Cainozoic Research, 5(1-2), pp. 71-88, November 2006

The Pliocene macro- and microflora of lacustrine sediments from Meleto (Valdarno, N. Italy) and its ecological, palaeobiogeographical and climatic interpretation

Dedicated to Ervín Knobloch†, Praha

Thilo C. Fischer[1] & Rainer Butzmann[2]

[1] *Institute for Ornamental Crops and Horticultural Plant Breeding, Technical University Munich, Am Hochanger 4, D-85350 Freising, Germany; e-mail: thilo.fischer@wzw.tum.de*
[2] *Fuggerstraße 8, D-81373 München, Germany*

Received 13 March 2004; revised version accepted 2 July 2006

The exceptionally well preserved flora from the Neogene sediments of Meleto, in the Valdarno region (Italy), comprises numerous taxa of leaves (58 taxa), diaspores (39 taxa) as well as pollen and spores (63 taxa). The plant taxa, many of which have been tentatively correlated with extant taxa, have been assigned to different ecological habitats representing vegetational units surrounding a lake. Palaeobiogeographically, the flora is dominated by arctotertiary elements, but also contains palaeotropical elements, some representing "old" taxa (*e.g. Trigonobalanopsis rhamnoides* (Rossmässler, 1840) Kvaček *et* Walther, 1988, *Sinomenium cantalense* (Reid, 1920) Dorofeev 1963). By using the climatic requirements of the nearest living relatives, a Cfa-climate has been inferred for the Pliocene Valdarno region. The carpoflora and the leaf assemblage closely resemble Upper Miocene and Lower Pliocene floras of Southern and Middle Europe in contrast to the published Late Pliocene to Pleistocene ages. The anomaly may be interpreted by a persistence of species characteristic for Miocene floras in the area. Altogether, the Meleto flora provides a new and detailed insight into the Neogene vegetation of the Valdarno region and significantly contributes to the understanding of floral development in the Mediterranean area.

KEY WORDS: Carpoflora, leaf flora, microflora, Pliocene, Neogene, palaeoclimate, palaeoecology, Italy.

Introduction

The Meleto site is located in the Arno valley, southeast of Florence (Valdarno, Italy; Fig. 1). Tectonically, the Valdarno region is a half-graben bordered by a fault in the northeast and folds in the southwest. The onset of sedimentation in the basin has been dated to the Late Pliocene, based on palaeomagnetic investigations (Albianelli, 1995) and mammal remains from the basal formation (triversa faunal unit with *Tapirus arvenensis*, *Ursus minimus*, *Dicerorhinus* sp. and *Leptobos* sp. (Azzaroli & Lazzeri, 1977)). The sediments have been subdivided into three units: the Castelnuovo Group, with Spedalino Gravels and Sands (50 m), the Meleto Clays (200 m), with two basal lignites, and the San Donato Sand (80 m); overlain by the Montivarchi and Monticelli Groups (Merla & Abbate, 1967; Magi, 1989; Billi *et al.*, 1991; Torre *et al.*, 1993; Bertini, 1994). Recently, however, palaeomagnetic investigations from the Faella section and the Galleria Tasso section in the Upper Valdarno (belonging to the younger Montevarchi Group) and subsequent correlation of the results with the Santa Barbara profile seem to indicate that the Meleto clay was deposited in the Gauss chron (3.04 Ma to 2.58 Ma) and would thus be of early Late Pliocene age (Napoleone *et al.*, 2003).

Despite their floral richness, only a few and mostly old reports exist on the fossil floras from the Valdarno. Gaudin and Strozzi (1858, 1859, 1862) and Ristori (1886) predominantly described leaves and large fruits, whereas Billi (1980) and Knobloch (1997) gave lists of taxa identified from old museum collections. Teodoridis and Gregor (2001) described a leaf flora comprising seven taxa from the Santa Barbara mine, close to Meleto. In contrast, numerous palaeocarpological studies on the Neogene of Northern Italy have been published (Bertoldi & Cavallo & Martinetto, 1996; Martinetto, 1995, 1996, 1998a, 1998b, 2001a; Günther & Gregor, 1989, 1990, 1992, 1993, 1997, 1998). In 1992, a landslide in the vicinity of Meleto exposed a section through the Meleto clays, allowing excavations. This offered the opportunity to study a fossil flora that is rich in species and has well preserved leaves, fruits, seeds and palynomorphs.

