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Monographing the Pliocene and early Pleistocene carpofloras of Italy: methodological challenges and current progress

by

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With 3 plates, 4 text-figures and 1 table

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Abstract

The fruits and seeds unearthed from Pliocene and Early Pleistocene deposits of Italy sum up to millions of specimens from over 50 sites, which have not yet been treated in a comprehensive way. To make all the information contained in these palaeofloras accessible, a monographic investigation similar to those published by Dieter Hans Mai and Harald Walther will be needed; including a very detailed taxonomic and nomenclatural framework. The present paper is the first step towards a monographic investigation of the Pliocene and Early Pleistocene floras of Italy, limited to a thorough taxonomic and nomenclatural revision of the carpological material of 19 species belonging to the Pinaceae (*Picea florschuetzii*, *Pinus sylvestris* subsp. *plioaenica*), Betulaceae (*Carpinus betulus* subsp. 1, *Corylus avellana*), Cornaceae (*Cornus maii* sp. nov.), Eucommiaceae (*Eucommia europaea*), Fagaceae (*Quercus* cf. *robur*, *Fagus deucalionis*), Hamamelidaceae (*Parrotia* cf. *persica*, *Parrotia reidiana*), Hydrocharitaceae (*Stratiotes intermedius*), Juglandaceae (*Carya globosa*, *Cyclocarya nucifera*, *Pterocarya limburgensis*, *Juglans bergomensis*), Lamiaceae (*Ajuga antiqua*), Magnoliaceae (*Liriodendron geminata*), Menyanthaceae (*Menyanthes trifoliata*), and incertae sedis (*Carpolites pliocurbitinus* nom. nov.).

Several taxa unequivocally represent extinct species, often belonging to genera that disappeared from Europe. Other taxa, found to be morphologically very similar but not identical to modern European species, were either treated as extinct species or as fossil-subspecies of modern species. In various cases, the fossil record illustrates a morphological transition from the fruits and seeds of a fossil-taxon to those of a modern species. Only in two cases the fossil remains were considered identical to those of a modern species, since the morphology and its variation in the fossil assemblages were the same as that observed in several modern individuals and populations of that modern species. Finally, open nomenclature has been used for fossils with poorly diagnostic characters or represented by scarce material.

Key words: Carpoflora, taxonomy, Betulaceae, Cornaceae, Eucommiaceae, Fagaceae, Hamamelidaceae, Hydrocharitaceae, Juglandaceae, Lamiaceae, Magnoliaceae, Menyanthaceae, Pinaceae, nomenclature, Pliocene and Early Pleistocene, Italy.

Abbreviations: **BS** = biological species; **CENOFITA** = palaeobotanical (mostly carpological) collection of the Earth Sciences Department, University of Turin, and related database; **E** = "exotic" as intended in this paper, i.e. "Category E" taxa; **FS** = Fossil-species; **FSS** = Fossil-subspecies; **ICN** = International Code of Nomenclature for algae, fungi, and plants (Melbourne Code); **L:W** = length:width; **MfN** = Museum für Naturkunde of Berlin; **MCC** = Modern Carpological Collection, University of Turin (catalog number); **N** = "native" as intended in this paper, i.e. "Category N" taxa; **PU000000** = Catalog numbers of the Earth Sciences Department, University of Turin; **X** = "Category X" taxa, i.e. belonging to an extinct or unknown genus or infrageneric taxon.

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1. Introduction

The legacy of Dieter Hans MAI and Harald WALTHER includes several monographic works (e.g., MAI & WALTHER 1988, 1991), which are extremely rich in various types of information, with a strong focus on taxonomy and nomenclature. When studying rich late Cenozoic carpofloras in Italy, during the last three decades, the production of a "MAI & WALTHER-like" monograph has always been in the author's list of wishes. Actually, MAI & WALTHER used to combine leaves and carpological material in their monographs, whereas the sampling of the late Cenozoic Italian palaeofloras has been biased towards carpological remains, so that the most appropriate type of work to be planned would be similar to those of MAI (1964, 1999, 2000a, 2000b, 2001, 2004).

This paper represents a first step towards a monograph of the Pliocene and Early Pleistocene carpofloras of Italy but also illustrates the main challenges in planning such a monograph at present times. Several Italian collections contain Pliocene and Early Pleistocene carpological fossils, but they mostly represent just a few species selected for the larger size (mostly pine cones and nuts), thus providing a very partial picture of the palaeoflora. More representative collections of fossil fruits and seeds from the Pliocene and Early Pleistocene of Italy were made by MAI (1995a, plus unpublished material) at the Museum für Naturkunde of Berlin and by GREGOR (1986, 1990) at the Museum of Augsburg (collection GREGOR).

The present study is largely based on the extensive collection of all sorts of carpological remains from a large number of northern and central Italian sites that is housed at the Earth Sciences Department of the Turin University. Since the publication of MARTINETTO & VASSIO (2010) this collection and the linked database are named CENOFITA. Recently, the CENOFITA database was enlarged as to incorporate also records from other collections. This database demonstrates that the fruits and seeds unearthed from Pliocene and Early Pleistocene deposits of Italy sum up to millions of specimens. Thus, the major challenge of a monographic treatment possibly consists in the time-consuming examination of this very abundant material, also involving comparative studies with modern carpological samples in order to place each taxon into a correct systematic position, with an adequate nomenclature.

Rather than discussing these issues on a purely theoretical basis, the focus of the present paper is on practical examples concerning selected fruit and seed taxa found in the Pliocene and Early Pleistocene deposits of Italy (Text-fig. 1). Age constraints for such fossil floras have been provided mainly by marine biostratigraphy, magnetostratigraphy and vertebrate biochronology (see BERTOLDI et al. 1994; VEZZANI & GHISSETTI 1998; BOANO & FORNO 1999; MARTINETTO 1999, 2001a, 2001b; MAZZA et al. 2004; VIOLANTI 2005; MARTINETTO et al. 2007; MUTTONI et al. 2007, VIGNA et al. 2010; IELPI 2011; IRACE et al. 2012; MARTINETTO et al. 2015). The chronological subdivision of the Pliocene and Pleistocene, with the stages Zanclean, Piacenzian, Gelasian and Calabrian, follows GIBBARD et al. (2010).

Several Pliocene freshwater and marine sections have been sampled for plant macrofossils in different districts of Italy. These investigations provided over 30 local floras (partly shown in Text-fig. 1), mainly consisting of fossil fruits and seeds (BRAMBILLA 1984; GREGOR 1990; MARTINETTO 1994a, 1995; MAI 1995a; BERTOLDI & MARTINETTO 1995; CAVALLO & MARTINETTO 1996; MARTINETTO & MAI 1996; BASILICI et al. 1997; MARTINETTO & RAVAZZI 1997; FISCHER &

BUTZMANN 2000; CAVALLO & MARTINETTO 2001; MARTINETTO 2001a, 2001b; CIANGHEROTTI et al. 2007; MARTINETTO et al. 2007, 2014b, 2015; IRACE et al. 2015).

The Early Pleistocene fruit and seed floras, scattered throughout northern and central Italy, have been mainly described by SORDELLI (1874, 1896), TONGIORGI (1936, 1946), GREGOR (1986, 1990); CAVALLO & MARTINETTO (2001); MARTINETTO (2001a); GIROTTI et al. (2003); RAVAZZI et al. (2005); CHIARINI et al. (2009); GHIOTTO (2010); SADORI et al. (2010); MARTINETTO et al. (2012, 2014b, 2015); MARTINETTO & FESTA (2013).

The aim of this paper is to discuss previous taxonomic concepts and to show how the taxonomic frameworks for the studied species can be improved. The importance of collaboration between recent botanists and palaeobotanists will be emphasized throughout the paper. This work also constitutes an experiment that allowed the author to evaluate the difficulties and time requirements for the preparation of a monograph.

2. Methods

The work presented here started with the initial investigation of the CENOFITA collection (see Introduction). This collection is mainly organized in a systematic order, so that a comprehensive species box contains all the samples from different Italian localities (each one preserved in a small box with appropriate label). Such an organization of the samples, inspired by the Mai collection at the Museum für Naturkunde, Berlin, facilitates the comparison of materials of different geographic provenance and age. For the fossils of the CENOFITA collection which are not in systematic order (e.g., Steggio: GHIOTTO 2010), and for those stored in other collections, the CENOFITA database (MARTINETTO & VASSIO 2010) provides a reference point facilitating comparative taxonomic studies.

The selection of the species to be dealt with in this paper was based on the abundance of documentation, paired with the necessity to discuss taxonomic or nomenclatural problems emerged during recent observations (in particular: MARTINETTO & FESTA 2013). For the species selected, a thorough overview of the Pliocene-Early Pleistocene fossil material available from Italy has been carried out. Broad comparisons with modern and fossil materials were accompanied by a comprehensive literature search, covering palaeobotany, plant taxonomy and molecular phylogeny papers.

2.1. Preparation method

The palaeocarpological assemblages have usually been gathered by processing dry sediment samples with 3-5% hydrogen peroxide. After complete reaction, the floating fraction was sieved separately (final mesh size: 0.3 mm) from the sunken material (final mesh size: 1.5 mm). Finally, fruits, seeds and related parts (cones, cupules, megaspores, etc.) were picked up from the residue of both fractions; whenever possible, different layers in the same fossil site were sampled separately. Up to now more than 200 sediment samples (volume 1-30 dm³) have been analyzed from ca. 50 Pliocene and Early Pleistocene deposits of Italy.

2.2. Delimitation of species within the carpological material

In the monographic investigations of late Cenozoic carpological assemblages (e.g., REID & REID 1915; DOROFEEV 1963; FRIIS 1985; MAI & WALTHER 1988; NEGRU 1972, 1986; MAI 1999, 2000a, 2000b, 2001, 2004; CZAJA 2003; VELICHKIEVICH & ZASTAWNIAK 2003; NIKITIN 2006; MELLER 2011) most taxa were discussed and named at the species level. Therefore, when planning a similar

work, a brief discussion on the difficult matter of species concepts appears appropriate (e.g., WHEELER & MEIER 2000); here the focus is on the late Cenozoic carpological record. CRACRAFT (2000) pointed out that, in dealing with fossils [fruits and seeds included], we cannot help using a morphological species concept. However, this concept is not so far away from the biological species concept, whereas it differs substantially from the typological concept in that it considers variation. In palaeocarpology, variation has sometimes been taken into account when circumscribing species (e.g., *Pterocarya limburgensis* C.REID et E.REID 1915, see below), and throughout this paper the importance of variation as a guideline in the delimitation and identification of species will be highlighted.

Most of the terrestrial plant species of a modern flora can be identified on the basis of fruit and seed morphology alone (e.g., COLLINSON 1986; CAPPERS 1993; BOJŇANSKÝ & FARGAŠOVÁ 2007). So, also in the fossil assemblages, the morphological traits of most fruits and seeds are usually characteristic enough for a successful repartition of carpological remains into several species. However, the modern plants provide several problematic examples of poorly differentiated fruits (or seeds) which actually belong to different species (see JIMÉNEZ-MEJÍAS & MARTINETTO 2013). Conversely, there are cases of fossils that are extremely variable, but share common morphological traits suggesting a single species (see *Symplocos casparyi* R.LUDW. in MAI & MARTINETTO 2006). In this paper, whenever possible, the observed inter- and intraspecific variability of a large quantity of recent material has been used (as DIETER H. MAI did) to propose an appropriate solution to the separation of poorly differentiated species. Otherwise, for very variable forms with common morphological traits, the shared diagnostic characters and the presence of intermediate forms have been evaluated to determine that the fossil material belonged to a single ancient biological species.

2.3. Species identification

The carpological assemblages of Plio-Pleistocene age, due to the coexistence of "native" and "exotic" elements (see below), are difficult to treat from the point of view of both systematics and nomenclature. For each species it is necessary to evaluate whether it represents a fossil-species (ICN: MCNEILL et al. 2012) or a modern species. This involves exhaustive comparison of the material with previously described fossil-species and re-examination of nomenclatural types. At the same time, the morphological variability of modern species needs to be evaluated. The comparison of fossil fruits and seeds with those of the type specimens of modern species has very rarely been performed by the authors of palaeocarpological studies. One reason is the lack, scarcity or inadequacy of fruits and seeds on type herbarium materials. Therefore, palaeocarpologists often have been relying on the correct identification of modern samples in the reference carpological collections (MARTINETTO et al. 2014a) or in atlases and plant taxonomy papers.

Fossil material should be assigned to a modern species only when it corresponds to modern material, which is definitely conspecific to the nomenclatural type of that living species. Even if seed and fruit characters are more conservative than vegetative characters within a given species, a considerable intraspecific variation is usually seen in modern plant individuals and populations. Therefore, the morphological comparison of the fossils cannot be carried out with the fruits and seeds of the nomenclatural type alone (often not available or not accessible); rather it has to be extended to several correctly identified modern specimens that are useful to illustrate the variability of the species. In order to be assignable to a modern species, the fossil specimens have to conform with the modern species in all diagnostic characters (apomorphies and shared synapomorphies) and have to show the same or a very similar pattern of morphological variation.

This standard will also be used for the future revisions of the Italian Plio-Pleistocene carpological material. For the time being, it has been verified that all the species treated in this paper would meet such a standard. The available sources of correctly identified modern material used in this paper are represented by all the available taxonomic literature (hundreds of papers), atlases (e.g., BERGGREN

1969; KAC et al. 1965; VELICHKIEVICH & ZASTAWNIAK 2006, 2008) and reference carpological collections (mostly those of the Museum für Naturkunde of Berlin, label MfN and of the Turin University, label MCC). Critical revisions of modern material with the help of experts for a particular plant group have been particularly useful (see MARTINETTO et al. 2014a).

During the last two decades a large number of molecular phylogenetic studies have become available and their results must be considered before drawing conclusions on a morphological basis, without altering the results of morphological research. In this work, when a fossil was found to be morphologically similar to a modern species of a given genus, the available phylogenies have been consulted in order to verify whether such species was part of a clade, thus pinpointing a group of modern related species to be compared to the fossil. The phylogenies usually point out the existence of species whose seeds and fruits are not available in atlases and reference collections, nevertheless they could be similar to the fossils.

Since fruit morphology often is conservative, several species assigned to a single phylogenetic clade normally show similar fruit morphology (e.g., MOON et al. 2009; JIMÉNEZ-MEJÍAS & MARTINETTO 2013).

2.4. Nomenclatural procedures and philosophy

The nomenclature adopted in this work conforms to the ICN rules (MCNEILL et al. 2012), and the names selected at species level are either names for living plants or names for fossils (fossil-species, see Art. 1.2. of ICN). FOREY et al. (2004) point out that "the main difference between species named for living plants and those for fossils is that the former are based on a connected set of organs that approximate to a 'whole organism' whereas the latter are, for the most part, based on single organs and the nomenclature is designed to deal with this". Of course, a carpological remain is only a part of the plant and we do not know if the rest of the plant would conform in all its particulars to the diagnosis of a modern species. This issue has already been discussed extensively by COLLINSON (1986), who provided a good guide for the use of modern plant names for fossils. Furthermore, KVAČEK (2008) pointed out that "Some authors ascribe detached organs to independent morpho-species and morpho-genera [fossil-species and fossil-genera according to MCNEILL et al. 2012], some others to a single name of the composite taxon"; both choices are allowed by the ICN. So, when the connection of different parts of an ancient plant species is assessed under a "whole plant approach" (KVAČEK 2005), it is a taxonomical decision whether to use a single name (e.g., KVAČEK & MANCHESTER 2004) or several names (e.g., KVAČEK 2005).

