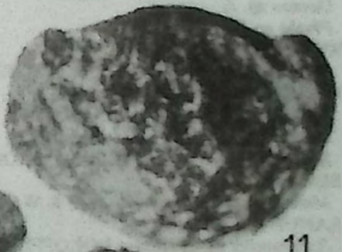

5

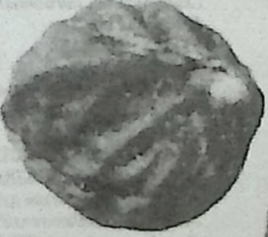

6

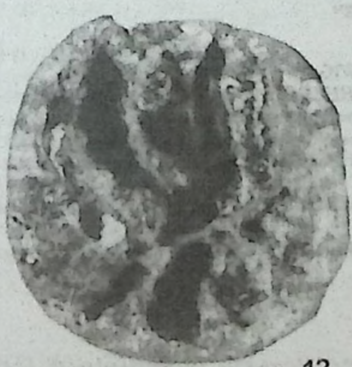

10


12


7


11


14


13

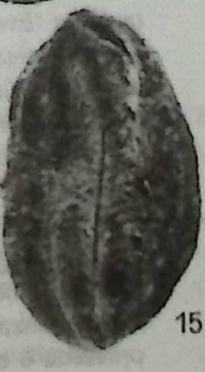

18

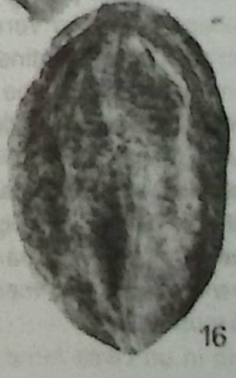

17


21


19


20


15


16


22

MA95-3 (MARTINETTO 1995, PLATE 3)

Typical assemblage of the Ca' Stura Floristic Complex, Middle Pliocene of NW Italy.

Fig. 1: *Selaginella kunovicensis* KNOBLOCH 1986
Megaspore, SEM. Stura di Lanzo near Nole Canavese, x124.

Fig. 2: *Glyptostrobus europaeus* (BRONGNIART 1833) UNGER 1850
Female cone. Stura di Lanzo near Nole Canavese, x3.5.

Fig. 3: *Sequoia abietina* (BRONGNIART 1822) KNOBLOCH 1964
Female cone. Momello near Lanzo, x3.

Fig. 4: *Taiwania* sp.
Female cone. Momello near Lanzo, x5.

Fig. 5: *Liriodendron geminata* KIRCHHEIMER 1957
Seed. Buronzo, x11.

Fig. 6: *Magnolia cor* LUDWIG 1857
Split seed, internal side (6a) and external view (6b). Stura di Lanzo near Nole Canavese, x5,5.

Fig. 7, 8: *Parrotia reidiana* KIRCHHEIMER 1957
Fig. 7: fruit, Stura di Lanzo near Nole Canavese, x5.5.
Fig. 8: seed, Stura di Lanzo near Nole Canavese, x10.

Fig. 9: *Morus sibirica* DOROFEEV 1963
Endocarp. Stura di Lanzo near Nole Canavese, x30.

Fig. 10: *Boehmeria lithuanica* DOROFEEV 1982
Fruit. Stura di Lanzo near Nole Canavese, x28.

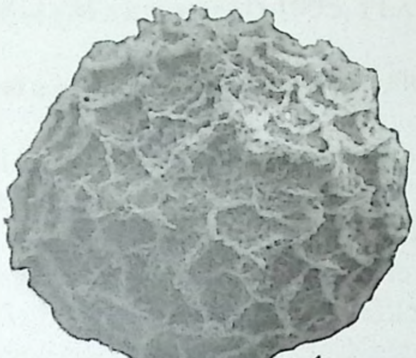
Fig. 11: *Fagus decurrens* C. & E. M. REID 1915
Cupula. Stura di Lanzo near Nole Canavese, x4.5.

Fig. 12: *Carpinus* cf. *europaea* NEGRU 1968
Fruit. Stura di Lanzo near Nole Canavese, x13.

Fig. 13: *Juglans bergomensis* (BALSAMO-CRIVELLI 1840) MASSALONGO 1852
Fruit. (?)Middle Pliocene deposit of Castelletto Cervo I (layer GA1), x0.8.

Fig. 14-16: *Pterocarya limburgensis* C. & E. M. REID 1915
Fig. 14: inner view of fruit. (?)Middle Pliocene deposit of Castelletto Cervo I (layer GA1), x7.
Fig. 15, 16: fruits in lateral view, (?)Middle Pliocene deposit of Castelletto Cervo I (layer GA1), x7.

Fig. 17-18: *Stewartia beckerana* (LUDWIG 1857) KIRCHHEIMER 1957
Fig. 17: Fruit in view lateral. Momello near Lanzo, x3.7.
Fig. 18: Fruit in apical view. (?)Middle Pliocene deposit of Castelletto Cervo I (layer GA1), x3.


1


2

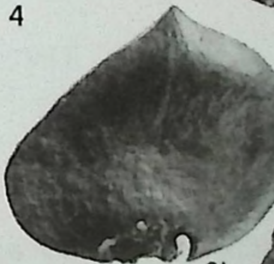

3


5


7


4

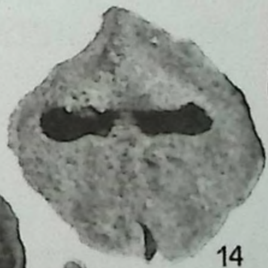

6a


6b


8


13


10


14


9


11


12


15


16

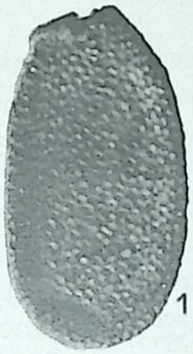

17


18

Ma95-4 (Martinetto 1995, plate 4)

Typical assemblage of the Ca' Stura Floristic Complex, Middle Pliocene of NW Italy.

Fig. 1: *Actinidia faveolata* C. & E. M. REID 1915
Seed. Stura di Lanzo near Nole Canavese, x11.
Fig. 2: *Styrax maximus* (WEBER 1852) KIRCHHEIMER 1949
Seed. Stura di Lanzo near Nole Canavese, x5.
Fig. 3: *Wikstroemia thomasii* GEISSERT & GREGOR 1981
Seed. Stura di Lanzo near Nole Canavese, x8.
Fig. 4: *Proserpinaca reticulata* C. & E. M. REID 1915
Fruit. Stura di Lanzo near Nole Canavese, x16.
Fig. 5: *Phellodendron elegans* (C. & E. M. REID 1907) C. & E. M. REID 1915
Seed. Stura di Lanzo near Nole Canavese, x13.
Fig. 6: *Toddalia rhenana* GREGOR 1979
Seed. Momello near Lanzo, x14
Fig. 7: *Meliosma wetteraviensis* (LUDWIG 1857) MAI 1973
Endocarp. Stura di Lanzo near Nole Canavese, x8.
Fig. 8-9: *Nyssa disseedsnata* (LUDWIG 1857) KIRCHHEIMER 1937
Fig. 8: Endocarp. Front, x5.5.
Fig. 9: Endocarp with dehiscence valve. Front, x5.5.
Fig. 10: *Frangula alnus* MILLER
Endocarp. Stura di Lanzo near Nole Canavese, x10.
Fig. 11: *Ampelopsis malvaeformis* (SCHLOTHEIM 1822) MAI in MAI & GREGOR 1982
Seed, dorsal side. Stura di Lanzo near Nole Canavese, x9.
Fig. 12: *Vitis parasylvestris* KIRCHHEIMER 1940 *sensu* KIRCHHEIMER 1957
Seed, dorsal side. Stura di Lanzo near Nole Canavese, x11.
Fig. 13: *Sambucus bashkirica* DOROFEEV 1977
Seed. Momello near Lanzo, x14.5.
Fig. 14: *Sambucus pulchella* C. & E. M. REID 1915
Seed; the sculpture is finer than in *S. bashkirica*. Front, x14.5.
Fig. 15: *Paulownia cantalensis* (E. M. REID 1923) MAI in MARTINETTO 1995
Seed. Stura di Lanzo near Nole Canavese, x20.
Fig. 16-17: *Carex flagellata* C. & E. M. REID 1915
Fig. 16: achene. Stura di Lanzo near Nole Canavese, x14.
Fig. 17: utricle. Stura di Lanzo near Nole Canavese, x14.
Fig. 18: *Epipremnites reniculus* (LUDWIG 1857) GREGOR & BOGNER 1989
Seed. Stura di Lanzo near Nole Canavese, x17.
Fig. 19: *Scindapsites crassus* (C. & E. M. REID 1915) GREGOR & BOGNER 1983
Seed. Stura di Lanzo near Nole Canavese, x17.