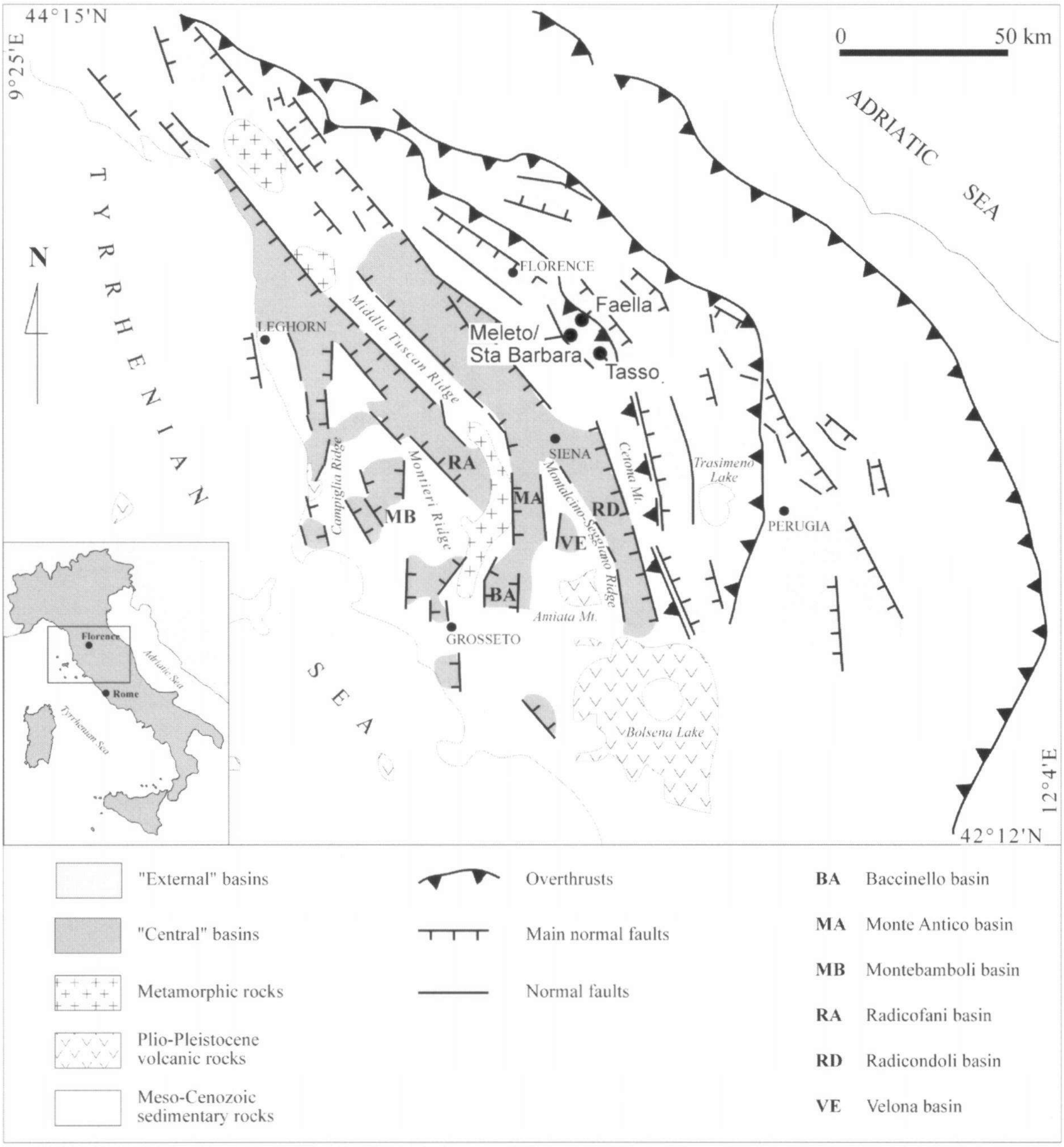

Figure 1. Structural sketch map of part of the Northern Apennines, showing the location of Meleto / Santa Barbara and the sites of the cited magnetostratigraphical investigations Faella and Tasso (reproduced with kind permission from Ghetti et al. (2002)).

As a result, a new *Citrus* species has been described (*Citrus meletensis* Fischer and Butzmann, 1998; Fischer *et al.*, 1998) and knowledge about the morphology, anatomy, palaeobiogeography and stratigraphical distribution of several taxa (*e.g. Taiwania schaeferi* Schloemer-Jaeger, 1858, *Acer pyrenaicum* Rérolle 1884-1885 (syn. *Acer ilnicense* Iljinskaja 1968; Ströbitzer-Hermann, 2002, Kvaček *et al.*, 2002), *Trigonobalanopsis*) was improved. These findings also demonstrate the huge potential of the Valdarno sediments for future palaeontological studies. The diatoms from Meleto were subsequently described by Witkowsky *et al.* (2001) and comprise more than 110 taxa.