In the European Cenozoic, the use of names for living plants or names for fossils has been generally different for three main categories of fossil carpological taxa, such as "native", "exotic" and "extinct" plants. Since these three categories have been used with different meanings, and are often misunderstood by non-palaeobotanists, in this paper they are re-defined and designated with the letters N, E, X (hereafter called "NEX" Categories). All the Categories are recognized at the level of genus or infrageneric group above the rank of species. Category N ("native" elements) refers to those fossil-species which can be assigned to a living plant genus (or infrageneric group above the rank of species) growing spontaneously in the studied territory, for this work indicated as the European continent, with the addition of the Euxinian (south of the Black Sea in north Anatolia) and Hyrcanian (south Caspian) areas and the exclusion of Macaronesia. Other fossil-species, here indicated as category E, can be assigned to genera growing today in other territories (continents), and in Cenozoic palaeobotany these have been called "exotic", following REID (1920). Of course the concept of "native" and "exotic" depends from the reference area: *Pterocarya* can be considered exotic for Italy, but native for Europe; *Parrotia* is exotic also for Europe, but in this paper is assigned to the N category because the Hyrcanian area is included in Europe sensu lato.

The third category, X, is represented by those fossil-species which cannot be assigned to living genera. This either implies that the modern relatives are still unknown or that they went extinct. For

a monographic treatment dealing with hundred of taxa it would be convenient to maintain a distinction between those that are clearly extinct versus those that have an unknown taxonomic position. Within category N, those species that exhibit "a diagnostic suite of characters all of which fall within the range of variation of comparable parts of a modern species and are also unique to that species" (COLLINSON 1986) can indeed be considered conspecific with the modern species. However, in this work a modern species name has been assigned to a fossil carpological species only when the morphology, and its variation in the fossil assemblage, was the same as that observed in the same carpological parts produced by several individuals and populations of the recent species. When fossil material, obviously belonging to the category N, did not conform to the case above (see below for *Cornus*), two possible options have been selected: the use of open nomenclature or the adoption of a fossil-species name, based on a fossil type. Fossil-species names have been used by some authors also for sets of fossils which shared the characters of several modern species ("Sammelart" of MAI & WALTHER 1991). For category X, the species are necessarily named by using a fossil-species name, based on a fossil type. For category E species, the use of modern plant names of far-away territories, occasionally practised in past works (REID & REID 1915: *Nyssa sylvatica* MARSHALL; SZAFER 1954: *Juglans cinerea* L., *Pseudolarix amabilis* (NELS.) REHD., etc.), is too presumptive and rarely seen in recent European monographic treatises (e.g. MAI 1999, 2000a, 2000b, 2001; CZAJA 2003; NIKITIN 2006; VELICHKIEVICH & ZASTAWNIAK 2006, 2008). Therefore, in this work only fossil-species names have been used for category E species. This choice may not be rigorous enough, as we cannot exclude that some species of remote phylogenetic origin (e.g., *Ginkgo biloba* L., *Pseudolarix amabilis*), which occur today outside Europe, may have been growing in this continent during past times. However, very accurate studies on both fossil and modern materials of these taxa would be needed to demonstrate such cases. The recent, consistent increase of comparative studies on late Cenozoic fossils and modern plants in East Asia (e.g., BHANDARI et al. 2009, HUANG et al. 2012, ZHANG et al. 2015) definitely provides new opportunities for the insertion of the "exotic" carpological taxa of Europe into a more accurate taxonomic and phylogenetic framework.

The use of names of modern species has been reserved for the fossil materials of category N, and the word "*fossilis*" was not applied after the species name (e.g., *Corylus avellana* L. *fossilis*), as discussed below. Conversely, it was followed the suggestion by COLLINSON (1986), repeated by FOREY et al. (2004), to place relevant information aside the Linnean binomial, after the author name, e.g.: [fruit - BS], [fruit - FS], etc., where BS means biological species name, and FS means fossil-species name.

The use of a fossil-species name was applied in these three cases:

1. the fossil material was assigned to a modern genus, and compared with material of all the available modern European (sensu lato) species of that genus, but it was not found to be totally identical to any of them (e.g., *Cornus maii* sp. nov.), or showed a different variability (e.g., *Pterocarya limburgensis*);
2. the fossil material was assigned to a modern genus, but it was not possible to compare it to all of the modern European species; the morphology or its variation was different from all the investigated species (e.g., *Ajuga antiqua* C.REID et E.REID);
3. the fossil material was compared with all the available modern European plant material, without finding a good correspondence to any genus, thus representing category E or X (e.g., *Eucommia europaea* MÄDLER, *Carpolites pliocurbitinus* nom. nov.).

Open nomenclature was used for species of all the three "NEX" categories when the morphological agreement with the nomenclatural type was insufficient, sometimes due to scarcity or bad preservation state of the studied material. As the ICN (MCNEILL et al. 2012) does not regulate open nomenclature, BENGTON (1988) was used as a guide (e.g., for the use of "cf.", different from "aff.!). This author does not mention the use of "vel", a Latin term used since long time to express that the material belongs either to the first named species or to the second (e.g., *Ajuga antiqua* vel *A. reptans*).

3. Systematic part

The description of the studied material is provided only when it is necessary to point out novelties or differences from what is reported in the literature, otherwise appropriate references are provided. The occurrences are listed according to an alphabetical order of localities, as reported in Table 1. Reference to the sampled layer (e.g., Baldichieri-Fornace-BA1) is reported by using the hyphenated label of the CENOFITA database (MARTINETTO & VASSIO 2010) after the locality name. The specimens figured in Plates 1-3 are deposited in the CENOFITA collection of the Earth Sciences Department of the Turin University. Catalogue numbers of particular specimens are reported with the label **PU** followed by 6 numbers.

Gymnospermae

Pinaceae SPRENG. ex F. RUDOLPHI 1830

Picea A. DIETR. 1824

The morphological types of *Picea* cones are illustrated by MAI (1995b), who reported a repartition into a Morinda-type (i.e. similar to *P. smithiana* (WALL.) BOISS., the Morinda Spruce) and a Cascita-type. In the Plio-Pleistocene of Italy only the Morinda-type occurs. According to MAI (1994) and MAI & PALAMAREV (1997) there are a few species documented by fossil cones in Europe: *P. beckii* MAI, *P. florschuetzii* HAMMEN, *P. heissiana* FRITSCH/*P. omoricoides* C. A. WEBER and *P. rotundae-squamosa* R. LUDW.

No remains (either cones or needles) of *P. abies* (L.) KARST are known to occur in the Pliocene of Italy, and their first dated occurrence seems to be in the late Early Pleistocene (RAVAZZI et al. 2005; Ranica).

Phylogenies: see BOUILLE' et al. (2011) and LOCKWOOD et al. (2013).

Picea florschuetzii HAMMEN 1951 [cones - FS]

Pl. 1, Fig. 1

Description: See VAN DER HAMMEN (1951) and MAI (1994): the rounded cone scale apex, large dimensions, and high number of scales are diagnostic characters.

Remarks: This species was described on the basis of fragmentary cones from Tegelen in The Netherlands (Early Pleistocene: Gelasian). The first complete cone was figured by MAI (1994) with the locality indication "Millepioppi bei Stirone; Coll. Gabriele 1986". The collector was probably Gabriele QUARANTELLI, who unearthed several plant fossils from the Stirone section in the 1980s and deposited his material in a small Museum at Salsomaggiore (Museo Paleontologico Il Mare Antico). Later, cones with an identical morphology occurred abundantly in the Castelletto Cervo II locality (CAVALLO & MARTINETTO 2001) and a few individual cones occurred in other sites listed below.

MAI (1994) already pointed out the similarity of the fossil cone he described and the modern ones of *P. smithiana*. Further comparison of the Castelletto Cervo II cones with a modern sample of *P. smithiana* (MCC0870) did not point out any relevant difference. On the other hand, *P. abies* (MCC0842) and *P. orientalis* (L.) LINK (MCC0868) have a bifid or obtuse cone scale apex, and *P. omorika* (PANČ.) PURK. (MCC0042) has shorter cones with lower number of scales. For this reason the fossil cones permit a definite assignment to the clade III of LOCKWOOD et al. (2013), including

only Asian and American plants, and in particular the very similar *P. smithiana*. However, due to the criteria selected for the plants of the category E (see above), the fossil-species name *P. florschuetzii* has been applied, also because a more careful study of all the clade III species, including anatomical and seed morphological characters, should be carried out before assigning this fossil material to a species now growing outside Europe.

"NEX" category: E (referred to clade III of *Picea*: LOCKWOOD et al. 2013).

Occurrence in the studied sites: The material in the CENOFITA collection is from Arda-Castell'Arquato (1 cone at ca. 80 m in the section of MARTINETTO et al. 2015), Enza-Traversetolo-EZ20 (1 cone), Castelletto Cervo II (GA5 and GA21, 24 cones), Poggio Rosso-MT5 (1 cone). Other collections: Stirone-Laurano-LA1 (1 cone, MAI 1994, Salsomaggiore Museum, missing), one cone from Poggio Rosso (coll. Accademia Valdarnese del Poggio, Montevarchi) and possibly another (abraded) from Fighille (Centro Studi sul Quaternario of Sansepolcro: BALDANZA & SPIRITO 2010).

Chronological distribution in Italy: The record of Castelletto Cervo II is probably of Gelasian age, that of Poggio Rosso dates to the latest Gelasian (MAZZA et al. 2004); the others are referred to the Calabrian.

Pinus L. 1754

Pinus sylvestris L. subsp. *pliocaenica* KINK. 1908 emend. MAI 1994 [cones - BS, FSS]

Synonyms:

?1908 *Pinus* cf. *sylvestris* L. *pliocaenica* KINK. in ENGELHARDT et KINKELIN, p. 202, pl. 24, fig. 6.

1985 *Pinus* cf. *halepensis* MILL. vel. *P. cf. brutia* TEN. – GREGOR, p. 31, pl. 2, fig. 1.

1994 *Pinus sylvestris* L. subsp. *pliocaenica* KINK. emend. MAI, pp. 211-212, pl. 7, figs 6, 7.

Pl. 1, Fig. 2

Description: MAI (1994) pointed out that the most important characters of the cones of *P. sylvestris* subsp. *pliocaenica* are the length below 4 cm (the type was 4.15 cm long: ENGELHARDT & KINKELIN 1908; the 5 Italian specimens studied are 2.5-3.7 cm long), the lack of the hook formation in the lower scales and the apparent elevation of the umbo in the vaulted middle scales. This description was probably based mostly on the two specimens from Stirone-Laurano (Calabrian, Italy) figured by him, since the holotype from Niederrad was lost during World War II (V. Wilde, pers. comm. 2004), so that only the images of ENGELHARDT & KINKELIN (1908) were available. MÄDLER (1939, p. 31), who was the last to investigate that cone, seemed to doubt about its fossil state. For an overview of the fossil record of *P. sylvestris* see MAI (1984).

MARTINETTO & FESTA (2013, pl. 1, fig. 3) assigned to *P. sylvestris* subsp. *pliocaenica* a cone from the Italian locality Castelletto Cervo I, of supposed Piacenzian age. This cone (3.7 cm long) has the same shape as the small-sized cones of *P. hampeana*, a fossil-species reported by MAI (1994) in the Italian Pliocene. It can be distinguished for the smaller apophyses and prominent, broader and not vallate umbos (Pl. 1, Fig. 2).

Remarks: MAI (1994) considered a fossil cone from the Pliocene of West Germany (ENGELHARDT & KINKELIN 1908, pl. 24, fig. 6) and two cones from the Calabrian of Northern Italy as showing only small differences in comparison to the modern *P. sylvestris*, thus assigning them to the fossil-subspecies *Pinus sylvestris* L. subsp. *pliocaenica* KINK. [*Pinus* cf. *sylvestris* L. *pliocaenica* KINKELIN" in ENGELHARDT & KINKELIN 1908]. In addition to the cones from the Stirone-Laurano-LA1 site studied by MAI (1994), a third Italian cone was figured in a preliminary paper by GREGOR (1985, pl. 2, fig. 1), and a fourth one (PU105917) is stored in the CENOFITA collection. A fifth cone from the Arda-Castell'Arquato-AD9 site (MARTINETTO et al. 2015), close to Stirone-Laurano-LA1 and almost contemporaneous, is present in the CENOFITA collection. A sixth cone is that from Castelletto Cervo I, cited above (Pl. 1, Fig. 2), which is accompanied by two other cones from

the same layer. No relevant differences have been noticed among these 8 Italian cones in the outline, dimensions, number and shape of scales, and particularly in the excentromucronate umbo with a small and erect mucro. The determination of other 3 cones from the Enza-Traversetolo-EZ30 (Calabrian) requires further analyses.

A recent request to the Fidenza and Salsomaggiore Museums did not permit to locate the specimens figured by MAI (1994), but a more accurate search will be carried out in the future. However, the 8 cones cited above are here regarded as belonging to the same taxon, and provide some information on the cone variation, which is important for the comparison with the German assemblages. Unfortunately, the variation of *Pinus sylvestris* subsp. *plioaenica* in the type locality (Niederrad, Germany) cannot be assessed because only the holotype was known. However, GEYLER & KINKELIN (1887, pl. 1, figs. 4, 6, 7) and ENGELHARDT & KINKELIN (1908, pl. 24, fig. 5c) figured other similar cones from the same locality, and assigned them to *P. montana* MILL. *fossilis* GEYL. ET KINK. or to *P. ludwigii* SCHIMP. One of these cones (GEYLER & KINKELIN 1887, pl. 1, fig. 7: *P. ludwigii*) is nearly identical to the cone from the Arda-Castell'Arquato-AD9 site. The problem is that MAI (1985) synonymized *P. montana* MILL. *fossilis* GEYL. et KINK. with another fossil-species related to *P. sylvestris*, i.e. *Pinus brevis* R.LUDW., whose type is from the locality Dornhassenheim (Germany, not far from Niederrad: LUDWIG 1857, MAI 1973), where again a single cone is known. In the meantime he did not revise *P. ludwigii* SCHIMP. (= *P. oviformis* R.LUDW.), also reported at Niederrad, and only the use of the brackets in his dichotomic key suggests that he believed this was a synonym of another valid species (*P. brevis*?). Possibly MAI (1985) did not want to put forth a too hazardous hypothesis for the taxonomic assessment of a rich cone assemblage (from Niederrad) that was no more available for further analyses, and whose details (umbo fine morphology) were not so clearly documented by GEYLER & KINKELIN (1887) and ENGELHARDT & KINKELIN (1908).