1


2

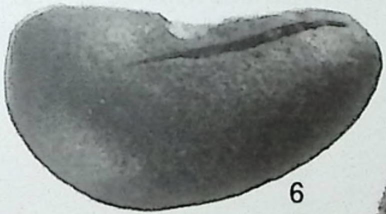

3

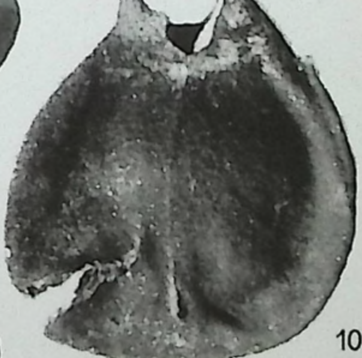

4


5


7


8


6

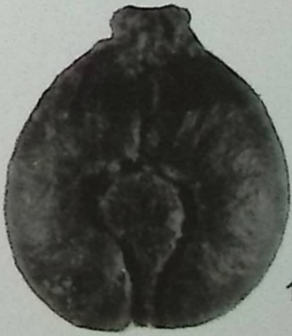

10


11


9

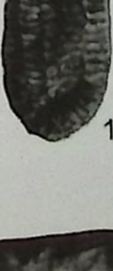

16


13


12


17


14


15


19


18

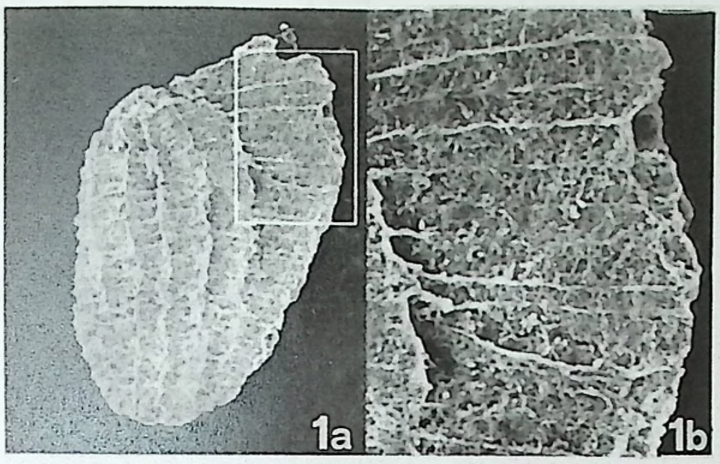
MA95-5 (MARTINETTO 1995, PLATE 5)

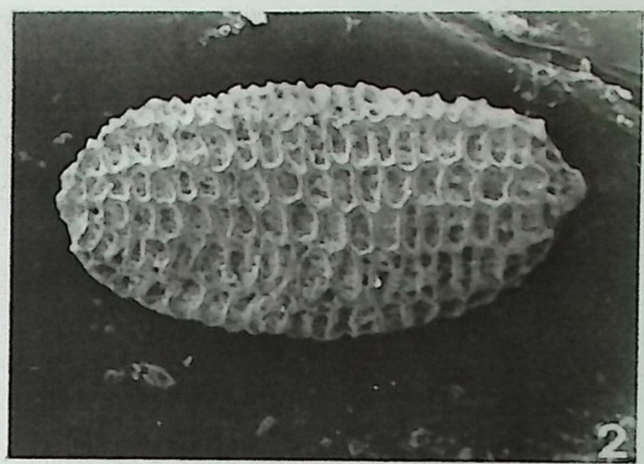
Fig. 1-3: *Paulownia cantalensis* (E. M. REID 1923) MAI in MARTINETTO 1995
  Fig. 1: seed with remain of the wing. Ca' Viettone near Levone Canavese, 1a: x35, 1b: x105.
  Fig. 2 and 3: seeds. Sento, bed S7, x49.

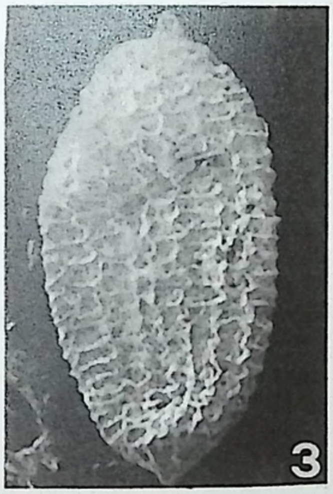
Fig. 4, 5: *Carpolithes cucurbitinus* MARTINETTO 1995
  Fig. 4a: seed or achene. Stura di Lanzo near Nole Canavese, x53.
  Fig. 4b: detail of the external sculpture of the same specimen. Stura di Lanzo near Nole Canavese, x 550.
  Fig. 5: holotype. Stura di Lanzo near Nole Canavese, x53.

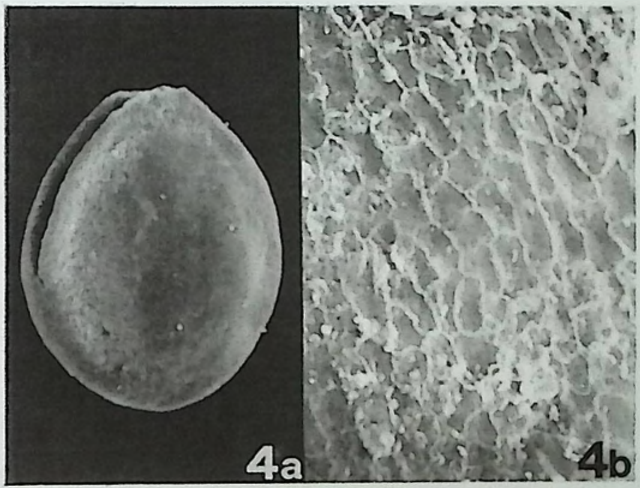
Fig. 6-8: *Carpolithes gratioloides* MARTINETTO 1995
  Fig. 6: holotype, seed. Baldichieri d'Asti, x70.
  fIg. 7: holotype, detail of the funnel-shaped beak. Baldichieri d'Asti, x260.
  Fig. 8a, b: seed with detail of the external sculpture. BA. 8a: x55, 8b: x440.

Fig. 9-11: *Carpolithes montioides* MARTINETTO 1995
  Fig. 9: holotype, seed in lateral view. Ronco Biellese, x45.
  Fig. 10: internal side of a seed valve. Ronco Biellese, x45.
  Fig. 11: seed in lateral view. Ronco Biellese, x45.