Here, the flora of Meleto has been closely characterised with respect to its ecology, palaeobiogeography and climatic interpretation. The systematic descriptions have already been given in Fischer & Butzmann (2000). For this, extensive comparisons to southern and middle European Neogene floras have been made and an approach to a comprehensive interpretation including recent progresses has been given.

Figure 2. Graphical illustration of the Meleto leaf flora providing an overview of characteristic taxa ("Florenbild" *sensu* Mai, 1995). Scale bar: 2 cm (exceptions indicated in the legend). 1: ***Magnolia liblarense***, 2: ***Pterocarya paradisiaca***, 3: ***Zelkova zelkovaefolia***, 4: ***Acer tricuspidatum***, 5: ***Ocotea hradekensis***, 6: ***Quercus drymeia***, 7: ***Quercus pseudocastanea***, 8, 29: ***Fagus*** cf. ***haidingeri***, 9: ***Grewia*** cf. ***staubi***, 10: ***Alnus cecropiaefolia***, 11: ***Salix*** sp., 12: ***Sassafras ferretianum***, 13: ***Sapindus falcifolius***, 14: ***Citrus meletensis***, 15: ***Zelkova*** sp. (x2), 16: ***Carpinus suborientalis***, 17: ***Glyptostrobus europaeus*** (x2), 18: ***Populus populina***, 19: ***Acer ilnicense***, 20: ***Trigonobalanopsis rhamnoides***, 21: ***Betula insignis***, 22: ***Betula subpubescens***, 23: ***Viscum*** cf. ***morlotti***, 24: ***Taxodium dubium*** (x3), 25: ***Ceratophyllum tertiarium***, 26: ***Taiwania schaeferi*** (x2), 27: ***Platanus leucophylla***, 28: ***Smilax weberi***, 30: ***Quercus ilicoides***, 31: ***Chionanthus*** sp., 32: ***Quercus czeczottiae***, 33: ***Laurophyllum markvarticense***, 34: ***Sapotacites*** cf. ***minor***, 35: Leguminosae, 36: ***Myrica lignitum***, 37: ***Laurophyllum*** cf. ***pseudoprinceps***, 38: ***Taxodium dubium***, 39: ***Acer intergerrimum***, 40: ***Daphnogene polymorphum***, 41: ***Quercus roburoides***.

Area and locality description, Methods, Material

The Meleto site (longitude 11°45' E, latitude 43°45' N), which was exposed by a landslide in 1992, is located south-west of the small village of Meleto, in the Valdarno region (Italy; Fig. 1). The village and the landslide are located near the former Santa Barbara coal pit (ENEL-Corporation). The landslide was about 300 m long, with the maximum height of the exposed section being about 10 m. There are no sedimentological data on the Meleto series. Meleto is the type locality for the "Meleto Clays", it is a monotonous profile, only interrupted by one silt horizon.

The plant remains were excavated in 1993 and subsequent years. Most fossils were derived from loose blocks at the bottom of the section. Fossil leaves and larger fruits or seeds were exposed from the clay by splitting. Leaves from the unoxidised sediments were excellently preserved and allowed studies on cuticles, although in many cases the application of a diluted aqueous solution of glue (20% Ponal^R) was necessary to prevent disintegration during drying. Unoxidised clay has a grey to light blue colour whilst weathered and oxidised clay has a light brown colour and sometimes still contained preserved leaf cuticles, but mostly only impressions remained. For the analysis of small-sized carpological material, about 30 kg of the silt layer was dried, disintegrated with 3% H_2O_2 and sieved. The remnant was dried and fossil plant remains were picked out using a binocular microscope. For pollen analysis, two clay samples were processed and studied by K.-J. Meyer (Niedersächsisches Landesamt für Bodenforschung, Hannover) using standard methods (Mielke, in Bender, 1981). Cuticular analyses of selected leaves were performed by Z. Kvaček (Charles University, Prague). The material collected by the authors and by C. Mayr (Fürstenfeldbruck) has been deposited at the Naturmuseum Augsburg and is catalogued with the reference numbers 1995-1/1289, 1999-series/1703, 1999-series/1691 and 1999-series /1695.