In the last revision of such material MÄDLER (1939) lumped some species and assigned individual cones to 4 species, related to *P. sylvestris* (*P. brevis*, *P. askenatii* GEYL. et KINK., *P. ludwigii*, *P. sylvestris*), sometimes rejecting the previous interpretations by ENGELHARDT & KINKELIN (1908). MAI (1985, 1994) still accepted for the Niederrad assemblage at least two of that species: *P. brevis* (possibly including also *P. askenatii* and *P. ludwigii*) and *P. sylvestris* subsp. *plioaenica*. Assessing the variation and the diagnostic characters of such two species would be crucial for their recognition in other sites. The intraspecific variation of *P. brevis* is shown by several other records from the Pliocene of Germany (in particular from the Rüterberg site), listed and partly figured by MAI (1985). *P. brevis* indeed occurs at Niederrad, and the question is only if the cone assemblage of that locality really permits to separate two species of *Pinus*, both related to *P. sylvestris*. The rejection of this hypothesis would automatically invalidate the name *P. sylvestris* subsp. *plioaenica*, which would be synonymized with *P. brevis*.

Now we come to the Italian material: the German sets of cones assigned to *P. brevis* can be easily differentiated from the 8 Italian cones cited above by the larger (mostly 4 to 6 cm vs 2.5 to 3.7 mm long), more broadly ovate cones, with more numerous scales. Therefore, the Italian material is clearly distinct from *P. brevis*, but corresponds to at least one specimen of the *P. sylvestris* group from Niederrad. This situation provides support to the hypothesis (MAI 1985, 1994) that at Niederrad at least 2 species of the *P. sylvestris* group occur. Therefore, in this paper the name *P. sylvestris* subsp. *plioaenica* is still considered valid and applied to the Italian fossils, but it is also highlighted that further research on Pliocene cones of the *P. sylvestris* group in the West German type area are badly needed in order to point out the characters and the variation of *P. sylvestris* subsp. *plioaenica*.

Another question is the separation of *P. sylvestris* subsp. *plioaenica* from *P. sylvestris* sensu stricto. MARCYSIAK & BORATYNSKI (2007) pointed out a large intraspecific variability of cone morphology in the modern *P. mugo* TURRA, *P. uliginosa* G.E.NEUMANN ex WIMM., *P. sylvestris* and *P. uncinata* RAMOND ex DC. The observation of several samples of the foregoing modern species in the MCC, carried out for this work, confirmed that cone shape and size are very variable within each species. Also the detailed observations carried out on the umbos (a very important

character: MAI 1985) of the modern cones revealed a broad variation in single cones. However, a general pattern was observed in *P. sylvestris*: umbo flat or much reduced in the basal scales, never sunk; in the middle scales the umbo is generally rhombic-pyramidal, avallate, occasionally very prominent; the mucro is commonly not developed, but when present it is small and denticulate, eccentric in the apical part of the umbo. These details agreed very well with those observed in the Italian fossils. However, as a whole, the set of the 8 fossil cones can be differentiated from the modern cone sets of *P. sylvestris* for the following characters: smaller mean length, more broadly ovate outline, more rounded scale apices, length of the apophyses nearly corresponding to the width. Indeed, more accurate studies on the variation of fossil cone sets, in comparison to the modern ones, are badly needed. Yet, the morphological differences so far observed in the Italian fossil cones are confirmed as meaningful for the distinction of a fossil-subspecies, and it must be pointed out that in other cases an analogous situation even led to the description of a fossil-species (see below for *Ajuga* and *Pterocarya*).

"NEX" category: N.

Occurrence in the studied sites: In the CENOFITA collection there are 3 cones from Castelletto Cervo I-GA3, and individual cones from Arda-Castell'Arquato-AD9 and Stirone-Laurano-LA3. Other 3 cones from Enza-Traversetolo-EZ30, still under investigation, are more broadly ovate and can be identified as *P. brevis* vel *P. sylvestris* subsp. *plioaenica*. The cone from the Stirone-Laurano site which was figured by GREGOR (1985, pl. 2, fig. 1) is stored at the Fidenza Museum of Fossils. More abundant material of *P. sylvestris* subsp. *plioaenica* is to be located at the Salsomaggiore Museum, including the specimens figured by MAI (1994).

Chronological distribution in Italy: The sure records are from a site of supposed Piacenzian age, and from two sites of the late Calabrian.

Angiospermae

Betulaceae GRAY 1822

Carpinus L. 1753

Carpinus betulus L. 1753 subsp. 1 [fruits - BS, FSS]

Pl. 1, Figs 3a-b, 4a-b

Synonyms:

1900 non *Peucedanites lommelii* KINKELIN, p. 134-136, figs 1a-c.

1908 *Carpinus betulus* L. *fossilis* - ENGELHARDT & KINKELIN, p. 232, pl. 8, fig. 10.

1947 *Carpinus betulus* L. *fossilis* - SZAFER, p. 63-64, pl. 5 figs 14-15.

Description: the features of this proposed new subspecies are those described for the well-studied Pliocene fruits from Kroszowice, Poland (SZAFER 1947; JENTYS-SZAFEROVA 1960, 1961). On the basis of the identical characters detected in the Polish and Italian fossil fruit assemblages (Buronzo, Casnigo, Castelletto Cervo II, Steggio, Stura Fossil Forest), *Carpinus betulus* subsp. 1 can be distinguished from the living *Carpinus betulus* by its smaller fruits, mostly 2.5 to 4.6 mm long, 1.9 to 5.2 wide, with length/width ratio mostly from 1.1 to 1.4, less obtuse apical angle (80-150°, mean 115-120°), and thinner wall. A good reference specimen was illustrated by SZAFER (1947, pl. 5, fig. 15).

Remarks: *Carpinus* nuts found in several Italian fossil sites of the Pliocene and Early Pleistocene (see below) distinctly show a longitudinally costate endocarp and therefore can be only compared to *C. betulus* among all living species (JENTYS-SZAFEROVA 1960). In addition, they have a range of dimensions (2.5 to 5.1 mm long, 2.1 to 5.2 mm wide) very similar to the Pliocene set of fruits from

Kroszcienko (Poland), assigned to *Carpinus betulus* by JENTYS-SZAFEROVA (1960, 1961). The fossils of *Carpinus* with distinct similarities to the modern *C. betulus*, including leaves, involucra and fruits, are extremely abundant in the late Cenozoic of Europe, and can be considered well-known, being treated in several papers (e.g., JENTYS-SZAFEROVA 1958, 1960, 1961; NEGRU 1969; DOROFEEV 1982; ZASTAWNIAK & WALTHER 1998; MAI 2001). We focus here on the fruit characters for which the situation in western-central Europe is rather clear: the fossil fruits are identical to the modern *C. betulus* in the Middle Pleistocene, whereas from the Early Pleistocene (GHOTTO 2010) to the Miocene (MAI 2001) they show the same morphology, but smaller mean dimensions (JENTYS-SZAFEROVA 1960; but see BIALOBRZESKA 1964 for alteration of size in fossils). The nomenclature used to describe this situation is not consistent. For example, NEGRU (1969), DOROFEEV (1982) and KOVAR-EDER (1988) used fossil-species names for *Carpinus betulus*-like fruits and/or involucra, e.g.: *C. moldavica* NEGRU in DOROFEEV 1982 (replacement name for *C. miocenica* NEGRU 1969), *C. bresciana* P.I.DOROF. 1982, *C. pannonica* P.I.DOROF. 1982, *Carpinus pyramidalis* (GOEPPERT 1852) GAUDIN et STROZZI 1858. Among these, *C. pyramidalis* should not be used for fruits and involucres (the type is a fossil leaf), unless in a whole-plant concept (KVAČEK 2005). Also VELICHKIEVICH (1982) erected a new fossil-species for the smaller fruits of the Early Pleistocene of Bielorrussia, *Carpinus betuloides* VELICHKIEVICH, but this name is invalid, since *C. betuloides* UNGER 1845 has priority.

However, is there really a sufficient basis to treat the slightly smaller *Carpinus betulus*-like fossils as a separate species? Most of the other authors had a different opinion and preferred to assign the Miocene-Early Pleistocene fossil fruits to *Carpinus betulus*, often attaching the word “*fossilis*” (e.g., MAI & WALTHER 1988; ZASTAWNIAK & WALTHER 1998; MAI 2001), that in the concept of SZAFER (1947) would mean that the fossils are similar, but not identical to the living species.

This case is really intricate for the use of an appropriate nomenclature; we must balance the need to trace back the modern species with the risk to provide a misleading modern name that can alter the phylogenetic analyses. By using such a name we can also overlook the importance of fruit size as possibly indicating a taxon which is different from the living one, as already suggested by JENTYS-SZAFEROVA (1960, 1961). The agreement in the dimensions of the Polish (SZAFER 1947; JENTYS-SZAFEROVA 1960, 1961) and Italian Pliocene-Early Pleistocene fruits (particularly abundant in the sites of Buronzo, >200 fruits, and Steggio, >500; see below for other localities) point to the presence of the same taxon in northern and southern Europe, as also confirmed by other records in Germany (e.g., MAI & WÄHNERT 2000). The differences of such fossil fruits from those of the modern *Carpinus betulus* seem to be significant for the separation of a fossil-taxon below the rank of species, here indicated as a subspecies.

By looking into the literature it seems impossible to select a good basionym for this Pliocene-Early Pleistocene taxon, whose characteristics have been well illustrated by SZAFER (1947) and JENTYS-SZAFEROVA (1960, 1961). Too many names have been validly published in East Europe, as summarized in DOROFEEV (1982). Only the name *Peucedanites lommelii* KINKELIN 1900 can be excluded as a candidate basionym for such late Cenozoic fossil-subspecies of *Carpinus betulus*, because the measures provided by KINKELIN (1900, p. 135: length 6.5-7.1 mm) point to the modern *Carpinus betulus*, so that KINKELIN's fruits can be suspected to be non-fossil material, mixed-up with the real Pliocene fossils of the Untermaintal (lower Main valley, Germany: material lost during World War II, pers. comm. V. Wilde, 2005). Therefore, waiting for further studies on the East European material, it is necessary to keep the open nomenclature *Carpinus betulus* L. subsp. 1.

"NEX" category: N.

Occurrence in the studied sites (CENOFITA collection, *Carpinus betulus* subsp. 1): Arda-Castell'Arquato-AD3, Arboschio (PAVIA 1970), Barbania-FN5, Boschi di Barbania, Breolungi-BR3-BR5, Buronzo (BU5, BU14: abundant), Ca' Viettone (CV3, CV5), Casnigo-CG2, Castellengo-TC1, Castelletto Cervo I (GA1, GA3), Castelletto Cervo II (GA5, GA21), Castelnuovo Don Bosco, Cortiglione d'Asti, Canale d'Alba, Crava di Morozzo I, Dunarobba-DU20, Marecchia-MR3, Momello-Lanzo-MO2 (moderately abundant), Pian Torinetto-CH1, Pocapaglia, Santa Barbara

Gregor's outcrop-SB6, Sento I-CH35, Sento II (BG3, BG7), Sezzadio-Rio della Lupa, Steggio (abundant), Stura Fossil Forest, Valle della Fornace-VF1, Valleandona-VD2, Villafranca d'Asti-RDB6. In most localities less than 5 fruits have been recovered.

Other collections: Lefte-LF11 (Caffi Museum of Bergamo).

Chronological distribution in Italy: The fossil data assess a long-lasting presence of *Carpinus betulus* sensu lato in the studied area from the latest Miocene (Messinian: CAVALLO et al. 1986), throughout the whole Pliocene (PAVIA 1970; MARTINETTO 1994a; CAVALLO & MARTINETTO 1996, 2001; MARTINETTO et al. 2015), the early Pleistocene (MARTINETTO & SAMI 2001; GHIOTTO 2010; MARTINETTO et al. 2015), the Middle Pleistocene (MARTINETTO 2009), to the Holocene (e.g., TONGIORGI 1936, VASSIO 2012). Unequivocal records of *Carpinus betulus* subsp. 1 are those of Pliocene and Early Pleistocene age, but the fruits, which are usually overrepresented in modern carpodeposits (GEE 2005, VASSIO & MARTINETTO 2012), are abundant only in two Early Pleistocene localities (Buronzo-BU14, Steggio). This suggests that in the Pliocene *Carpinus betulus* subsp. 1 was an uncommon plant, though broadly distributed.

Corylus L. 1753

Corylus avellana L. 1753 [fruits - BS]

Pl. 1, Figs 5a-b

Description: See GEYLER & KINKELIN (1887), SZAFER (1947) and MAI & WALTHER (1988). *Corylus* nuts found in several Pliocene and Early Pleistocene sites in Europe are very similar to those of the modern European populations of *C. avellana*. The fossils just show deeper longitudinal grooves, but this is possibly an effect of the partial decay and compression.

Remarks: GEYLER & KINKELIN (1887) described in detail the variation of fossil nuts found in several European sites, also citing the Italian localities of Lefte, Pianico and Re. They listed several fossil-species names published by previous authors which should not be considered distinct from *Corylus avellana* L. (as repeated by MAI & WALTHER 1988). Even if GEYLER & KINKELIN (1887) put the word “*fossilis*” after the name “*Corylus Avellana* L.” it is clear from the text that they did not see any difference between the fossil and the modern fruits, and they did not intend to describe an infraspecific entity. Therefore, in this case (unlike *Carpinus betulus*), there is no reason to formalize a subspecies.

ERDOGAN & MEHLENBACHER (2000), FOREST & BRUNEAU (2000) and BASSIL et al. (2013), who dealt with the molecular phylogeny of *Corylus*, agree for the recognition of 11 modern species. The Italian fossils have been compared with fruits of 8 of the 11 species, and only *C. avellana* corresponded. According to BASSIL et al. (2013) *C. avellana* includes also other European populations that had been considered separate species (*Corylus maxima* MILL., *C. pontica* KOCH, and *C. colchica* ALB.). The other European species (*C. colurna*) did show significant morphological differences as for the shape and dimensions of the nut and extension of the basal scar (attachment of the involucre). So the fossils exhibit a diagnostic suite of characters all of which fall within the range of variation of comparable parts of modern *C. avellana* and are also unique to this species.

"NEX" category: N.

Occurrence in the studied sites. CENOFITA collection: Arda-Castell'Arquato-AD3, Buronzo-BU14 (abundant), Casnigo-CG1/CG2, Castelletto Cervo I-GA6, Castelletto Cervo II (GA5, GA21), Cerro Tanaro, Cherasco-CHS34, Front-FR1, Momello-Lanzo-MO2, Pocapaglia, Steggio, Torre Picchio-PI1, Stura Fossil Forest, Villafranca d'Asti-RDB6 (abundant).

Other collections: Lefte-LF11, Caffi Museum of Bergamo.

Chronological distribution in Italy: Fruit impressions already occur in the Messinian (CAVALLO et al. 1986). Compressed fruits are rare in the Zanclean (Pocapaglia) and more frequent from the

Piacenzian to the Calabrian. The Middle-Late Pleistocene fruits (Pianico, Botro Maspino) are identical to the Piacenzian-Calabrian ones.

Cornaceae DUMORT. 1829

Fossil-species of Cornaceae in the Cenozoic of Europe have been described by HARTZ (1909), ZABŁOCKI (1930), DOROFEEV (1955, 1965, 1969, 1988), CHANDLER (1961), SZAFER (1961), NEGRU (1972, 1986), VELICHKIEVICH (1973), MAI (1976), MAI & GREGOR (1982).