1a
1b

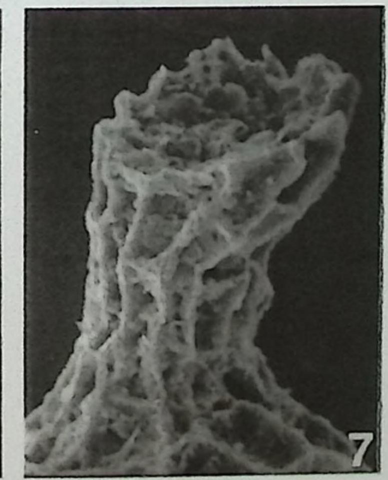

2

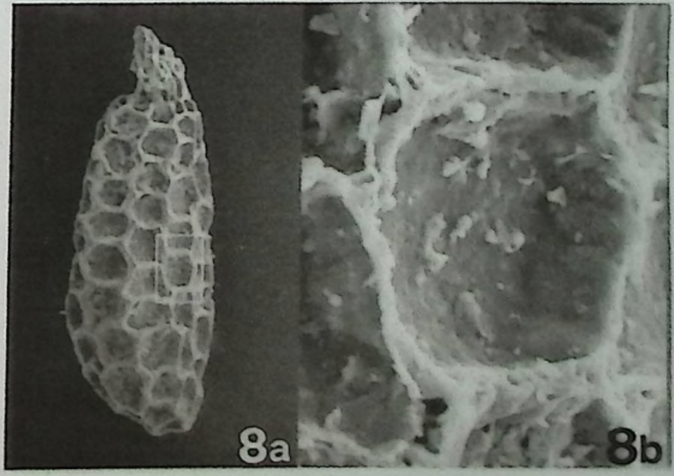

3

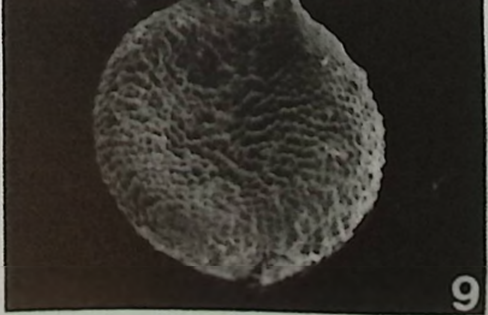

4a
4b

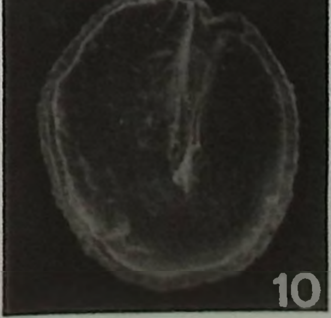

5


6


7


8a
8b


9


10


11

MA98-1 (MARTINETTO 1998, PLATE 1)

Figs 1-3. *Cephalotaxus* sp.
1, 2: seeds from the (?)Middle Pliocene deposit of Castelletto Cervo, northern Italy. 3: laterally compressed seed with mosaic-like structure of the external surface: Early Pleistocene deposits of Stirone, northern Italy (layer S7 of Gregor, 1986).

Fig. 4. *Cephalotaxus harringtonia* (Forbes) K. Koch.. Seed, Recent.

Fig. 5. *Cathaya van-der-burghii* Gossmann in Mai 1994
cone from the Candelo fossil site of northern Italy (Martinetto, 1995).

Figs 6-9. *Pseudolarix schmidtgenii* Kräusel 1925
6: mummified cone scale from the (?)Middle Pliocene deposit of Castelletto Cervo (4 m above layer GA1 of Martinetto, 1995, p. 64).
7, 8: impressions of cone scales from the Front fossil site, Middle Pliocene of northern Italy.
9: cone scale impression from the Sento fossil site, Early Pliocene of northern Italy.

Fig. 10. *Pseudolarix amabilis* (Nelson) Rehder. Recent cone scale, Villa Taranto Garden, northern Italy.

Figs 11-13. *Cryptomeria rhenana* Kilpper 1968
11, 12: seeds from the Ca’ Viettone fossil site, Early Pliocene of northern Italy. 11b: Detail of the seed surface.
13: cone from the Castellengo fossil site, Early Pliocene of northern Italy

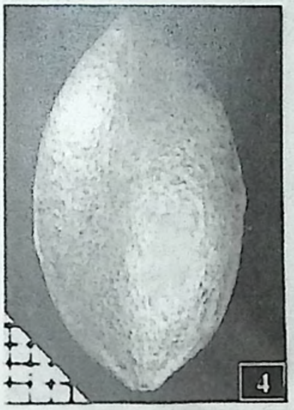
Fig. 14. *Cryptomeria* cf. *rhenana* Kilpper 1968. Twig fragment from the Lanzo fossil site, Middle Pliocene of northern Italy.

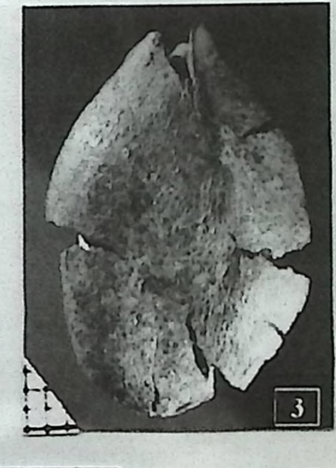

1

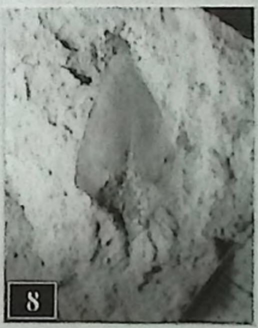

2


5


6


4

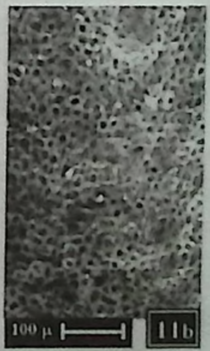

3


8


7


9

11a



11b


10


14

12


13

MA98-2 (MARTINETTO 1998, PLATE 2)

Figs 1-4. *Glyptostrobus europaeus* (Brongniart 1833) Unger 1850
1: cone, La Cassa, Middle Pliocene of northern Italy;
2: winged seed, Stura, Middle Pliocene of northern Italy;
3: wingless seed, Dunarobba, Pliocene of central Italy;
4: cone scale, La Cassa, Middle Pliocene of northern Italy.

Fig. 5. *Taiwania* sp.. Cone from the Middle Pliocene fossil site of Lanzo, northern Italy

Figs 6, 7. *Euryale nodulosa* C. & E. M. Reid 1915. Fossil seeds from the site of Buronzo in northern Italy (Martinetto, 1995), probably of Late Pliocene or Early Pleistocene age.
6: apical view of depressed specimen with hilum and embryotega;
7: lateral view.

Fig. 8. *Pseudoeuryale limburgensis* (C. & E. M. Reid 1908) Dorofeev 1972. Lateral view of a seed, Late Pliocene or Early Pleistocene of Buronzo, northern Italy.

Fig. 9. *Euryale ferox* Salisbury. Lateral view of a seed with hilum and embryotega. Recent, cultivated in the Botanical Garden of Genua, Italy.

Fig. 10. *Cyclea palatinati-bavariae* Gregor 1977. Seed from the fossil site of Valle della Fornace (Varese), Early Pliocene, northern Italy.

Fig. 11. *Sinomenium cantalense* (E. M. Reid 1920) Dorofeev 1963. Seed from the fossil site of Sento, Early Pliocene, northern Italy.