NEGRU (1986), DOROFEEV (1988) and MAI (in MAI & GREGOR 1982) assigned some bilocular, elliptic to ovate and often somewhat flattened Cenozoic fossil fruits to the genus *Swida* OPIZ 1838. This genus is no longer accepted, since EYDE (1987), in recent morphological (WOŹNICKA et al. 2014) and phylogenetic works (XIANG et al. 2006), so that all the fossil-species of *Swida* are here recombined to *Cornus*, if not already published elsewhere:

Cornus bessarabica (NEGRU 1972) comb. nov. (basionym *Swida bessarabica* NEGRU 1972, p. 144-147, pl. 28, figs 1-12; text-ill. 37);

Cornus bugloviana (NEGRU 1972) comb. nov. (basionym *Swida bugloviana* NEGRU 1972, p. 149-151, pl. 30, figs 1-12; text-ill. 39);

Cornus discimontana (MAI in MAI et GREGOR 1982) comb. nov. (basionym *Swida discimontana* MAI in MAI et GREGOR 1982, Neue und interessante Arten aus dem Miozäne von Salzhausen am Vogelsberg, pp. 413-414, pl. 19, figs 1-8; text-ill. 5);

Cornus krauselii (GEISSERT, GREGOR et MAI 1990) comb. nov. (basionym *Swida krauselii* GEISSERT, GREGOR et MAI 1990, Die "Saugbaggerflora" eine Frucht- und Samenflora aus dem Grenzbereich Miozän - Pliozän von Sessenheim im Elsass (Frankreich), pp. 55-56, pl. 13, figs 1-3; text-ill. 5);

Cornus roshkii (NEGRU 1972) comb. nov. (basionym *Swida roshkii* NEGRU 1972, p. 147-148 pl. 29, figs 1-10; text-ill. 38);

Cornus rotundata (P.I.DOROF. 1988) comb. nov. (basionym *Swida rotundata* P.I.DOROF. 1988, Miocene Floras of the Tambovsk territory, p. 157, pl. 36, figs 13-16; text-ill. 37, figs 1-8).

Also *Dendrobenthamia* is not accepted in the current taxonomy of Cornaceae, which imposes the following new combination:

Cornus tegeliensis (MAI 1976) comb. nov. (basionym *Dendrobenthamia tegeliensis* MAI 1976, *Dendrobenthamia tegeliensis* nov. sp. – ein neues ostasiatisches Florenelement im Altquartär Europas., p. 114-115, pl. without number, figs 1-6).

Cornus L. 1753

Cornus maii sp. nov. [fruits - FS]

Pl. 1, Figs 6a-b, 7-9; Text-fig. 2.

Synonyms:

1994b *Swida gorbunovii* (P.I.DOROF.) NEGRU - MARTINETTO, pl. 1, figs 8, 9.

2014b *Cornus* aff. *anomum* MILL. - MARTINETTO et al., pl. 1, fig. 3.

Material used for the description of the new species: PU105901 - PU105916 endocarps from layer CV3 of the Ca' Viettone site.

Holotype: Pl. 1, Fig. 7. PU105902.

Figured paratypes: Pl. 1, Figs 6, 8-9; text-fig. 2. PU105901, PU105903-PU105916.

Type locality: Ca' Viettone near Levone Canavese (Turin province), NW Italy.

Type stratum: the single fruit-bearing layer in section 3 (MARTINETTO 1995, p. 33), indicated by the label CV3.

Age: Surely not older than Zanclean (MARTINETTO 2001b), and supposed to be late Zanclean (Early Pliocene), but not yet demonstrated by non-palaeobotanical data.

Etymology: Dedicated to DIETER HANS MAI, who had seen these fossils, and suggested that they could represent a new species.

Diagnosis (terminology according to WOŹNICKA et al. 2014): Endocarp bilocular, 3.7-6.2 mm long, 3.7-4.8 mm wide, ca. 2 mm thick, minimum L:W ratio = 1.10, maximum L:W ratio = 1.68, laterally flattened or intermediate, not furrowed on sides. Apical cavity absent; vascular bundles raised, surface rough, conspicuously irregularly ribbed, apex usually shortly acuminate, base short- or long-acuminate to cuspidate, or bluntly acute or wedge-shaped.

Remarks: The endocarps of *C. maii* sp. nov. share most characters with *C. amomum* MILL., but probably were slightly more flattened laterally. This compression has been much enhanced by post-burial sediment load, and only a single specimen transversely cut by animals was filled by sediment and better preserved the original endocarp thickness (ca. 2 mm). The thickness provided in the diagnosis is exclusively referred to this specimen (Pl. 1, Fig. 8). The other specimens, compressed during fossilization, never exceed 1 mm of thickness. The elevation of the ribs and the shape show a consistent variation, in particular at the apical and basal ends (Text-fig. 2).

These endocarps had been assigned to *Cornus gorbunovii* P.I.DOROF. 1955 by MARTINETTO (1995). However, the observation of the original material (Komarov Botanical Institute, St. Petersburg) in October 2013 showed that the Italian fossils are morphologically distinct from the types of *Cornus gorbunovii*.

Most probably the fruits described as "*Swida* sp." by DOROFEEV (1988, pl. 36, figs 10, 11) belong to *C. maii*. Additionally, some specimens of *C. maii* from Ca' Viettone slightly resemble *Clematis uralensis* P.I.DOROF. 1970a (3-4 x 2.8-3 mm), but the fruits of that species are definitely smaller and have a different pedicellate base. The other species described by DOROFEEV (1955, 1965, 1969b, 1988), CHANDLER (1961), SZAFER (1961), NEGRU (1972, 1986), VELICHKIEVICH (1973), MAI & GREGOR (1982) and GEISSERT et al. (1990) are readily distinguishable. *Cornus salinarum* ZABŁOCKI 1930, due to the loss of the original specimen (see ŁAŃCUCKA-ŚRODONIOWA & ZASTAWNIAK 1997), should be considered a problematic name to be abandoned.

The results of the accurate investigations of WOŹNICKA et al. (2014) suggest that *C. maii* sp. nov. does not correspond completely to any living species, and represents an extinct form, possibly to be positioned on the clade of *C. amomum* (BW clade II: XIANG et al. 2006): However, the poorly raised vascular bundles and the shape of the base of some endocarp specimens still approach the morphology of the modern species of the BW clade III.

"NEX" category: N (referred to the genus *Cornus*, as the infrageneric placement is not sure).

Occurrence in the studied sites (CENOFITA collection): Ca' Viettone-CV3 (moderately abundant), Castelnuovo Don Bosco, Cava Toppetti I-TP1, Dunarobba (DU1, DU10, DU20, DU21, DU23, DU25; more than 200 specimens: MARTINETTO 1994b; MARTINETTO et al. 2014b), Front-FR1, Roatto, Sento II-BG3.

Chronological distribution in Italy: This species occurs in northern Italy in two possibly Zanclean sites (Ca' Viettone, Sento II) and three Piacenzian ones; in central Italy only in sites of uncertain, Piacenzian or Gelasian age.

Eucommiaceae ENGL. 1907

Eucommia OLIV. 1890

Eucommia europaea MÄDLER 1939

Pl. 1, Figs 10, 11.

Description: See BAAS (1932), MÄDLER (1939), SZAFER (1952, 1954), KIRCHHEIMER (1957). None of the 21 compressed fruit specimens sampled in Italy so far preserved the winged margin of the samara. A specimen with complete wing, drawn by GREGOR (1986), is an impression on a yellowish silt (Fidenza Museum of Fossils). The compressed fossil fruits consist of the endocarp covered by a network of fine, brown to golden coloured, latex filaments that still retain their elasticity. The capitate termini of such filaments, as described by CALL & DILCHER (1997) have been observed at high magnification.

Remarks: The shape of the fruit remains, the dimensions, and particularly the dense cover of elastic latex filaments bearing capitate termini warrant the assignment to *Eucommia*. The figured fruits from Castelletto Cervo II (Pl. 1, Figs 10, 11) perfectly correspond in preservation and structure to those of the German locality Schwanheim, figured by BAAS (1932). Although SZAFER (1961) suggested that two species occurred in the Neogene of Europe, the distinction was only based on fruit size, and TRALAU (1963) reported that fruit size varies considerably in the single living species *E. ulmoides* OLIV., depending on the ecological conditions. Also KVAČEK et al. (2008) noted that the *Eucommia* fruits from the Pliocene of Alsace, treated by them as "*Eucommia* sp.", were larger than in the living *E. ulmoides*. These had already been assigned to *E. europaea* by GEISSERT (1987, pl. 3, fig. 11), and actually GEISSERT's determination can be confirmed here, because all the fruits so far described from the Pliocene and Early Pleistocene of central-southern Europe seem to be very uniform, and can be assigned to a single species whose valid name is *E. europaea* (MANCHESTER et al. 2009).

Occurrence in the studied sites: GÜNTHER & GREGOR (1990) listed this species for the Santa Barbara Gregor's site. In the CENOFITA collection there are fruits from: Arda-Castell'Arquato-AD3 (Gelasian), Arda-Castell'Arquato-AD13, AD14 (Calabrian), Castelletto Cervo II-GA5-GA21 (supposed Gelasian: CAVALLO & MARTINETTO 2001, 18 fruits). Finally, the impression of a complete fruit from the Stirone-Laurano site (GREGOR 1986) stored at the Fidenza Museum of Fossils was collected (A. ORZI, pers. comm. 2015) in a layer just above the LA3 one (late Calabrian). In most localities (apart Castelletto Cervo II) a single fruit was recovered.

Chronological distribution in Italy: The Santa Barbara record cited by GÜNTHER & GREGOR (1990) needs to be verified, but would constitute the single Piacenzian occurrence. Recently reported by MARTINETTO et al. (2015) in a dated early Gelasian locality (Arda-Castell'Arquato-AD3), also occurring in another possibly Gelasian site, Castelletto Cervo II (CAVALLO & MARTINETTO 2001). GREGOR's (1986) report for the latest Calabrian (Stirone-Laurano site) is confirmed here by two previously unpublished fruit findings in the late Calabrian portion of the Arda-Castell'Arquato section (MARTINETTO et al. 2015).

Fagaceae DUMORT. 1829 (as "Fagineae")

Fagus L. 1753

The fossil record of this genus has been studied in connection to modern morphological and molecular data accompanied by a detailed reconstruction of the evolution and biogeography since the Eocene (DENK & GRIMM 2009a). This study suggests that in Europe, during Pliocene, *Fagus* was represented by a form which may be treated as the *Fagus haidingeri* KOVÁTS "whole plant" (KVAČEK 2005). The name *F. haidingeri* KOVÁTS 1856 sensu ERW.KNOBLOCH 1969 was introduced to describe leaf remains, and its application to cupules and fruits may be problematic because of the impossibility to check diagnostic characters (DENK 2004), so that DENK & MELLER (2001) suggested to use the name *Fagus deucalionis* UNGER for these last remains.

Fagus deucalionis UNGER 1847 emend. DENK et MELLER 2001 [cupules and fruits - FS]

Pl. 3, Fig. 4; Text-fig. 3

Synonyms:

1847 *Fagus deucalionis* UNGER: pp. 101–103, pl. 27, figs 1–4 (non 5 and 6).

1915 *Fagus decurrens* C.REID et E.REID: pp. 78-79, pl. 5, figs 19, 20, 22-28.

Description: See REID & REID (1915), DENK & MELLER (2001) and DENK (2002). The cupules of some Italian Pliocene sites are often found with complete peduncles, whose length shows a great variability, from 3 times the cupule's length (Text-fig. 3) to as long as the cupule (Pl. 3, Fig. 4). The mean dimensions of such cupules (without peduncles) are definitely smaller than those of modern samples of *F. sylvatica* L. (DENK & MELLER 2001, DENK 2002).

Remarks: The fossil record of *Fagus* in Europe has been extensively analyzed in the recent papers by DENK & MELLER (2001), DENK (2002, 2004) and DENK & GRIMM (2009a), whose conclusions are accepted here. There are very abundant and well preserved remains of *Fagus* in the Pliocene of Italy, especially in the Piacenzian, and these were only marginally considered in the foregoing studies. Therefore, here is provided for the first time an overview with a focus on the cupule/nut complex. In several past works (e.g., MARTINETTO 1994a; CAVALLO & MARTINETTO 2001) the Pliocene cupules had been assigned to *F. decurrens* C. REID et E.REID (the type material of this species is from the Reuverian of the Lower Rhine Embayment: REID & REID 1915), since direct comparison of the Italian material with several specimens from the Reuverian of the Lower Rhine Embayment showed that the morphology and its variation was identical. DENK & MELLER (2001) synonymized the type material of *F. decurrens* with *F. deucalionis*, but DENK (2004) did not synonymize it with *F. haidingeri* KOVÁTS 1856 sensu KNOBLOCH 1969 (possibly for the lack of leaves in REID & REID 1915). The discussions in DENK (2004) and DENK & GRIMM (2009a) suggest that the cupule/fruit material assigned to *F. decurrens* (e.g., MÄDLER 1939, SZAFFER 1961) is most probably a part of the *Fagus haidingeri* “whole plant”. However, according to the present ICN (MCNEILL et al. 2012) the decision to apply a separate name for leaves versus cupules and fruits is legitimate.

Even if the assignment of the Pliocene cupules to a fossil-species seems to be well-grounded, the long-lasting Italian fossil record poses the following problem: how and when can we detect the first fossil record of the modern *Fagus sylvatica*? DENK (2004) and DENK & GRIMM (2009a) suggest a gradualistic transition in leaf morphology between *F. haidingeri* and *F. sylvatica*, without a definite morphological differentiation. DENK & MELLER (2001) and DENK (2002) assign a poor diagnostic value to the cupule/nut complex, however they accept that the fossil-species *F. deucalionis* can be distinguished from the modern *F. sylvatica*. Conversely, the proposal by MAI (2001) to separate, mainly on the basis of cupule/fruit dimensions, the fossil-species *F. deucalionis* from another fossil-species ("*F. decurrens*") would need to be supported by more definite evidence.

The Italian record of *Fagus* is rich for the Zanclean and Piacenzian (typical *F. haidingeri* leaves and *F. deucalionis* cupules: Text-fig. 3, MARTINETTO 2003, DENK 2004), but poor in the Gelasian and Calabrian. The analysis of the rich cupule/nut assemblages from Barbania, Castelletto Cervo I (GA1, GA8), Stura Fossil Forest (Text-fig. 3) and Santa Barbara Gregor's outcrop indicates that in the Pliocene of Italy only one species was present, which is here named *F. deucalionis*. A single well-dated latest Gelasian site (Poggio Rosso, central Italy) yielded a rich assemblage of cupules that can be assigned to *F. deucalionis*. Other two (Piacenzian or Gelasian) sites in central Italy yielded non-diagnostic cupules, indicated as *Fagus* sp. The single late Calabrian cupule so far recovered (*Fagus* sp. from Stirone-Laurano-LA3) is morphologically compatible with both *F. deucalionis* and *F. sylvatica*. The ca. 3 Ma old cupules of *F. deucalionis* are readily distinguished from the very variable modern cupules of *F. sylvatica* (DENK & MELLER 2001) by the tendency to

have smaller dimensions and longer peduncles. A cupule assemblage already typical of modern *F. sylvatica* is displayed by a rich assemblage from the Middle or Late Pleistocene Re site (Nr. 9 in Text-fig. 1) in the Vigizzo Valley (NW Italy), which also permits to study the variability. In conclusion, the discontinuity of the present carpological record does not allow us to follow the transformation of cupule morphology in the last 3 million years.

"NEX" category: N.

Occurrence in the studied sites (CENOFITA collection): Barbania-FN5, Canton Iuli-CC7, Castelletto Cervo I (GA1, GA3, GA6, GA8: abundant), Castelnuovo Bormida I, Castelnuovo Bormida III (abundant), Momello-Lanzo-MO2, Poggio Rosso-MT5 (abundant), San Giustino Valdarno, Santa Barbara Gregor's outcrop (SB1, SB6, SB9: abundant), Stura Fossil Forest, Terzoglio-TZ8 (abundant). Probable records (scarce and/or badly preserved cupules, *Fagus* cf. *deucalionis*): Arda-Castell'Arquato-AD3, Baldichieri-Fornace-BA2, Baldichieri-North, Benasso-BE1, Boschi di Barbania, Breolungi-BR3, Ca' Viettone (CV4, CV10-6, CV18), Candelo, Castellengo, Crava di Morozzo I, Fossano-FO2, Pocapaglia, Santerno-Codrignano, Sento I-CH35, Sento II-BG2. Other records of not diagnostic cupules, surely of *Fagus*: Dunarobba-DU20, Stirone-Laurano-LA3.

Chronological distribution in Italy: Rare cupule impressions of *Fagus* sp. already occur in the Messinian (CAVALLO et al. 1986), where some leaves have been assigned to *F. haidingeri* (DENK 2004). A few cupules with incomplete peduncles, tentatively referable to *F. deucalionis*, occur in several Zanclean sites (e.g., Breolungi-BR3, Pocapaglia). Typical cupules of *F. deucalionis* are only frequent in the Piacenzian, and in the latest Gelasian Poggio Rosso site. The distinction of *Fagus deucalionis* from *F. sylvatica* requires to study the variation of several cupules, therefore the scanty Calabrian records so far available are not suitable to assess the last occurrence of *F. deucalionis*.

Quercus L. 1753

Quercus cf. *robur* L. 1753 [cupules and fruits - BS]

Pl. 3, Figs 1, 2, 3

Description and occurrence in the studied sites: Isolated cupules that agree in size and morphology with the modern cupules of *Quercus robur* occur in the Zanclean sites Breolungi, Candelo and Sento II and in the Zanclean-Piacenzian one of Castellengo. These older records are not sufficiently well preserved to demonstrate a cupule morphology of the same type as in the modern *Quercus robur* L., in particular the typical peduncle is always lacking due to pre-burial fragmentation. Furthermore, long peduncles are also present in another modern species of southern Europe, *Q. hartwissiana* STEV. (T. DENK, pers. comm. 2015). Similar remains have also been found in a few possibly Piacenzian (Castelletto Cervo I, Front) and possibly Gelasian (Castelletto Cervo II) sites. The abundant Early Pleistocene cupules from Buronzo and Steggio are more significant, because they have the same variation as cupule assemblages of *Q. robur* detected in Middle-Late Pleistocene (BERTINI et al. 2014) and modern sediments (BERTOLOTTI et al. 2012; VASSIO & MARTINETTO 2012). Therefore, they most probably represent such species. This is most evident for the fossil cupules of the locality Buronzo, with almost complete, long peduncles.

Remarks: DENK & GRIMM (2010) showed the complex phylogeny of *Quercus*. Both *Q. robur* and *Q. hartwissiana* belong to the "roburoid oaks", including 18 species in W Eurasia, mostly poorly differentiated and suspected of a relatively recent speciation.

"NEX" category: N.

Occurrence and chronological distribution in Italy (CENOFITA collection): *Quercus robur*-like cupules occur in the Zanclean and Piacenzian, but they are poorly preserved and should be better investigated, so the oldest reliable record of *Quercus* cf. *robur* should be considered the one

of Buronzo (BU10, BU14), of possible Gelasian-Calabrian age. The later documentation is scanty: Calabrian of Steggio, Middle-Late Pleistocene of the Upper Valdarno Basin (Cava Campitello: VASSIO 2012; BERTINI et al. 2014).

The material from Stirone-Laurano-LA1, documenting another latest Calabrian occurrence of *Quercus cf. robur* (GREGOR 1985, pl. 1, figs 18, 19: cupules, layer "S3"), is stored in the Fidenza Museum of Fossils.

Hamamelidaceae R. Br. 1818

Parrotia C.A.MEY. 1831

This genus has been considered monotypic for long time, and limited to the Hyrcanian area, until the description of an East Asian species in the 1990s (LI & DEL TREDICI 2008). The Pliocene material is abundant and well preserved, and definitely correspond to a fossil-species described from Germany. The Early Pleistocene Italian carpological material is very scarce, with a single diagnostic fruit specimen that could yet belong to the living Hyrcanian species.

Parrotia reidiana KIRCHH. 1957 [fruits and seeds - FS]

Pl. 3, Figs 12-14

Description: The rather well-preserved fruits and seeds from the Pliocene of Italy have been compared with samples from many modern genera of Hamamelidaceae, and *Parrotia persica* C.A.MEY. was definitely the most similar one for the fruit shape, short calyx remain and seeds with rounded base (see MARTINETTO 1994a). *Parrotia subaequalis* (H.T. CHANG) R.M. HAO et H.T. WEI was not available for direct comparison, but the image provided by LI & DEL TREDICI (2008) suggest that the general characters are shared with *P. reidiana* and the external ornamentation is similar, even if the fruit seems to be more globose. Another difference is seen in the apical style-bearing protuberance, that in *P. subaequalis* is extended laterally to the fruit's maximum width, whereas in *P. reidiana* is limited to 1/2 to 2/3 of the fruit's width. As for the fossil-species, there is no question that the Italian material has the same characters as the specimens described by BAAS (1932) as *Parrotia cf. persica*. The latter specimens were considered by KIRCHHEIMER (1957) to belong to the new fossil-species *Parrotia reidiana* KIRCHH.

Dicussion: The similarity of the rich Pliocene samples with *Parrotia persica* is noteworthy, but the fruits are smaller (7-11 mm vs 12-16 mm long), with a more rugose and less tuberculate external surface; the seeds have a rounded base (instead of acute). Direct comparison with *Parrotia subaequalis* would be very interesting in view of the recent time of divergence (ca. 8-3 Ma) estimated for the two living species (LI & DEL TREDICI 2008).

"NEX" category: N (*Parrotia persica* does not grow in Europe, but in the Hyrcanian area).

Occurrence in the studied sites (CENOFITA collection): Castelletto Cervo I-GA1, Ceresole d'Alba, Momello-Lanzo-MO10 (abundant), Santa Barbara Gregor's outcrop, Stura Fossil Forest (abundant), Villafranca d'Asti-RDB1 (abundant). Doubtful at Castelletto Cervo II-GA5: only endocarps and badly preserved fruits.

Chronological distribution in Italy: Not reported before the Piacenzian. Common in some Piacenzian sites (swamp facies: Villafranca d'Asti, Stura Fossil Forest). The few incomplete remains (mostly endocarps) of the possibly Gelasian site of Castelletto Cervo II (GA5) are not sufficient to identify either *P. reidiana* or *P. cf. persica*.

Parrotia cf. persica C.A.MEY [fruit - BS]

Pl. 3, Fig. 11

Description: A single fruit from the Enza River site near Traversetolo (Text-fig. 1) is so well-preserved as to permit a detailed comparison with *P. reidiana* from the Pliocene of Italy, and with the modern *Parrotia persica*. The Enza fruit is 12 mm long (i.e. 1 mm longer than the longest available fruit of *P. reidiana*), it is abundantly tuberculate and not apparently rugose. So, at first glance, it would not seem to belong to the same species as the Pliocene material. However, the transformations which occurred during fossilization should be accurately evaluated. In fact the strong rugosity of several fruits from the Pliocene may have been caused by the marked compression due to preservation in muddy sediments. Only the fruits from Momello-Lanzo are preserved in sandy silt and, being less compressed, show a weak rugosity. They differ from the Enza specimen by the absence or scarcity of tubercles in the basal part of the fruit, as well as by the smaller dimensions.

Discussion: Despite the alterations induced by different conditions of fossilization, the differences cited above suggest to assign the Enza fruit specimen to a separate species. It must also be noted that the youngest fruit of *P. reidiana* in Italy has an age of ca. 3 Ma (Stura Fossil Forest: MARTINETTO et al. 2007), whereas the age of the EZ38 layer of the Enza section approaches 1.0 Ma (MARTINETTO et al. 2015). The presence of a *Parrotia* species around 1.0 Ma is also proved by leaves very similar to those of *Parrotia persica* (GREGOR 1986; MARTINETTO & SAMI 2001). The similarity of the Enza fruit (Pl. 3, Fig. 11) to *Parrotia persica* is noteworthy in all details, and only the dense cover of hairs is completely missing (most probably due to fossilization). Unfortunately no seed is available.

At the moment, the availability of a single fruit does not seem to be sufficient for the assignment to a definite species, therefore an open nomenclature is used and this material is referred to *Parrotia* cf. *persica*.

"NEX" category: N.

Occurrence in the studied sites (CENOFITA collection): Enza-Traversetolo (EZ38), late Calabrian.

Hydrocharitaceae JUSS. 1789

Stratiotes L. 1753

Fossil seeds of the genus *Stratiotes* are very abundant in Europe from the middle Eocene (48 Ma) to the Holocene, and there is a rich literature dealing with past records (e.g., CHANDLER 1923; HOLÝ & BŮŽEK 1966; PALAMAREV 1979; COOK & URMI-KÖNIG 1983; SILLE et al. 2006; MELAMED et al. 2011). The morphological characteristics of seeds allowed to differentiate several fossil-species. Today this genus is represented by the single species *S. aloides* that grows in the Euro-Siberian region (FEDCHENKO 1934).

Stratiotes intermedius (HARTZ 1909) E.CHANDLER 1923 [seeds - FS]

Pl. 3, Fig. 5

Description: The 22 seeds from Buronzo have the same dimensions and morphological characters as described by CHANDLER (1923), even if comparison with the original material of HARTZ (1909) was not performed.

Remarks: *S. intermedius* was reported for the first time in Italy in MARTINETTO (1995, p. 85), where the explanation of the meaning of the locality label "BU3" was omitted. Actually, the single

occurrence cited for *Stratiotes* was the Buronzo locality (MARTINETTO, 1995, p. 65). In the early-1990s this locality was characterized by small outcrops with very short sections (1-4 m), and only around the year 2000 the Cervo River produced better exposures, which allowed to reconstruct the stratigraphy. This was shown in a figure by MARTINETTO & FESTA (2013, p. 175), where the "Stratiotes bed" was accompanied by the label "BU16"; these authors also figured for the first time seeds from this bed, assigned to "*Stratiotes* sp.". The label "BU3" has been used in an ambiguous way by FESTA (2011), and was erased from the CENOFITA database. Therefore, in order to avoid confusion, the *Stratiotes* bed of Buronzo is indicated as "BU16", that definitely corresponds to "BU3" in MARTINETTO (1995, p. 85).

Stratiotes intermedius is usually interpreted as an extinct species that comprises an intermediate stage of evolution between the fossil-species *Stratiotes tuberculatus* E.REID and the extant *Stratiotes aloides* L. (CHANDLER 1923; COOK & URMI-KÖNIG 1983; MELAMED et al. 2011).

General distribution: *Stratiotes intermedius* occurs in Europe (The Netherlands, Denmark, Germany, France, Poland, Bielorrussia: VELICHKIEVICH & ZASTAWNIAK 2003) and SW Asia (MELAMED et al. 2011) in fresh-water deposits assigned mostly to the Pliocene and Early Pleistocene, Gelasian in particular, such as Tegelen (REID & REID 1915) and Maalbek (WESTEROFF et al., 1998). The Miocene record by PALAMAREV (1979) from the Sofia basin (Balsha, Gnilyane Formation, lower Pontian) seems to be doubtful because in the same assemblage there are seeds assigned to *S. tuberculatus* E.REID. The presence of *S. intermedius* in the Holocene (MELAMED et al. 2011) is definitely cited by mistake.

"NEX" category: N.

Occurrence in the studied sites (CENOFITA collection): Buronzo-BU16 (22 seeds).

Chronological distribution in Italy: The total absence in the fossil record of pre-Pleistocene deposits of Italy could suggest that this genus immigrated in our country only during the Quaternary, being rare in any case. In the Gelasian it occurs only at Buronzo, in the Calabrian a morphologically distinct set of seeds (*S. cf. intermedius*) occurs in central Italy at Pietrafitta (MARTINETTO et al. 2014b). One fragment of seed from Torre Picchio (GIROTTI et al. 2003) is also determinable as *S. cf. intermedius*, but it is impossible to verify the affinity either to the Buronzo or Pietrafitta seed sets.

Juglandaceae A. RICH. ex KUNTH 1824

Carya NUTT. 1818

Carya globosa (R. LUDW. 1857) MÄDLER 1939 [fruits - FS]

Pl. 2, Fig. 1, 2

Synonyms:

1857 *Juglans globosa* LUDWIG, p. 103, pl. 21, fig. 12.

1939 *Carya globosa* (LUDWIG) MÄDLER, p. 66, pl. 6, figs 6-8.

Description: See MÄDLER (1939), MAI (1973), GHIOTTO (2010).

Remarks: There is no doubt that the coarsely rugose *Carya* fruits found in several Italian localities (see below) are conspecific with the holotype indicated by MAI (1973). Furthermore, MÄDLER (1939) better described the fruit characters and variation, which corresponds to what the present author observed in the Italian collections. The question is whether other *Carya* species occur in Italy, as suggested by GREGOR (1985, 1990). Up to now no confirmation to this hypothesis was found, but several fossil fruits show a scarce rugosity and should be better studied, even if they are strongly compressed and deformed. The locality Stirone-Laurano (GREGOR 1986) contained a

lenticular deposit (LA1) very rich in *Carya* fruits. This plant assemblage was certainly autochthonous and contained mostly immature fruits in several stages of development, with the endocarp covered by the husk, which possibly had been shed by the ancient mother plants all over the year (collection Quarantelli, at the Salsomaggiore Museum). The few ripe specimens without husk, two of which are in the CENOFITA collection, showed the rugose endocarp surface of *C. globosa*. Several other specimens from the same locality, figured by GREGOR (1985) and tentatively assigned to 4 different species (*C. cf. ventricosa* (STBG.) UNGER, *C. angulata* C.REID et E.REID, *C. sp.*, *C. cf. paludis-naabi* GREGOR), seem to be covered by the husk and therefore do not show the endocarp characters, which are necessary for a sound determination.

"NEX" category: E.

Occurrence in the studied sites: In the CENOFITA collection there is material from Arda-Castell'Arquato-AD9, Buronzo-BU21, Castelletto Cervo I and II, Lombardore, Pian Torinetto-CH10, Santa Barbara Gregor's outcrop-SB1, Steggio, Stirone-Laurano-LA1 and LA3. *Carya cf. globosa*: Casnigo, Cava Toppetti II-NJ1, Dunarobba-DU21, Enza-Traversetolo-EZ50, Poggio Rosso-MT4, Stura Fossil Forest.

Other collections have fruits of *Carya globosa* from Almenno and Leffe-LF11 (Caffi Museum of Bergamo), and Fighille (Centro Studi sul Quaternario of Sansepolcro: BALDANZA & SPIRITO 2010).