Figs 12-16. *Cyclocarya nucifera* (Ludwig 1857) Mai 1964. From the fossil site of Castelletto Cervo in northern Italy, Middle Pliocene.
12: endocarp in lateral view with equatorial ridge and exocarp remains, which testify the original presence of a wing;
13: endocarp in lateral view with equatorial ridge;
14: inner part of a half endocarp, showing the seed locule;
15: endocarp, lateral view;
16: deiscent endocarp, apical view;

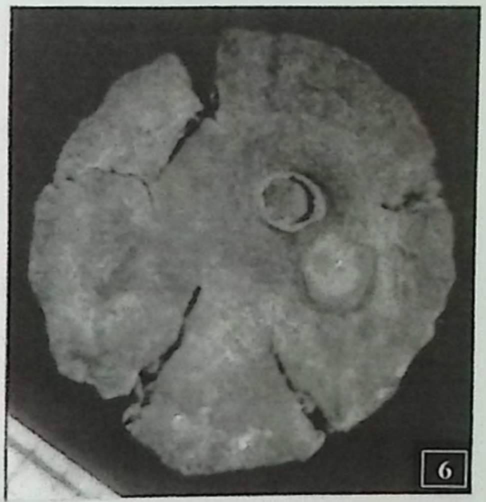

1


2


3

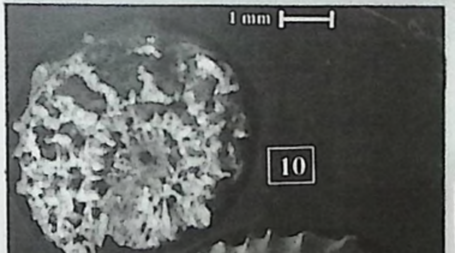

4

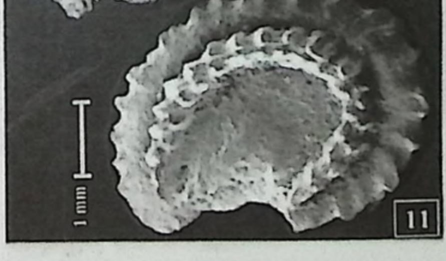

5

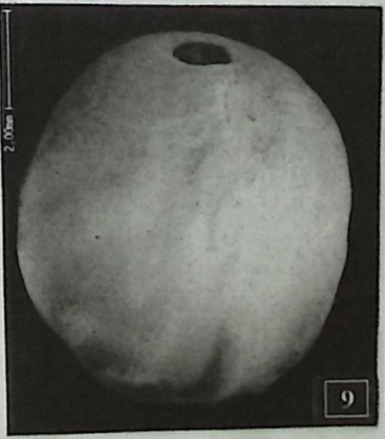

6

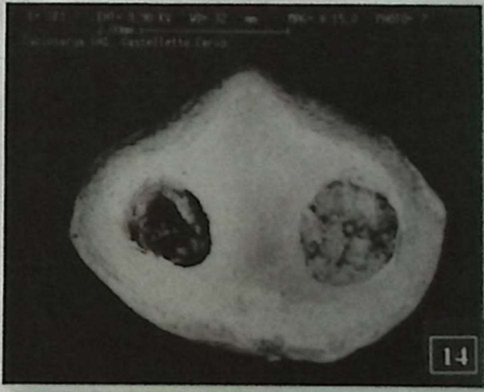

7


8


10


11

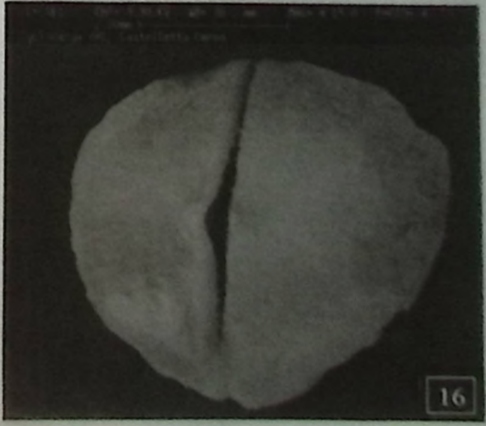

9


14


12


13


15


16

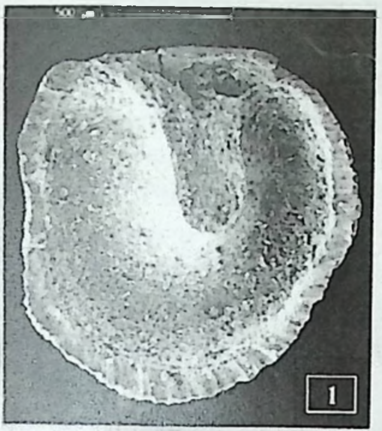
MA98-3 (MARTINETTO 1998, PLATE 3)

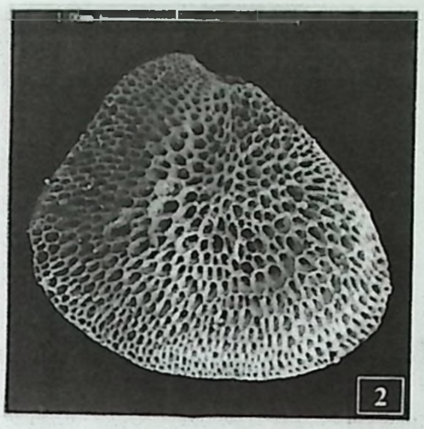
Figs 1-3. *Eurya stigmosa* (Ludwig 1860) Mai 1960
1: half a seed in internal view, Sento, Early Pliocene, northern Italy;
2 seed in lareal view, Ca' Viettone, Early Pliocene, northern Italy;
3: detail of the external surface of a seed, Valle della Fornace, Early Pliocene, northern Italy.

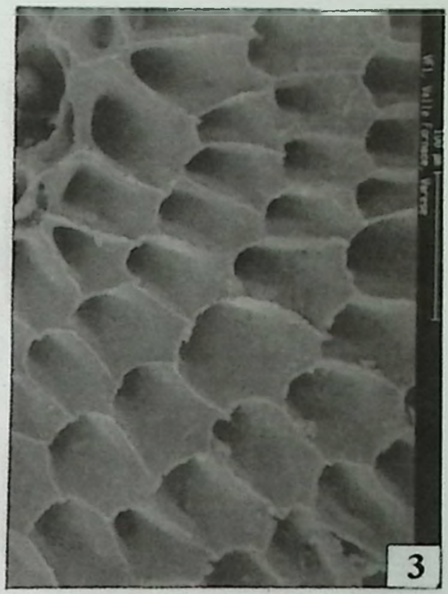
Figs 4, 5. *Actinidia faveolata* C. & E. M. Reid 1915. Seeds from Stura, Middle Pliocene of northern Italy.

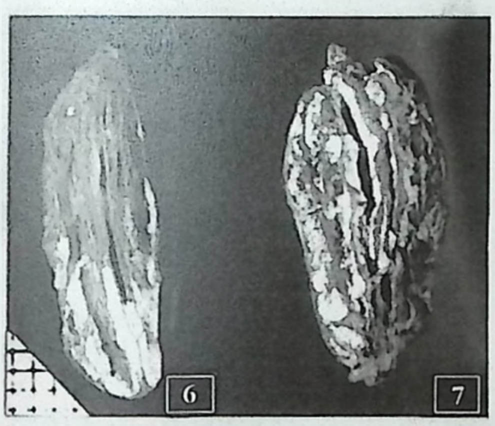
Figs 6-12. *Rehderodendron ehrenbergii* (Kirchheimer 1935) Mai 1970. Endocarps from the Candelo fossil site, Early Pliocene of northern Italy
6, 7: specimens in lateral view showing apparent longitudinal ridges;
8: endocarp with mesocarp remains;
9-12: cross-sections of endocarps enclosed in sandy silt, with three or two seed locules.

Fig. 13. *Mallotus* sp., from the Ca' Viettone fossil site, Early Pliocene, northern Italy.
13a: half a seed, view of the inner side;
13b: the same in lateral external view.

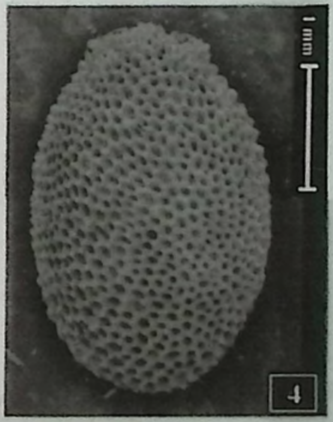

500 µm
1

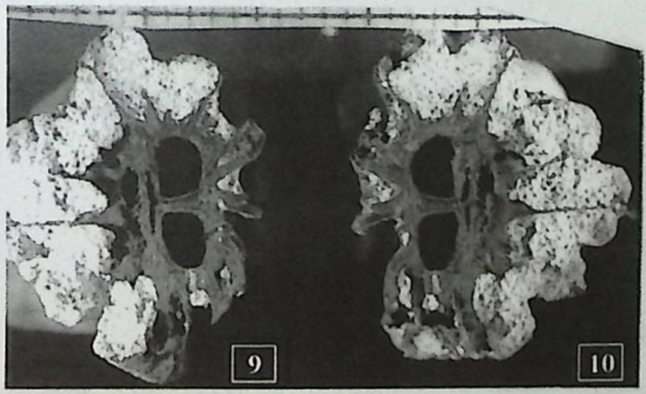

2


3

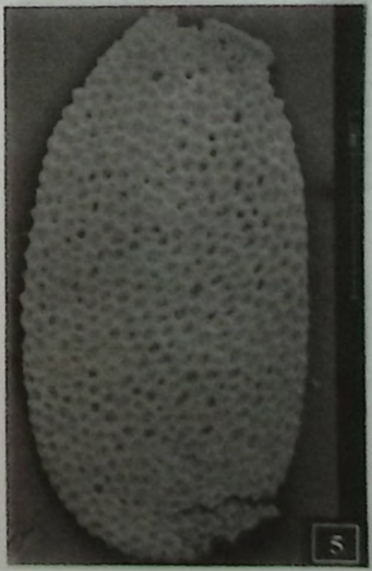

6
7

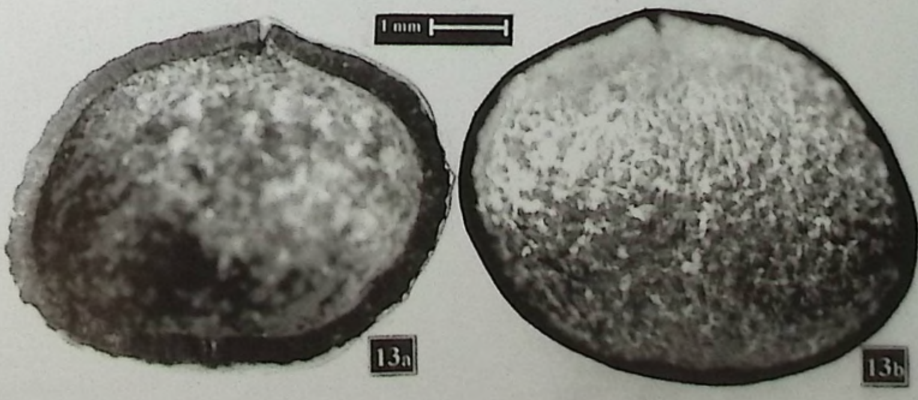

8


1 mm
4


9
10


11
12


5


1 mm
13a
13b

MA98-4 (MARTINETTO 1998, PLATE 4)

Figs 1-3. *Mallotus* sp.. Ca' Viettone fossil site, Early Pliocene, northern Italy.
1: seed in apical view;
2a: internal view of a seed divided into halves;
2b: detail of the seed wall of 2a with palisade cells curved at the base;
3: seed in basal view.

Figs 4, 5. *Phellodendron elegans* (C. & E. M. Reid 1907) C. & E. M. Reid 1915. Fossil seeds from the site of Buronzo in northern Italy, probably of Late Pliocene or Early Pleistocene age.
4: seed in lateral view;
5a: seed in lateral view;
5b: detail of the seed surface.

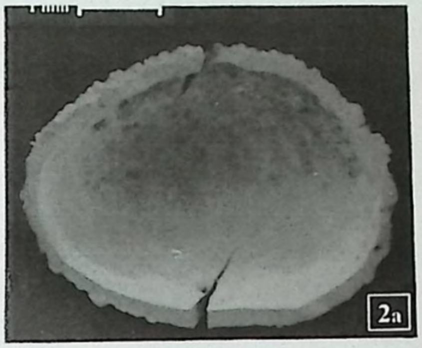
Fig. 6. *Sabia europaea* Czeczott & Skirgiello 1959. Endocarp in lateral view from Stura, Middle Pliocene of northern Italy.

Fig. 7. *Alangium deutschmannii* Geissert & Gregor 1981. Endocarp from Sento, Early Pliocene, northern Italy.

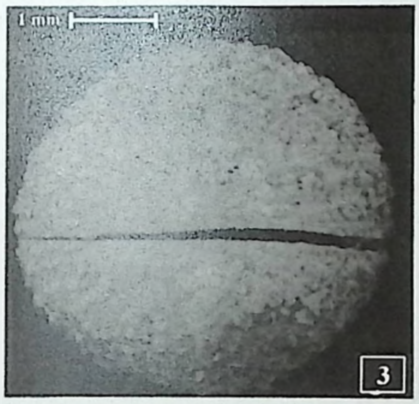
Figs 8, 9. *Paulownia cantalensis* (E. M. Reid 1923) Mai in Martinetto 1995.
8a: seed with wing remains;
8b: detail of the wing's venation.

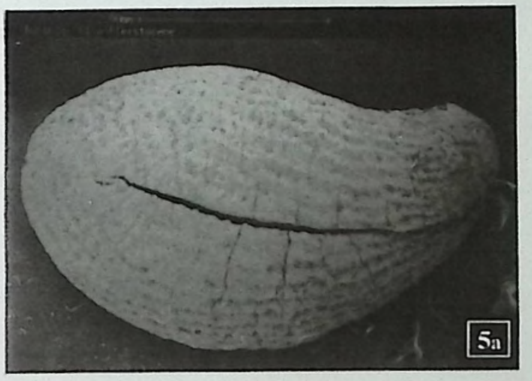
Fig. 10. *Epipremnites reniculus* (Ludwig 1857) Gregor & Bogner 1989. Stura, Middle Pliocene of northern Italy. Seed in lateral-ventral view.