Chronological distribution in Italy: Not reported before the Pliocene. Only one specimen in the Zanclean (Pian Torinetto), rare in the Piacenzian (mostly Santa Barbara), more common in the Gelasian and Calabrian (Steggio, Stirone-Laurano). Last certain occurrence at Stirone-Laurano-LA3 (ca. 0.9 Ma), but deformed endocarps of *Carya* (most probably *C. globosa*) also occur in the layer EZ50 of the Enza-Traversetolo site, that has been dated to the earliest Middle Pleistocene by means of magnetostratigraphy (MARTINETTO et al. 2015).

Cyclocarya ILJINSK. 1953

Cyclocarya nucifera (R. LUDW. 1857) MAI 1964 [fruits - FS]

Pl. 2, Figs 3, 4

Synonyms:

1857 *Zyziphus nuciferus* LUDWIG, p. 102, pl. 20, fig. 23.

1973 *Cyclocarya nucifera* (R.LUDW.) MAI, p. 98, pl. 3, figs 8, 9.

Description: About 30 endocarps have been found in the Castelletto Cervo I site, thought to be of Piacenzian age (MARTINETTO 1995, 1998, 1999). The endocarps are very broadly ovate, thick walled, with a pointed apex, dehiscent in two hemispheric parts. Some specimens distinctly show a thin equatorial ridge, often bearing exocarp remains, which testifies the original presence of an equatorial wing. According to MANCHESTER (1987) this is a typical feature of *Cyclocarya*. In internal view the seed locule appears shifted towards the lower half.

Remarks: Fossil endocarps of this type were known in central Europe since the last century (LUDWIG 1857), but they were first identified as *Cyclocarya* by MAI (1964). *Cyclocarya nucifera* is known from the Miocene and Pliocene of Central Europe (MAI & WALTHER 1988). DOROFEEV (1970a) erected a separate form-genus (*Sphaerocarya*) for fossil fruits similar to those of *Cyclocarya*, and suggested to assign *Zyziphus nuciferus* R.LUDW. 1857 to *Sphaerocarya*. This suggestion has been rejected by MAI (1973), MAI & WALTHER (1988), GEISSERT et al. (1990) and MARTINETTO (1998), because a thin equatorial ridge suggests the former presence of a wing, a typical feature of *Cyclocarya* according to MANCHESTER (1987). DOROFEEV (1970b) described other four fossil-species of *Cyclocarya*, and two of *Sphaerocarya*.

"NEX" category: E.

Occurrence in the studied sites (CENOFITA collection): Castelletto Cervo I (GA1, GA3, GA6, GA8, ca. 30 endocarps).

Chronological distribution in Italy: Not reported before the Pliocene. Only found in the Castelletto Cervo I site, of supposed Piacenzian age.

Juglans L. 1753

Juglans bergomensis (BALS.-CRIV. 1840) A.MASSAL. 1852 [fruits - FS]

Pl. 2, Figs 9-11

Synonyms:

1838 *Juglans cinerea* L. - BRONN, p. 867.

1840 *Juglandites bergomensis* BALSAMO CRIVELLI, p. 291. [sub "*Juglandites*"]

1850 *Juglans tephrodes* UNGER, p. 469.

1852 *Juglans bergomensis* (BALS.-CRIV.) MASSALONGO, p. 255, pl. 3, figs 2-5.

Description: Rich collections of fruits of this species from the type locality Leffe (BALSAMO CRIVELLI 1840) are available in the Natural History Museums of Bergamo, Milano and Verona. The CENOFITA collection contains assemblages with more than 10 fruits from several layers of the upper Cervo River section (Castelletto Cervo I-GA1, Castelletto Cervo II-GA5-GA21, Buronzo-BU21) and from the locality Lombardore near Turin, newly discovered in the year 2013. The late Gelasian Poggio Rosso site (Central Italy) yielded 8 whole specimens. Other sites, with less than 3 nuts known, are listed below.

The original description by BALSAMO CRIVELLI (1840) can be literally translated as follows: "This nut has a very elongated oval outline, has the husk in the upper part very rugose and ending in a curved acuminate tip. The length of this nut from the husk apex to the nut base is 46 mm, the apex of the husk is two mm, and the maximum width of this fruit is 22 mm". The term husk ("mallo") is most probably improperly used and referred to the shell (endocarp).

Remarks: MARTINETTO et al. (in press) indicated a neotype for *Juglandites bergomensis* BALS.-CRIV. and summarized the earliest reports of this species. MASSALONGO (1852) emended the description on the basis of a rich collection from the Leffe locality which is now stored at the Natural History Museum of Verona. These nuts have the same morphological characters and variation pattern as the 18 nuts of *J. bergomensis* from Leffe studied by the present author in the collection of the Caffi Museum of Bergamo. Furthermore, also the rich assemblages from Buronzo, Castelletto Cervo I and II, Lombardore and Poggio Rosso (see above) have the same set of characters and variation as the Leffe nuts, so the *J. cinerea*-like fossil fruits from the Pliocene-Early Pleistocene of Italy can be assigned to a single fossil-species, whose correct name is *Juglans bergomensis* (BALS.-CRIV.) A.MASSAL. The few specimens from the Zanclean (Ca' Viettone), and from the Piacenzian of Santa Barbara (Tuscany) have smaller mean dimensions than those of the Gelasian-Calabrian, but are assigned to the same species.

More detailed information on this species is provided by VAN DER HAM (this volume), who points out a broad variability of shape and size detected in several fossil nuts from Europe as well as in the living *J. cinerea* L. (North America). Even if the fossils are definitely *J. cinerea*-like (but also similar to East Asian species), the use of this name for the European fossils (as in GEISSERT et al. 1990) is hazardous and most probably incorrect.

"NEX" category: E, referred to *Juglans* sect. *Cardiocaryon*.

Occurrence in the studied sites: The specimens of the CENOFITA collection originate from Buronzo (BU0, BU2, BU21: abundant), Ca' Viettone, Castelletto Cervo I (GA1: CAVALLO & MARTINETTO 2001), Castelnuovo Bormida II, Cellino Attanasio, Chiavenna, Lombardore (abundant), Poggio Rosso (moderately abundant), Santa Barbara Gregor's outcrop, Steggio, Torre

Picchio. Other occurrences at Bagnone in northern Tuscany (MESCHINELLI & SQUINABOL 1893; SORDELLI 1896), Castell'Arquato BRONN's site (BRONN 1938 reported having collected a fruit of "*Juglans cinerea*" from the "Subappennine Formation" of Castell'Arquato, and probably this same fruit was the basis for the new name *J. tephrodes* UNGER 1950), Giffenga (site corresponding to the above-cited Buronzo but sampled underground, from a well: MATTIROLO 1930), Fighille (BALDANZA & SPIRITO 2010), Imola (Plio-Pleistocene, coll. Scarabelli of Imola: VAN DER HAM 2015 (this volume), Leffe (see above), Monteu Roero ("Roero" by GÜNTHER & GREGOR 1990), Stirone-Laurano-LA1 (GREGOR 1985, material stored in the Fidenza Museum of Fossils; other specimens from the same site at the Salsomaggiore Museum), Upper Valdarno Basin (Castelnuovo dei Sabbioni and Terranuova Bracciolini after RISTORI 1886, Santa Barbara after GREGOR 1990; Natural History Museum of the Florence University).

Chronological distribution in Italy: Not reported before the Pliocene. Only a few specimens in the Zanclean (Ca' Viettone, Monteu Roero), rare in the Piacenzian (mostly Santa Barbara Gregor's outcrop), more common in the Gelasian and Calabrian (Leffe, Poggio Rosso, Steggio). Last occurrence at Stirone-Laurano-LA1 (GREGOR 1985) (ca. 1.0 Ma: MARTINETTO et al. 2015).

Pterocarya KUNTH 1824

Pterocarya limburgensis C. REID et E. REID 1915 [fruits - FS]

Pl. 2, Figs 5-8.

Description: See REID & REID (1915) for an excellent analysis of variability: "the endocarps vary ...so greatly...we should be inclined to refer our fossils to several species... but a very large series of intermediate forms seem to connect all these extremes". Absolutely the same situation is observed in all the very rich Italian assemblages.

Remarks: Endocarps of *Pterocarya* are very common fossils in the Italian Pliocene and Gelasian. The Zanclean assemblages show a smaller mean size with respect to the Piacenzian, and particularly to the Gelasian ones. However, in this paper all the Italian material is assigned to a single, very variable fossil-species, whose correct name is *Pterocarya limburgensis* C. REID et E. REID .

In Italy the fruit fossil record of *P.* is rather dense from the Zanclean to the Gelasian, then there is a surprising lack in the Calabrian, where *P.* is documented only by one endocarp in the earliest Calabrian site Santerno-Codrignano and by scanty leaves at the Oriolo site (MARTINETTO & SAMI 2001), assigned to *Pterocarya* sp. There is also a Middle Pleistocene record at Riano Romano (FOLLIERI 1958; MASTRORILLI 1965), where the fossils have been assigned to the modern species *P. fraxinifolia* (POIR.) SPACH [sub. *P. caucasica* C.A. MEY.]. REID & REID (1915) discussed the relationship of *P. limburgensis* with two recent species: *P. fraxinifolia* [sub. *P. caucasica* C.A. MEY.] ("strongly beaked") and *P. hupehensis* SKAN ("smaller short pointed"). They concluded that the morphology of the endocarp sets from the Pliocene (Reuver, Swalmen) of Limburg (and Gelasian: Tegelen) could be differentiated from both modern species. LU et al. (2001) state that the genus *Pterocarya* includes 6 species, among which the present author could analyze cultivated material of *P. fraxinifolia*, *P. rhoifolia* SIEBOLD & ZUCC., *P. stenoptera* DC. It is here accepted REID & REID'S (1915) view that Zanclean-Gelasian endocarp assemblages can be distinguished by those of all of the recent species: the variability observed is different, also from that of the single surviving species in SE Europe, *P. fraxinifolia*, in particular for the beak length. On the other hand, BAAS (1932), MÄDLER (1939) and MAI & WALTHER (1988) assigned their Piacenzian-Calabrian fossils to *P. fraxinifolia*.

Winged fruits are unknown in the Pliocene and Gelasian, whereas the Middle Pleistocene fossils (FOLLIERI 1958), preserved as adpressions, bear perfect wings and are 20-25 mm wide. The comparison with the older material can only be carried out on the basis of endocarp dimensions and beak shape (rugosity is analogous). The three endocarps inside the winged fruits figured by FOLLIERI (1958) and MASTRORILLI (1965) are 5-6 mm wide and have small and short beaks, agreeing with those of several Gelasian endocarps from Poggio Rosso-MT4 (and Castelletto Cervo II-GA5), but also with material from the type locality Reuver (REID & REID 1915). So, the distinction between the Pliocene-Gelasian and Middle Pleistocene forms is really difficult, and the endocarps from Riano Romano (especially their variability!) are not studied in sufficient detail to prove the affiliation with the modern species *P. fraxinifolia*.

Considering all this information, my proposal is to use for the Zanclean-Gelasian assemblages the name *P. limburgensis*, eventually indicated as *P. cf. limburgensis* in case of scarce or badly preserved material. Further studies should point to verify if the Zanclean assemblages of *Pterocarya*, with smaller endocarps, have to be considered a separate taxon. The open nomenclature *P. cf. limburgensis* seems to be appropriate also for the Middle Pleistocene assemblage (because the morphology is more *limburgensis*-like than *fraxinifolia*-like). Most probably there is a gradual phyletic transition between the two species, and much more records than those available today would be needed to establish an accurate timing of the process in the Calabrian-Middle Pleistocene interval.

"NEX" category: N (*P. fraxinifolia* grows today on the South and East coast of the Black Sea).

Occurrence in the studied sites (CENOFITA collection): Arda-Castell'Arquato-AD3, Breolungi-BR3, Buronzo (BU2, BU5, BU11, BU15, BU21: abundant), Ca' Viettone (CV5, CV9, CV10-3, CV10-6, CV12, CV20: abundant), Canale d'Alba, Candelo, Casnigo, Castelletto Cervo I (GA1, GA3, GA4, GA8: abundant), Castelletto Cervo II (GA5: abundant), Cossato, Castelnuovo Bormida III (abundant), Dunarobba (DU10, DU20, DU21), Fossano-FO5, Pocapaglia, Poggio Rosso (MT1, MT4: abundant), Ronco Biellese, Santa Barbara Gregor's outcrop (SB6, SB9), Santerno-Codrignano, Sento II, Sezzadio-Rio della Lupa, Stura Fossil Forest, Valle della Fornace (VF1, VF2, VF3, VF10, VF20), Villa San Faustino-SFST2.

Chronological distribution in Italy: Common in the Zanclean (e.g., Ca' Viettone), in the Piacenzian and particularly in the Gelasian or supposed Gelasian (Castelletto Cervo II, Lombardore). Very rare to absent in the Calabrian (only 1 endocarp at Santerno-Codrignano). Possibly passing into the Middle Pleistocene (Riano Romano) with a gradual transition to the present relict species *P. fraxinifolia*.

Lamiaceae LINDL. 1836

Ajuga L. 1753

Fossil-species descriptions: Fossil-species were described by REID & REID (1915), DOROFEEV (1967) and NEGRU (1986). REID (1892) cited for the first time the occurrence of fossil fruits of the modern *Ajuga reptans* L., and TOLPA (1961) those of *Ajuga genevensis* L., both records are of Pleistocene age.

Ajuga antiqua C.REID et E.REID 1915 [fruits - FS]

Pl. 3, Fig. 6; Text-fig. 4.

Description: See REID & REID 1915, MAI & WALTHER (1988).

Remarks: The *Ajuga* fruits of the Italian Plio-Pleistocene are very similar to those of the living *A. reptans* L., very common in most of Europe. BALL (1972) lists 9 modern species of *Ajuga* in Europe, and the fruits of 4 species (2 from East Europe: *A. laxmannii* (L.) BENTHAM and *A. salicifolia* (L.) SCHREBER; 2 local endemics: *A. piskoi* DEGEN et BALD. and *A. tenori* C. PRESL in J. et C. PRESL) do not seem having been documented yet. The analysis of the most common European species (MARTIN MOSQUERO et al. 2001), also carried out for this paper on rich samples of the MCC, showed that fruit morphology permits to distinguish rather easily *A. iva* (L.) SCHREB., *A. chamaeptychys* (L.) SCHREB. and *A. orientalis* L., whereas the fruits of *A. reptans*, *A. genevensis* and *A. pyramidalis* L. can be differentiated mostly based on dimensions. It is necessary to observe the variability of at least 3-5 fruits, and the characters of the single specimen are hardly useful. For this reason the present author studied, similarly to SZAFER (1947, p. 332), the rich assemblages of the Italian Plio-Pleistocene (Text-fig. 4) in order to evaluate if they showed the same morphological variability as the modern samples of *A. reptans*. The fruits from modern sediment samples (VASSIO & MARTINETTO 2012) have been particularly important for comparison (mean dimensions 1.9 x 1.1 mm). Fruit assemblages of the Pliocene (mean dimensions 1.5 x 1.1 mm) differ for a single detail from modern fruit sets: the smaller L:W ratio (1.36 vs 1.73). Single Pliocene fruits are indistinguishable from the most isodiametric Holocene fruits. This situation constitutes a very interesting nomenclatural challenge. The Pliocene members, with more isodiametric fruits, have been assigned to the fossil-species *A. antiqua* C.REID et E.REID 1915, even if SZAFER (1947) and MAI & WALTHER (1988) considered this species identical to *A. reptans*. The long-lasting Italian record (see-below) suggests that we are probably following the microevolution of an *Ajuga* lineage which led to the modern *A. reptans*. We have rich assemblages at the beginning of the Middle Pleistocene (Pianico site: MARTINETTO 2009) that still conform to *A. antiqua* (L:W ratio 1.45), but already show a trend towards longer fruits. This is more evident at the end of the Middle Pleistocene (VASSIO 2012), but still in a few samples the L:W ratio is smaller (1.64) than the Holocene one, when the fruits must indeed be assigned to *A. reptans*. So, when recognizing the fossil-species *A. antiqua*, it is difficult to set a boundary between *A. antiqua* and *A. reptans*. In this paper it was decided to use the name *A. antiqua* for the more isodiametric fruit sets of the Pliocene and the Early Pleistocene. For the Middle Pleistocene fruit sets, showing an intermediate L:W ratio (1.45-1.64), the open nomenclature *A. antiqua* vel *A. reptans* seems preferable, in order to point out that the fruits are *A. reptans*-like and do not represent the fossil record of any other modern European species.

"NEX" category: N.

Occurrence in the studied sites (CENOFITA collection): Arda-Castell'Arquato-AD3, Buronzo (BU14, BU21), Ca' Viettone (CR3, CV4, CV12), Canton Iuli, Casnigo (moderately abundant), Castelletto Cervo I (GA1), Castelletto Cervo II (GA5: moderately abundant), Castelnuovo Bormida I and III, Ceresole d'Alba, Dunarobba-DU23, Monticello Umbro, Santerno-Codrignano-SNT1, Steggio (abundant), Stirone-Laurano-LA4, Stura Fossil Forest (moderately abundant), Torre Picchio-PI0, Villafranca d'Asti-RDB6.

Chronological distribution in Italy: Not reported before the Pliocene, *A. antiqua* occurs in sediments of supposed Zanclean age only at Ca' Viettone; more common in the Piacenzian, and even more in the Gelasian. Distributed from the base to the top of the Calabrian (PI0, SNT1, Stirone-Laurano), with a gradual transition to the poorly differentiated *A. reptans* in the Middle Pleistocene.

Magnoliaceae Juss. 1789

Liriodendron L. 1753

Liriodendron geminata KIRCHH. 1957 [seeds - FS]

Pl. 3, Figs 7, 8

Description: See KIRCHHEIMER (1957) and MARTINETTO et al. (2015).

Remarks: The seeds of *Liriodendron* found in the Neogene and, very rarely, in the Early Pleistocene of Central-South Europe have usually been assigned to *L. geminata*; there is no evidence of other species, as suggested by DOROFEEV et al. (1974) in Russia.

In the record of the long Cervo River section (CAVALLO & MARTINETTO 2001; MARTINETTO & FESTA 2013) *L. geminata* occurs only in two out of ca. twenty fruit-bearing layers of possible Gelasian and/or Calabrian age: This fact, in addition to the evidence shown by MARTINETTO et al. (2015), could indicate that the *L. geminata* plant has left a detectable fossil record only in limited Early Pleistocene time slices, which could be better pinpointed by future research.

"NEX" category: E.

Occurrence in the studied sites (CENOFITA collection): Aulla (abundant), Baldichieri-Fornace, Buronzo (BU2, BU5, BU21), Ca' Viettone (several layers), Canton Iuli, Castelletto Cervo I (several layers), Castelnuovo Bormida I, Castelnuovo Bormida I and III, Cherasco-Stura-CHS34, Chiavenna, Crava di Morozzo I, Dunarobba-DU20, Enza-Traversetolo-EZ38, Fossano-FO3 (abundant), Momello-Lanzo-MO2, Pocapaglia (CAVALLO & MARTINETTO 1996: pl. 1, fig. 4), Santerno-Codrignano, Sento II-BG3, Stura Fossil Forest, Terzoglio-TZ8 (moderately abundant), Torre Picchio, Villafranca d'Asti-RDB1.

Chronological distribution in Italy: Not reported before the Pliocene, *L. geminata* occurs in several Zanclean and Piacenzian sites, rarely abundant (Aulla, Fossano). Rare in the Gelasian (Buronzo) and early Calabrian (Torre Picchio, Santerno-Codrignano). Last occurrence at Enza-Traversetolo-EZ38 (late Calabrian, ca. 1 Ma).

Menyanthaceae Dumort. 1829

Menyanthes L. 1753

Menyanthes trifoliata L. 1753 [seeds - BS]

Pl. 3, Fig. 9

Description: See TRUCHANOWICZÓWNA (1964) and BENNIKE (1990). The determination of the Early Pleistocene seeds from Buronzo, Lefte and San Pietro di Ragogna is based on the comparison of the seed shape, wall thickness and cell pattern with two modern seed samples (MCC collection) and a fossil one (from the Eemian of Klinge, eastern Germany), certainly referable to *M. trifoliata*. The differences are really irrelevant, so that the Early Pleistocene seeds from Italy can confidently be assigned to *M. trifoliata*.

Remarks: Miocene records assigned to *M. trifoliata* have been reported by TRUCHANOWICZÓWNA (1964), ŁAŃCUCKA-ŚRODONIOWA (1966, 1979), STACHURSKA et al. (1971). However, MAI (2000a) assigned the Miocene records from Germany to *M. germanica* (R.LUDW.) KIRCHH., pointing out that they can be differentiated from *M. trifoliata* by their "smalles cross-section and somehow thinner testa". Conversely, MAI & WÄHNERT (2000) affirm that "The structure of the testa of *Menyanthes germanica* is exactly the same as the structure of the testa of the modern *M. trifoliata* seeds". Another species described as corresponding in all details to *M. trifoliata* is *M. miocenica* P.I.DOROF., described by DOROFEEV (1963). All of these *M. trifoliata*-like fossil records have seeds longer than 2 mm.

A more clearly differentiated fossil-species (seeds shorter than 2 mm) has been described from Poland: *Menyanthes carpatica* JENT.-SZAF. et TRUCHANOWICZÓWNA 1953. MAI (2004) lists occurrences of this species in the middle and late Miocene, Pliocene, but also Middle Pleistocene: Lichvin Interglacial at Njemen, probably Russia (KAC & KAC 1959). According to MAI (2004) two other fossil-species are very similar to *M. carpatica*: *M. minima* P.I.DOROF. 1963 and *M. parvula* R.A.NIKITIN 1965. *M. microsperma* JESSEN et al. 1959 has been recombined to the genus *Nymphoides* (WATTS 1971).

WESTEROFF et al. (1998) suggested that *M. carpatica* can be distinguished on the basis of seed morphometry and anatomy from a new species described by them: *M. preglacialis* WESTEROFF et al., from Early Pleistocene sediments. Even if this name does not seem to be validly published (no diagnosis, no designation of the type), the authors conducted an interesting comparative analysis of the cell size, testa thickness, etc. (which should be repeated on more abundant material, originating from a broader geographical area), showing that some Early Pleistocene forms were not identical to modern *M. trifoliata*. Conversely, BENNIKE (1990) and VELICHKIEVICH & ZASTAWNIK (2003) assign their Piacenzian-Gelasian seeds to *M. trifoliata*. NIKITIN (1957), YAKUBOVSKAYA (1984), DOROFEEV (1986a and 1986b), VELICHKIEVICH 1990 and VELICHKIEVICH & ZASTAWNIK (2003) report seed records of *M. trifoliata* from the "Late Pliocene" of Russia and Belarus. This species has also a fossil record from Japan, and MOMOHARA (2015) interpreted the first occurrences in the Early Pleistocene to reflect severe climatic cooling. Our European records, and particularly the Italian ones, may well have the same meaning: The plant may have expanded during cooler phases of the Gelasian, and then persisted during interglacials in relict habitats, such as the peaty margins of the Leffe palaeolake (RAVAZZI 2003). It should be noticed that relict stands of *M. trifoliata* are also present today in the lowlands of northern and Central Italy (PIGNATTI 1982), in definitely warm climatic conditions.

"NEX" category: N.

Occurrence in the studied sites (CENOFITA collection): Buronzo-BU00 (abundant in a single centimetric layer), Casnigo, Leffe-VGT2, San Pietro di Ragogna (abundant).

Chronological distribution in Italy: Seeds of *M. trifoliata* have been found in two localities of the Gelasian (Casnigo, San Pietro di Ragogna: MARTINETTO et al. 2012), in a single layer (BU00) of the possibly Gelasian-Calabrian, long section of Buronzo (between layers BU20 and BU0: MARTINETTO & FESTA 2013) and in the Calabrian of the Leffe Basin (see RAVAZZI 2003). There are too many gaps in the Italian fossil record for an adequate reconstruction of the history of this species from its first occurrence in the late Gelasian (Casnigo) to the present small populations: it is not reported in the whole Middle Pleistocene.

Incertae sedis

Carpolites STBG. 1820

Carpolites is a repository for carpological remains, from almost all geological horizons, that cannot be assigned to a natural plant group (ANDREWS 1970). According to the ICN rules *Carpolites* STBG., published by STERNBERG (1820) has priority over *Carpolithes* BRONGN. published by BRONGNIART (1822), whereas *Carpolithus* L. is invalid because published before the starting date for fossils (ICN, Art. 13: MC NEILL et al. 2012).

Carpolites pliocucurbitinus nom. nov. [FS]

Replaced name: *Carpolites cucurbitinus* MARTINETTO 1995 [sub *Carpolithus*], p. 92, pl. 5, figs 4, 5. This name is not valid being an homonym of *Carpolites cucurbitinus* A.MASSAL. [sub *Carpolithus*: MASSALONGO 1859]. According to the ICN (Art. 7.4) the type of the replacement name is the same as that of the replaced synonym.

Holotype: MARTINETTO 1995, pl. 5, fig. 5.

Figured paratype: MARTINETTO 1995, pl. 5, fig. 4.

Type locality: Stura Fossil Forest near Nole Canavese (Turin province), NW Italy.

Type stratum: "Villafranchiano" unit, layer 1 in MARTINETTO (1994a), clayey silts of swamp facies.

Age: Piacenzian (Pliocene): MARTINETTO et al. (2007).

Etymology: From the age of the type stratum and the morphological features of this fossils, close to the seeds of Cucurbitaceae, but incomparably smaller.

Material originally studied (MARTINETTO 1995): 85 specimens from the Stura Fossil Forest and 47 specimens from: Baldichieri-Fornace, Ca' Viettone, Sento II, Castelletto Cervo I, Momello-Lanzo, Crava di Morozzo I, Villafranca d'Asti.

Original diagnosis (MARTINETTO 1995): Seed or achene ovate, symmetric, with a broad, regular and slightly raised margin. Length 0.7-1.0 mm, width 0.6-0.8 mm, length/width ratio: 1.67 to 1.12. Faces almost flattened, but often one face shows a low fold along the longitudinal axis. Apical end [this would be the basal end, in the case it is an achene of Lamiaceae] continued in a short and truncated protrusion. Surface distinctly ornamented by polygonal to rectangular cells with thin anticlinal walls, only visible at the SEM. These cells represent the remains of an external tissue, preserved in a few specimens, whose surface does not show any pattern, but a faint spotting. The wall of the fossil is about 23 μ thick.

Remarks: This species was improperly identified as *Mentha* sp. in a foregoing work (MARTINETTO 1994a) for the coincidence in size and shape with the achenes of modern species of this genus. *Carpolites pliocucurbitinus* differs from *Mentha* and related genera by the scarce relief of the longitudinal [median] ridge and by the lack of the two scars on both sides of such a ridge, which characterize the achenes of many Lamiaceae. The shape, size and particularly the low longitudinal [median] relief on one side are comparable with those of a lamiaceous achene, but none of the modern genera examined until now shows achenes entirely identical to those of *Carpolites pliocucurbitinus*; therefore the assignment to the Lamiaceae is still not demonstrated. The fossils from the German site of Berga (Pliocene) described as *Mentha longifolia* (L.) HUDSON by MAI & WALTHER (1988) seem to correspond to *Carpolites pliocucurbitinus*.

"NEX" category: X.

Occurrence in the studied sites (CENOFITA collection): Baldichieri-Fornace-BA2, Buronzo (BU14, BU21: abundant), Ca' Viettone, Casnigo-CG2, Castelletto Cervo I (GA1, GA4 GA6: abundant), Castelletto Cervo II (GA5, GA21: abundant), Castelnuovo Bormida I, Castelnuovo Bormida III, Cava Toppetti-TP1, Cherasco-CHS34, Crava di Morozzo I, Momello-Lanzo-MO20, San Giustino Valdarno, Sento I, Sento II, Stura Fossil Forest (abundant), Terzoglio (TZ5, TZ8), Villafranca d'Asti (RDB6, RDB8). Less than 5 specimens recovered from most localities.

Chronological distribution in Italy: Not reported before the Pliocene. Only a few specimens in dated Zanclean sites (Crava di Morozzo I, Sento I), common in the Piacenzian, less common in the Gelasian. Last dated occurrence at Casnigo (ca. 2.0-1.9 Ma).

4. Discussion

In this work 19 groups of fossils from several Italian localities have been selected, each one interpreted as belonging to a distinct species. A thorough taxonomic revision of the Pliocene-Early Pleistocene carpological material as well as a nomenclatural verification has been carried out, in order to evaluate the difficulties and time requirements for the preparation of a monograph. Broad

comparisons with modern and fossil materials have been made, and an abundant literature has been consulted, including palaeobotanical, plant taxonomical and molecular phylogenetic papers.

One of the major difficulties was the location of modern comparative material, as already stressed by MARTINETTO et al. (2014a). For several species-rich genera (e.g., *Ajuga*, *Cornus*) it was impossible to compare the fossils with all the modern species, but this occurred also for some species-poor genera (e.g., *Pterocarya*). In these cases an accurate documentation of the fossil entity was provided, which could be useful for future studies carried out with an improved collection of modern materials. It does not seem a good choice to leave in the drawers the interesting fossils for decades, just because the modern comparative material is scarce. When several specimens can definitely be assigned to a single species, its effective documentation and designation by a formal fossil-species name (as for *Cornus maii* sp. nov.) can promote future work by plant taxonomists, who will more easily gather modern comparative material for future revisions.

Although FOREY et al. (2004) suspect that "the use of morphotaxa [term used in the former ICBN, now replaced by fossil-taxa according to ICN: MC NEILL et al. 2012] tends to inflate the absolute number of plant species recorded in fossil floras", each of the species listed in this paper are likely to represent a single ancient biological species. The problem of inflation can be generated when counting the species in the 5 Ma range of the studied floras. In this case we would count two species of *Ajuga* in Italy (*A. antiqua* and *A. reptans*), whereas possibly, as discussed above, this was only one species slightly changing through time.