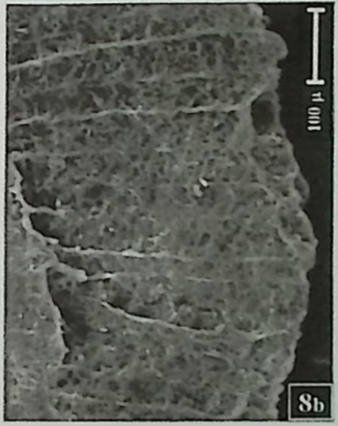

1 mm
1

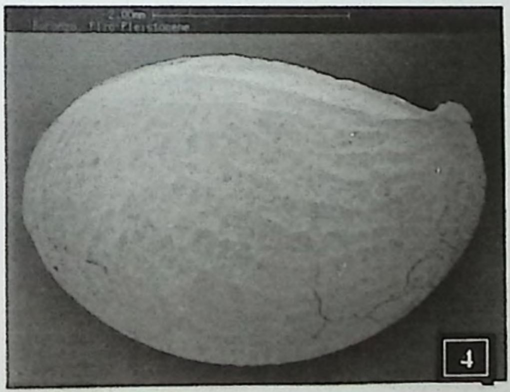

1 mm
2a

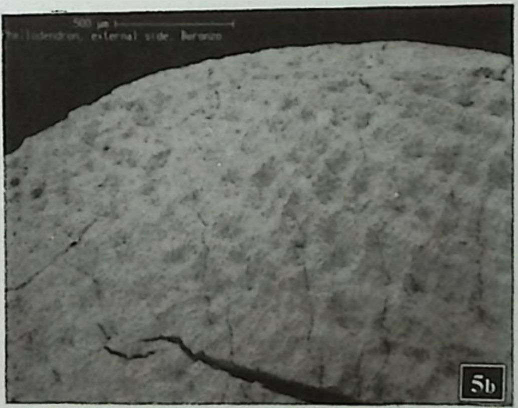

2b

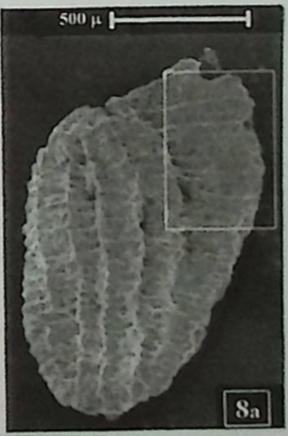

1 mm
3


Pleistocene
5a

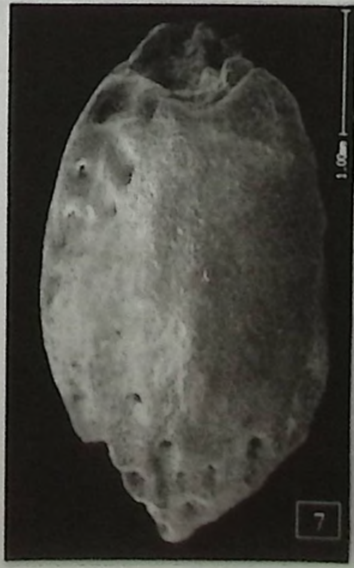

100 µ
8b

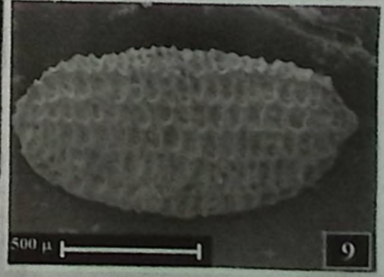

2.00mm
Plio-Pleistocene
4


500 µm
Phellodendron, external side, Beronzo
5b


500 µ
8a


1 mm
6


1.00mm
7


500 µ
9


10

MA-RA97-1 (MARTINETTO & RAVAZZI 1997, PLATE 1)

Selected fruits and seeds from the Valle della Fornace near Varese, Early or Middle Pliocene of NW Italy. Scale bar 1 mm.

Fig. 1a, b - *Cathaya van-der-burghii* Gossmann in Mai 1994. Cone seen from both sides.

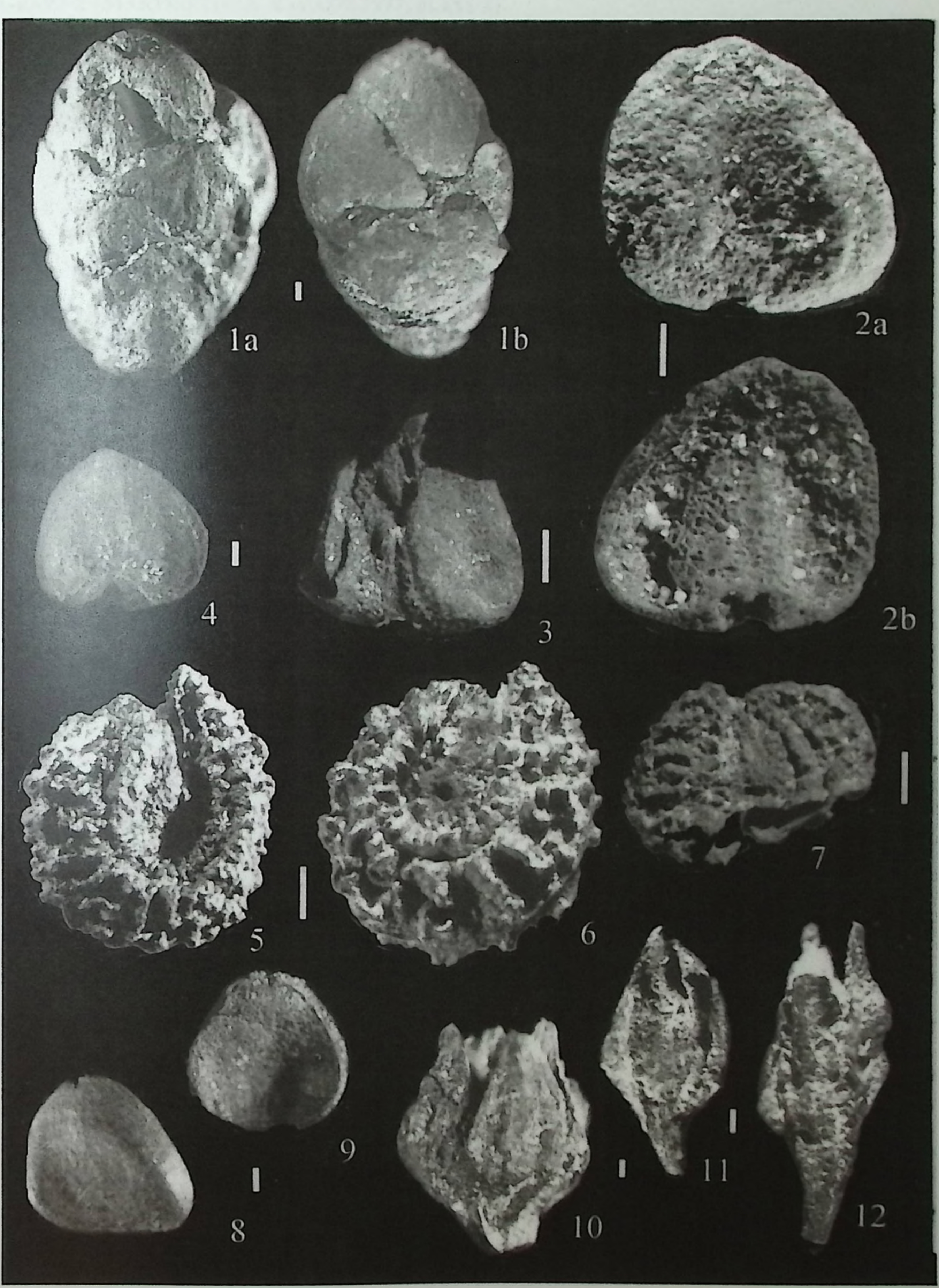
Figs 2, 3 - *Magnolia allasoniae* MARTINETTO 1995. 2a: split seed seriously damaged by grain imprints, external side. 2b: internal side. 3: basal part of a fragmentary seed, showing the typical ridges, apparent both inside and outside the seed.

Fig. 4 - *Magnolia lignita* (Unger 1861) Mai 1975. Internal side of a split seed, showing the broad chalaza at the base. The external side is totally smooth. Layer VF/e.

Figs 5-7 - *Cyclea palatinati-bavariae* Gregor 1977. Seeds of different shape.

Figs 8, 9 - ?*Gironniera* cf. *carinata* Mai 1970. 8. Endocarp in lateral view. 9. Internal view of a split endocarp.

Figs 10-12 - *Trigonobalanopsis exacantha* (Mai 1970) Kvacek & Walther 1989. 10. Four-lobed cupula. 11, 12. Three-lobed cupulas.


1a
1b
2a
4
3
2b
5
6
7
9
10
11
8
12

MA-RA97-2 (MARTINETTO & RAVAZZI 1997, PLATE 2)

Selected fruits and seeds from the Valle della Fornace near Varese, Early or Middle Pliocene of NW Italy. Scale bar 1 mm.

Figs 1-5 - *Pterocarya limburgensis* C. & E. M. Reid 1915. 1, 2. External side. 3, 4. Internal side of split specimens. 5. Apical view showing an endocarp partly split into two halves.

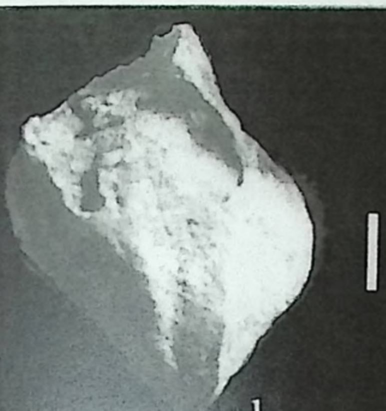
Figs 6-8 - *Toddalia rhenana* Gregor 1979. Seeds. 6, 7. Lateral view. 8. Ventral view.

Figs 9, 10 - *Meliosma* aff. *reticulata* (Reid) Chandler 1950. 9. Endocarp in lateral view. 10. Inner view of a split endocarp.