Several species listed in this paper obviously belonged to "exotic" genera or infregeneric taxa above the rank of species (E category) and have been treated with fossil-species names: *Carya globosa*, *Cyclocarya nucifera*, *Eucommia europaea*, *Liriodendron geminata*, *Parrotia reidiana*, *Picea florschuetzii*. A single fossil-species could not be assigned to any living genus: *Carpolites pliocurbitinus*. Other species, belonging to genera spontaneously growing in Europe sensu lato (N category), did not correspond to any modern species living in this continent, so they have been given fossil-species names too: *Cornus maii* sp. nov., *Juglans bergomensis*, *Stratiotes intermedius*. Those species found to be morphologically very similar, but not identical, to modern European species have been treated case by case: the beech cupules and fruits from the Pliocene have been assigned to the fossil-species *Fagus deucalionis*, that is possibly a collective species ("Sammelart" of MAI & WALTHER 1991), because the history of beeches has been deeply studied by DENK & MELLER (2001), DENK (2004) and DENK & GRIMM (2009a), who suggested that the cupules/fruit complex is poorly diagnostic, and three Cenozoic species can be distinguished in Europe on the basis of leaf morphology. One of these, *F. haidingeri*, is thought to be the ancestral form from which *F. sylvatica* derived in the Quaternary (DENK & GRIMM 2009a). The discontinuity of the carpological record does not allow to follow the transformation of cupule morphology in the last 3 million years; it has only been assessed that the ca. 3 Ma old cupules of *F. deucalionis* are readily distinguished from the very variable modern cupules of *F. sylvatica* (DENK & MELLER 2001) by the tendency to have smaller dimensions and longer peduncles.

The less thoroughly studied *Pterocarya* tells a similar history: the Pliocene endocarp assemblages assigned to the fossil-species *P. limburgensis* combined characters of the modern East Asian species *P. roxburgii* and the few (relict) SE European populations of *P. fraxinifolia*; however the morphological differences of the Pliocene and modern European fruits are minimal, and only fruit variation distinguishes *P. limburgensis* from *P. fraxinifolia*.

The most difficult decision concerned *Ajuga*, a genus with many living species, also in Europe. It was shown above that several sets of *Ajuga* fruits from Italy, each encompassing a slightly different range in morphology, follow one another in a chronological succession from 5 to 0 Ma. For the Pliocene-Early Pleistocene fruit sets the name *A. antiqua* has been applied. This name may represent a chronospecies or stratigraphic species (WHEELER & PLATNICK 2000), the use of which has been discouraged by FOREY et al. (2004), invoking that species be established on unique combinations of characters. However, our fossil *Ajuga* fruits do actually show a morphological character (L:W ratio) distinguishing them from *A. reptans*, but this is only detectable by analyzing

the variability of several specimens from an assemblage (e.g., >10 fruits), and not a single fruit specimen.

Another particularly intricate case concerned *Carpinus betulus*, since its very abundant fruits were not identical to the modern fruit sets, being generally smaller; therefore the application of the criterion used for *Ajuga antiqua* would have required the selection of a fossil-species name. However, the two cases are different: *Ajuga* needs further investigations, whereas *Carpinus* has been deeply investigated by JENTYS-SZAFEROVA (1960, 1961) who concluded that the Pliocene fossils "cannot be separated from those of the modern *Carpinus betulus*". Actually, the Pliocene-Early Pleistocene fossil fruits are not totally identical to the modern ones (dimension and cross section), so an infraspecific rank (*Carpinus betulus* L. subsp. 1) was used in this paper to highlight the distinction of the fossil-taxon from the modern *Carpinus betulus*. The same choice was made by MAI (1994), and accepted here, for *Pinus sylvestris* subsp. *plioaenica*.

Among the species treated in this paper, two cases were found in which the morphology and its variation in the fossil assemblage were the same as the one observed in the fruits of several individuals and populations of a recent species: *Corylus avellana* and *Menyanthes trifoliata*. For the fossil record of still living species it was not applied the word "*fossilis*" after the species name, even if used by previous authors (e.g., "*Corylus avellana* LINNÉ *fossilis*" in MAI & WALTHER 1988). It risked to generate confusion (it may seem an infraspecific taxon name) more than providing information. SZAFER (1947) attributed to KINKELIN (1900) the first explanation of the word "*fossilis*" applied after the name of modern species, however it was already used in GEYLER & KINKELIN (1887). SZAFER (1947) also pointed out two different approaches: 1) the word "*fossilis*" applied to all the names of living species (as in KINKELIN 1900; MAI & WALTHER 1988; MAI & WÄHNERT 2000); 2) the word "*fossilis*" applied only to the name of selected species whose fossil remains show some morphological disagreement with the modern ones (SZAFER 1947, 1954). In the second case it would be better to formalize an infraspecific taxon of the living species according to the rules of the ICN. For what explained above, it does not seem appropriate to formalize the frequently used word "*fossilis*" as an infraspecific plant name (even if it is not cited as invalidly published by ICN, Art. 24.3: MC NEILL et al. 2012).

Finally, in this paper open nomenclature has been used for the species represented by scarce material or showing poorly diagnostic characters. As for *Quercus* cf. *robur*, the presence of another similar modern species (*Q. hartwissiana*) and the lack of completely preserved peduncles were the limiting factors for a definite species assignment, whereas for *Parrotia* cf. *persica* it was the need of more abundant fossil material which could show the variation of the fossil assemblage.

In conclusion, a monographic treatment of all the carpological material from the Pliocene-Early Pleistocene of Italy still seems to be feasible in a long-time perspective by collecting and synthesizing the information of several papers, more deeply investigating particular taxa. Conversely, a detailed investigation of individual problematic taxa (e.g., JIMÉNEZ-MEJÍAS & MARTINETTO 2013) is beyond the possibility of a monographic investigation, because it requires several months of work only to visit the necessary collections of modern and fossil plants, and to locate and analyze the modern reference material. The major difference from the times when the MAI & WALTHER (1988, 1991) monographs were published is the increasing availability of molecular phylogenies, which have to be considered for the assessment of an appropriate nomenclature and taxonomy of the fossil taxa. Some authors (e.g., CHEN et al. 1999, DENK & GRIMM, 2009a) even showed that a molecular phylogenetic framework allows mapping carpological characters on a phylogenetic tree and to assess the evolutionary significance of a particular morphological character: Diagnostic, synapomorphic, or not diagnostic (i.e. evolved in parallel in unrelated groups) for a particular natural group of species (e.g., DENK & GRIMM 2009b). At the same time, a well-understood fossil can provide biogeographic and temporal information that is not captured in a phylogenetic tree based on modern species alone.

The Plio-Pleistocene plant remains represent the fossil record of the crown area of phylogenetic trees. On the one hand their study requires a hard taxonomic work because of the difficulties posed

by the small morphological changes implicit in the transition from fossil-taxa to modern species. On the other hand, the results are very interesting because they permit to follow step by step (JENTYS-SZAFEROVA 1958) the origin of several plants forming the modern European vegetation. For such a purpose, this paper shows the advantage of a broad spatial and temporal sampling (Text-fig. 1, Table 1), which permits to define the chronological and geographical distribution of each species in the Pliocene-Early Pleistocene of Italy, thus pinpointing the widespread taxa (e.g., *Carpinus betulus* subsp. 1) and those which were restricted to certain areas or time slices (e.g., *Stratiotes intermedius*). Furthermore, all of the floras of the Italian Pliocene-Early Pleistocene are characterised by a considerable percentage of species assigned to the E category ("exotic elements", 20% to 60% of the species), which mostly belong to genera now living in East Asia and/or North America. The rather dense temporal sampling allowed by the Italian floras (MARTINETTO et al. 2015), even if not so continuous as in Japan (MOMOHARA 2015), contributes to substantially improve our knowledge of the actual time of disappearance from Europe of several tens of plant species from 4.0 to 0.8 Ma (SVENNING 2003), thus telling us how much such phenomenon was a gradual retreat or a sequence of a few, definite events.

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7. Plates 1-3 and explanations

Plate 1

The scale bar is 1 mm, unless differently specified.

- Fig. 1. PINACEAE - *Picea florschuetzii*, cone, Castelletto Cervo II-GA21;
- Fig. 2a-b. *Pinus sylvestris* subsp. *pliocaenica*, cone, Castelletto Cervo I-GA3;
- Figs 3a-b, 4a-b. BETULACEAE - *Carpinus betulus* subsp. 1, fruits, Castelletto Cervo II-GA21. 3a, external view of a fruit with 3 thin ribs and style base preserved; 3b, opposite face of the fruit showing a hole, likely produced by animals; 4a, internal view of a split fruit; 4b, external view.
- Figs 5a-b. *Corylus avellana*, small-sized fruit (nut), Castelletto Cervo II-GA5.
- Figs 6a-b. CORNACEAE - *Cornus maii* sp. nov., endocarp from both sides showing the internal septum (6a) between the two seed locules; paratype PU105901, Ca' Viettone-CV3.
- Fig. 7. *Cornus maii* sp. nov., endocarp; holotype PU105902, Ca' Viettone-CV3.
- Fig. 8. *Cornus maii* sp. nov., endocarp dissected before burial and therefore infilled by sediment and poorly compressed. Notice the cross-section of the two seed locules and the internal septum. Paratype PU105903, Ca' Viettone-CV3.
- Fig. 9. *Cornus maii* sp. nov., endocarp with cuspidate base; paratype PU105904, Ca' Viettone-CV3.
- Figs 10a-b, 11a-b-c. EUCOMMACEAE - *Eucommia europaea*, partly decayed remains of fruits (samaras) covered by latex filaments, Castelletto Cervo II-GA5. 10a, b: fruit seen from both flat faces; 11 a-c: fruit seen from both the flat faces and from one side, to show the thickness.

Plate 2

The scale bar is 1 mm, unless differently specified.

- Figs 1, 2. JUGLANDACEAE - *Carya globosa*, endocarps, Castelletto Cervo I-GA1. 1, complete endocarp in external view; 2, internal view of one of the two valves of a split endocarp.
- Figs 3a-b, 4a-b. *Cyclocarya nucifera*, endocarps, Castelletto Cervo I-GA6 and GA1; 3a, internal view of one of the two valves of a split endocarp; 3b, external view; 4a, complete endocarp in apical view; 4b, basal view.
- Figs 5a-b, 6a-b, 7, 8. *Pterocarya limburgensis*, endocarps, Castelletto Cervo I-GA1. 5a, external view of one of the two valves of a split endocarp; 5b, internal view; 6a, complete endocarp in lateral view; 4b, view from the opposite side; 7, 8, complete endocarps.
- Figs 9, 10, 11. *Juglans bergomensis*, endocarps, resp. Buronzo-BU21, Castelletto Cervo I-GA1 and Buronzo-BU21. 9, 11, complete endocarps in external view; 10, internal view of one of the two valves of a split endocarp.

Plate 3

The scale bar is 1 mm.

- Fig. 1a-b, 2a-b, 3a-b. FAGACEAE - *Quercus* cf. *robur*, cupules, Buronzo-BU11, BU0;
- Fig. 4. *Fagus deucalionis*, cupule with complete, short peduncle, Canton Iuli-CC3;
- Figs 5a-b. HYDROCHARITACEAE - *Stratiotes intermedius*, seed, Buronzo-BU16.
- Fig. 6a-b. LAMIACEAE - *Ajuga antiqua*, achene with the same L:W ratio as those of the modern *A. reptans*, Castelletto Cervo II-GA21.
- Figs 7a-b-c, 8a-b. MAGNOLIACEAE - *Liriodendron geminata*, isolated seed seen from three sides, and pair of fused seeds, Buronzo-BU2 and Castelletto Cervo I-GA4.
- Fig. 9a-b. MENYANTHACEAE - *Menyanthes trifoliata*, seed, Buronzo-BU00.
- Fig. 10 a-b. INCERTAE SEDIS - *Carpolites pliocucurbitinus*, Castelletto Cervo II-GA5.
- Fig. 11. HAMAMELIDACEAE - *Parrotia* cf. *persica*, fruit, Enza-EZ38.
- Figs 12-14. *Parrotia reidiana*, fruits, Villafranca d'Asti-RDB1.

Text-figures

Text-fig. 1. Map of the Italian localities with carpofloras of Pliocene-Early Pleistocene age (circles), see Table 1 for additional information. A few Middle-Late Pleistocene sites cited in the text have also been reported (pentagons). The numbers correspond to those listed in Table 1, and indicate one or several neighbouring localities. 1 - Momello-Lanzo; 2 - Stura Fossil Forest, i.e. Pliocene outcrop with in situ stumps in the bed of the Stura di Lanzo River, close to the village of Nole Canavese; 3 - Lombardore; 4 - Barbania, Boschi di Barbania, Front; 5 - Ca' Viettone; 6 - Benasso, Pian Torinetto, Sento I and II; 7 - Buronzo, Candelo, Canton Iuli, Castellengo, Castelletto Cervo I and II, Cossato, Giffenga, Ronco Biellese, Terzoglio (i.e. the long Cervo River section); 8 - Boca, Pello; 9 - Re in the Vigezzo Valley (Middle or Late Pleistocene); 10 - Valle della Fornace; 11 - Almenno, Casnigo, Lefte (and Pianico, Middle Pleistocene); 12 - Steggio; 13 - San Pietro di Ragogna (and Valeriano Creek, Late Pleistocene); 14 - Castelnuovo Don Bosco; 15 - Arboschio, Baldichieri-Fornace, Baldichieri-North, Roatto, Valleandona, Villafranca d'Asti-RDB Quarry; 16 - Ceresole d'Alba; 17 -

Breolungi, Crava di Morozzo I and II; 18 - Cherasco-Stura, Fossano, Pocapaglia; 19 - Canale d'Alba, Cerro Tanaro, Rocche dei Perosini; 20 - Castelnuovo Bormida I-III, Cortiglione d'Asti, Sezzadio-Rio della Lupa; 21 - Arda-Castell'Arquato, Castell'Arquato-Monte Falcone, Chiavenna, Lugagnano; 22 - Stirone-Laurano; 23 - Enza-Traversetolo; 24 - Santerno-Codrignano; 25 - Marecchia; 26 - Botro Maspino and Cava Buttero (Middle or Late Pleistocene), Cava Campitello (Middle or Late Pleistocene), Meleto, Poggio Rosso, San Giustino Valdarno, Santa Barbara-Gregor's outcrop (Upper Valdarno area); 27 - Aulla; 28 - Borro Strolla, San Miniato; 29 - Ghirlanda basin; 30 - Fighille; 31 - Pietrafitta; 32 - Cava Toppetti I-II, Dunarobba, Monticello Umbro, Torre Picchio, Villa San Faustino; 33 - Cellino Attanasio; 34 - Riano Romano (Middle Pleistocene).

Text-fig. 2. *Cornus maii* sp. nov.; variability of the endocarps (paratypes) from the later CV3 of the locality Ca' Viettone, supposed Zanclean. PU105905-PU105916.

Text-fig. 3. *Fagus deucalionis*; cupules with complete peduncles (field photograph, year 2003) extracted from a particular lense-shaped concentration of plant remains at the base of the plant-bearing portion (ca. 2 m thick) of the Stura Fossil Forest succession. Piacenzian, Pliocene.

Text-fig. 4. *Ajuga antiqua*; variability of the nutlets from the basal layer (STU0) of the plant-bearing portion (ca. 2 m thick) of the Stura Fossil Forest succession. Piacenzian, Pliocene.

Table

Table 1. List of the Italian localities of Pliocene-Early Pleistocene age cited in the text. The numbers in the left column are reported in Fig. 1 as to roughly show the location of each site. More detailed information can be found in the publications listed in the right columns. B = brackish or tidal sediments; F= freshwater sediments; M = marine sediments.