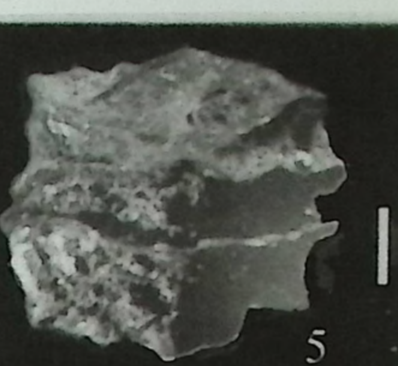
Fig. 11 - *Ampelopsis malvaeformis* (Schlotheim 1822) Mai in Mai & Gregor 1982. Seed.

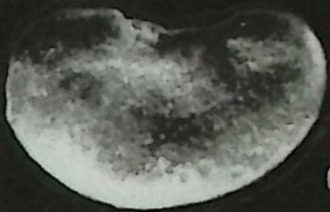
Figs 12, 13 - *Sambucus pulchella* C. & E. M. Reid 1915

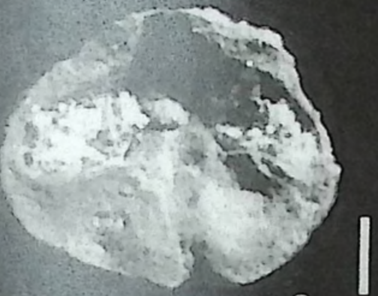
Fig. 14 - *Sapindoidea margaritifera* (Ludwig 1860) Kirchheimer 1936. Endocarp from both sides.

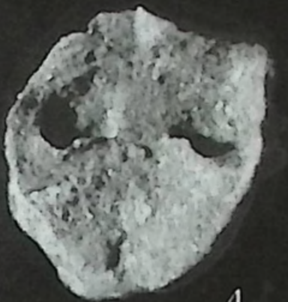

1


2


5

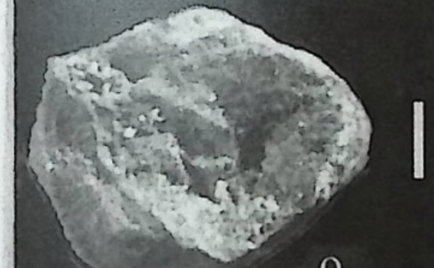

6

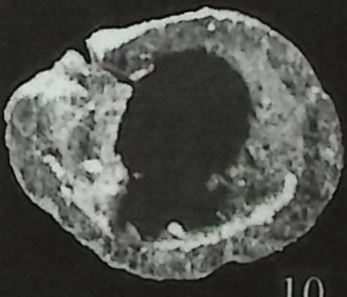

3


4


7


8


9


10


11


12


13


14a


14b

MA-RA97-3 (MARTINETTO & RAVAZZI 1997, PLATE 3)

Selected fruits and seeds from the Valle della Fornace near Varese, Early or Middle Pliocene of NW Italy. Scale bar 1 mm.

Fig. 1- *Myrica* cf. *altenburgensis* Kirchheimer 1938. Split endocarp. 1a. External side. 1b. Internal side.

Fig. 2 - *Coriaria* sp. Seed.

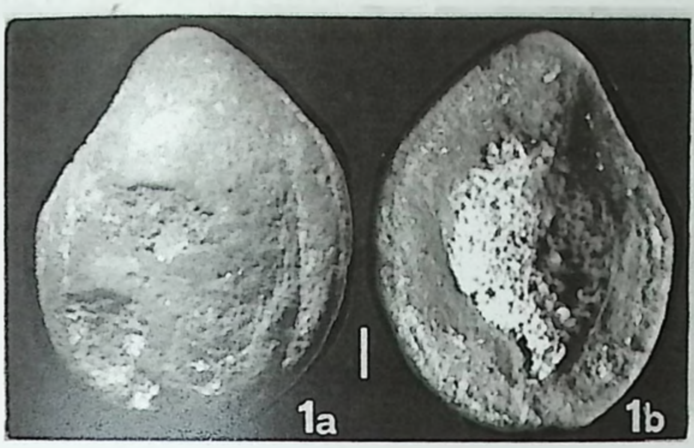
Figs 3, 4 - *Sinomenium cantalense* (E. M. Reid 1920) Dorofeev 1963. Seeds, layer VF/e.

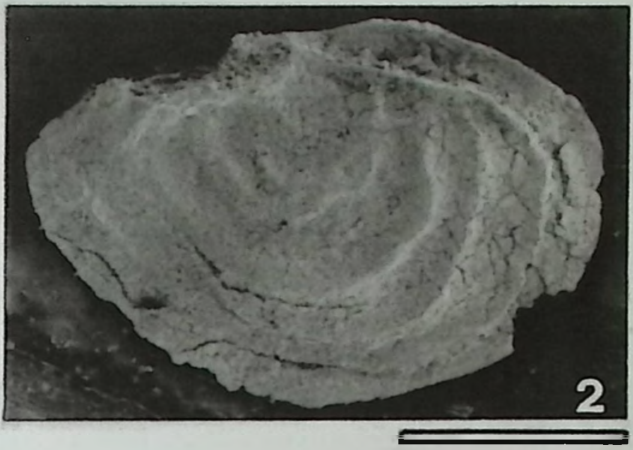
Figs 5, 6 - *Eurya stigmosa* (Ludwig 1860) Mai 1960. Seeds, layer S7. 5. Internal side of a split seed. 6: external side of a whole seed.

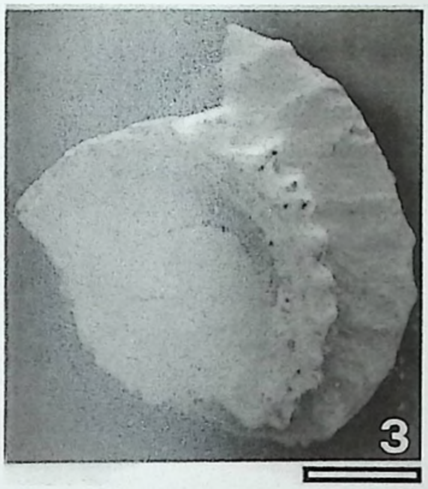
Fig. 7 - *Visnea germanica* Menzel 1913. 7a. This fruit is so deeply abraded to be unrecognizable, but it can be identified thanks to the typical structure of the seeds it contains (arrow). 7b. Detail of 7a showing a seed with elongated polygonal cells.

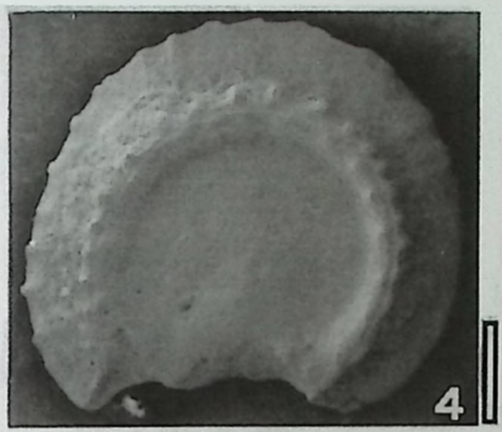
Fig. 8 - *Sambucus pulchella* C. & E. M. Reid 1915. Seed.

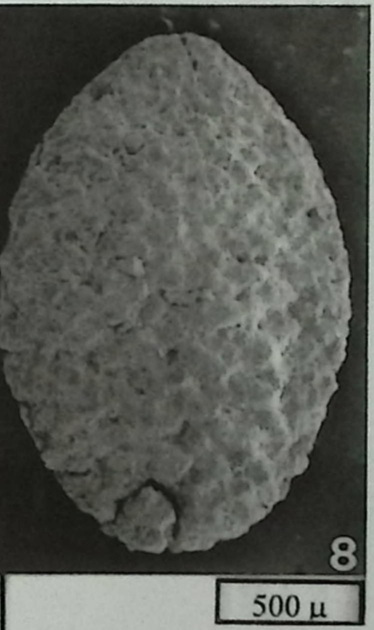
Fig. 9 - *Spirellea* aff. *bohemica* Knobloch & Mai 1984. Seed.

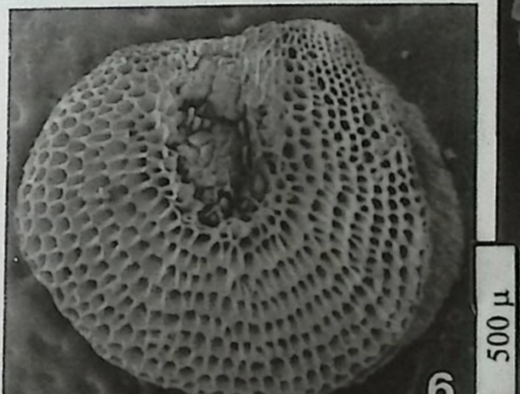

1a 1b

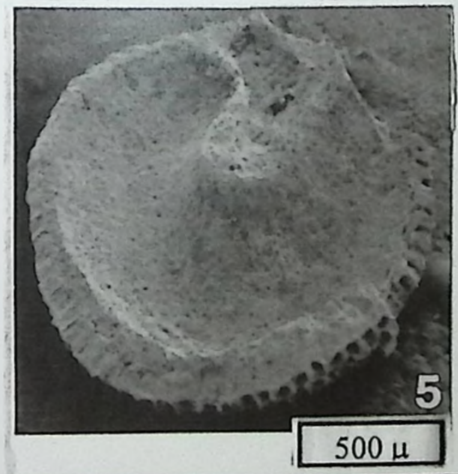

2


3


4

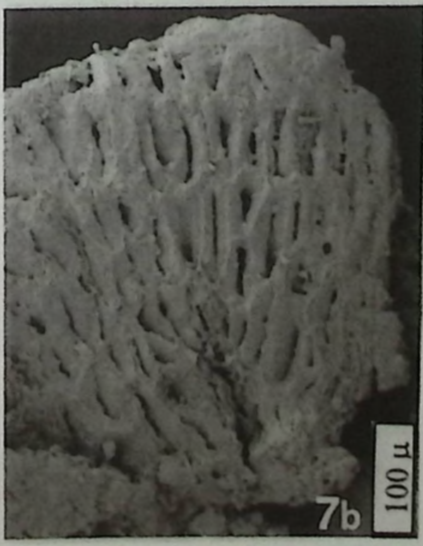

8


6


5


9


7a


7b

PA70-1 (PAVIA 1970, PLATE 1)

Bedding plane covered by leaf impressions, base of lithozone 1, Middle Pliocene of Arboschio near Asti, NW Italy, 0,4 x.

PA70-2 (PAVIA 1970, PLATE 2)

Fossil leaves and fruits from the Middle Pliocene of Arboschio near Asti, NW Italy.

Fig. 1: *Pteris ruppensis* HEER; lithozone 4. 0,95 x.

Fig. 2: *Pinus pinaster* SOLAND; lithozone 4. 1,05 x.

Fig. 3: *Zelkova crenata* SPACH; lithozone 4. 0,95 x.

Fig. 4: *Carpinus betulus* L.; lithozone 4. 0,95 x.

Fig. 5. *Zelkova* aff. *acuminata* PLANCK; lithozone 4. 1,1 x.

Fig. 6: *Fagus pliocenica* SAP., lithozone 4. 1,15 x.

1

2

3

4

5

6

PA70-3 (PAVIA 1970, PLATE 3)

Fossil leaves from the Middle Pliocene of Arboschio near Asti, NW Italy.

Fig. 1: *Fagus pliocenica* SAP., lithozone 4. 0,9 x.

Fig. 2: *Fagus pliocenica* SAP.; lithozone 4. 1,3x.

Fig. 3: *Ulmus plurinervia* UNG.; lithozone 4. 1,6x.

Fig. 4: *Populus tremula* L. (+ *Carpinus betulus* L.); lithozone 4. 0,8 x.

Fig. 5: *Carya* cfr. *minor* SAP.; lithozone 4. 1,1 x.

1

2

3

4

5

PA70-4 (PAVIA 1970, PLATE 4)

Fossil leaves and fruits from the Middle Pliocene of Arboschio near Asti, NW Italy.

Fig. 1: *Trapa natans* L.; fronte di cava 4, lithozone 4; sampled by Dr. F. GRASSO, Istituto di Geologia di Torino.

Fig. 2: *Cornus rubra* REHD.; lithozone 4. 1,05 x.

Fig. 3: *Taxodium distichum pliocenicum* GEY. & KINK.; lithozone 4. 1,3 x.

Fig. 4: *Acer decipiens* A. BR.; base of lithozone 1. 0,8x.

1

2

3

4

PA70-5 (Pavia 1970, plate 5)

Fossil leaves from the Middle Pliocene of Arboschio near Asti, NW Italy.

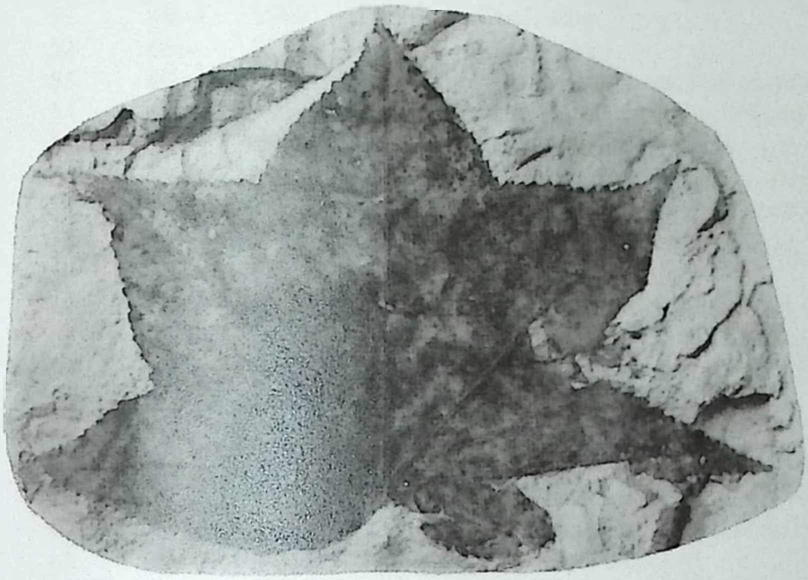
Fig. 1: *Liquidambar europaea* A. BR.: lithozone 4; 1,15x.

Fig. 2: *Platanus aceroides* GOEPP.; lithozone 4. 0,75x.

Fig. 3: *Oreodaphne heeri* GAUD., lithozone 4. 0,75x.

Fig. 4: *Oreodaphne heeri* GAUD.; lithozone 4. 0,65 x.

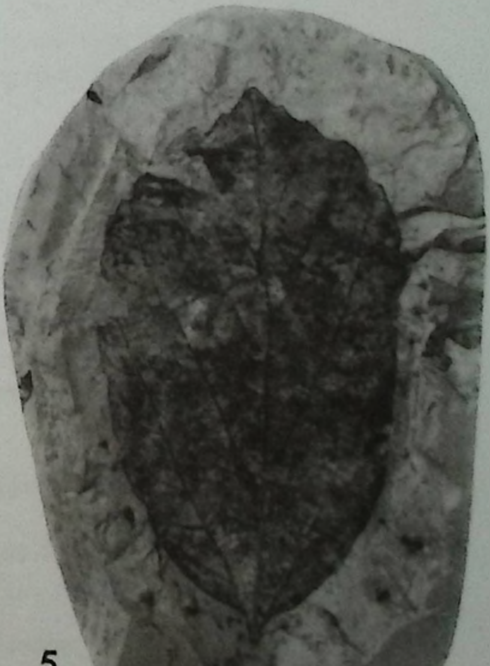
Fig. 5: *Parrotia fagifolia* (GOEPP.); lithozone 4. 1 x.


1


2


3


4


5