Results

Characterization of the Meleto flora – Leaf compressions are the dominant macrofossils; more than 1000 specimens have been assigned to taxa on the base of leaf morphology. When the morphology did not lead to an unambigious identification, an additional cuticular analysis was performed. In total, 58 leaf taxa have been identified (Table 1). A "Florenbild" *sensu* Mai (1995) provides a graphical overview of the leaf flora (Fig. 2).

Relative abundances of all taxa have been summarised in Table 4. The flora is dominated by legumes, *Acer* and *Zelkova*, although many other taxa are also abundant. Exceptional findings were *Citrus meletensis*, *Chionanthus* sp., a *Ceratophyllum tertiarum* shoot and a well preserved *Taiwania schaeferi* twig. Carpological fossils (39 taxa) were mostly recovered from the accompanying silt, except for large or winged diaspores recovered from clay deposits (Table 2). Among the carpological fossils, *Liquidambar* and *Trigonobalanopsis* are dominant.

In total, the macroflora comprises 58 taxa of leaves/needles/twigs and 39 taxa of diaspores. Figures 3, 4 and 5 show examples of the dominant species or of exceptional specimens. The microflora was also investigated in detail; a total of 63 taxa have been identified (Table 3).

As indicated in Tables 1-3, several taxa (genera, families) could be identified as diaspores, leaves or pollen/spores, thus allowing clues about possible correlations of organ taxa. However, definite affiliation to the same biological species has not been claimed with these assignments, but might support such conclusions in the future. Thus, the fossils provide a very extensive database, available for interpretations of the palaeoecology, palaeobiogeographical relations, palaeoclimate and age of the Meleto flora.

Ecological interpretation

The sedimentary sequence exposed is a monotonous series of clays, interrupted only by a 15 cm layer of silt; these lithologies indicate a lacustrine facies with an intervening influx of slowly moving water. The presence of vivianite (Thewalt & Gregor, 2001), a blue Fe^{II} phosphate forming under chemically reducing conditions, is evidence for anoxic conditions in at least the deeper regions of the water body. These conditions were most likely caused directly by the influx of organic matter or indirectly by anorganic nutrients (N, P) from surrounding forests, with the subsequent growth of green algae (*Pediastrum* fsp., *Botryococcus* sp.) and diatoms.

The floral elements from Meleto have been assigned to different habitats by comparing them with the ecological requirements of their nearest related living species, using the classification of Van der Burgh (1983, 1987).

The correlations and resulting ecological assignments have been given in Table 4, together with the respective abundance of the fossil species.

With the exception of streamside vegetation (2), heath (8), and peat bog (9), all vegetational units were present. Species of vegetational units 3-7 are most abundant; these are wetland forest, forest border-scrub vegetation, flood plain forest, upland forest and coniferous forest. Only few waterplants (*Ceratophyllum*, *Trapa*), representing open water vegetation (1) have been found, and no species belonging to a streamside vegetation (2). Together with the facies of the clay and the silty sediments, this hints at slowly moving or quiet water as the origin of the sediments. Vegetation units 3-7 represent the typical floral zones around a lake and are each represented by several species: The wetland forest (3) was dominated by *Taxodium*, *Alnus*, *Liquidambar*, Lauraceae (*Daphnogene*, *Laurophyllum*, *Ocotea*, *Sassafras*), *Myrica*, Salicaceae (*Salix*, *Populus*), *Palaeocarya* and *Fraxinus*. The forest border-scrub vegetation (4) was composed mainly of *Acer* species, and the same Lauraceae, *Pterocarya*, and *Populus*. The drier vegetation unit of flood plain forest (5), in contrast, was made up of *Acer*, *Carpinus* and *Quercus* species. An upland forest (6) consisted predominantly of Fagaceae (*Trigonobalanopsis*, *Quercus*, and *Fagus*), *Acer* species, *Zelkova*, and *Platanus*. With increasing distance from the water and altitude, the terrain was drier. Conifers adapted to these conditions (*Abies*, *Cedrus*, *Picea*) obviously grew in remoter habitats (coniferous forest (7)). As a consequence, cones, seeds and needles of these conifers are rare. In contrast, the number of conifer taxa detected as pollen is larger, most likely due to wind transport of pollen (Table 3); *Quercus* may also have been present there. The vegetation unit peat bog (9) can be excluded from the interpretation: the studied exposed profile of the Meleto clay does not contain any lignitic components. Correspondingly, the few taxa recovered from the Meleto profile that may occur in a peat bog (*Cathya vanderburghii*, *Pinus urani*, *Pinus hampeana*, and *Myrica lignitum*) are also indicative of one or two other vegetation units, which are themselves represented by many more other taxa.

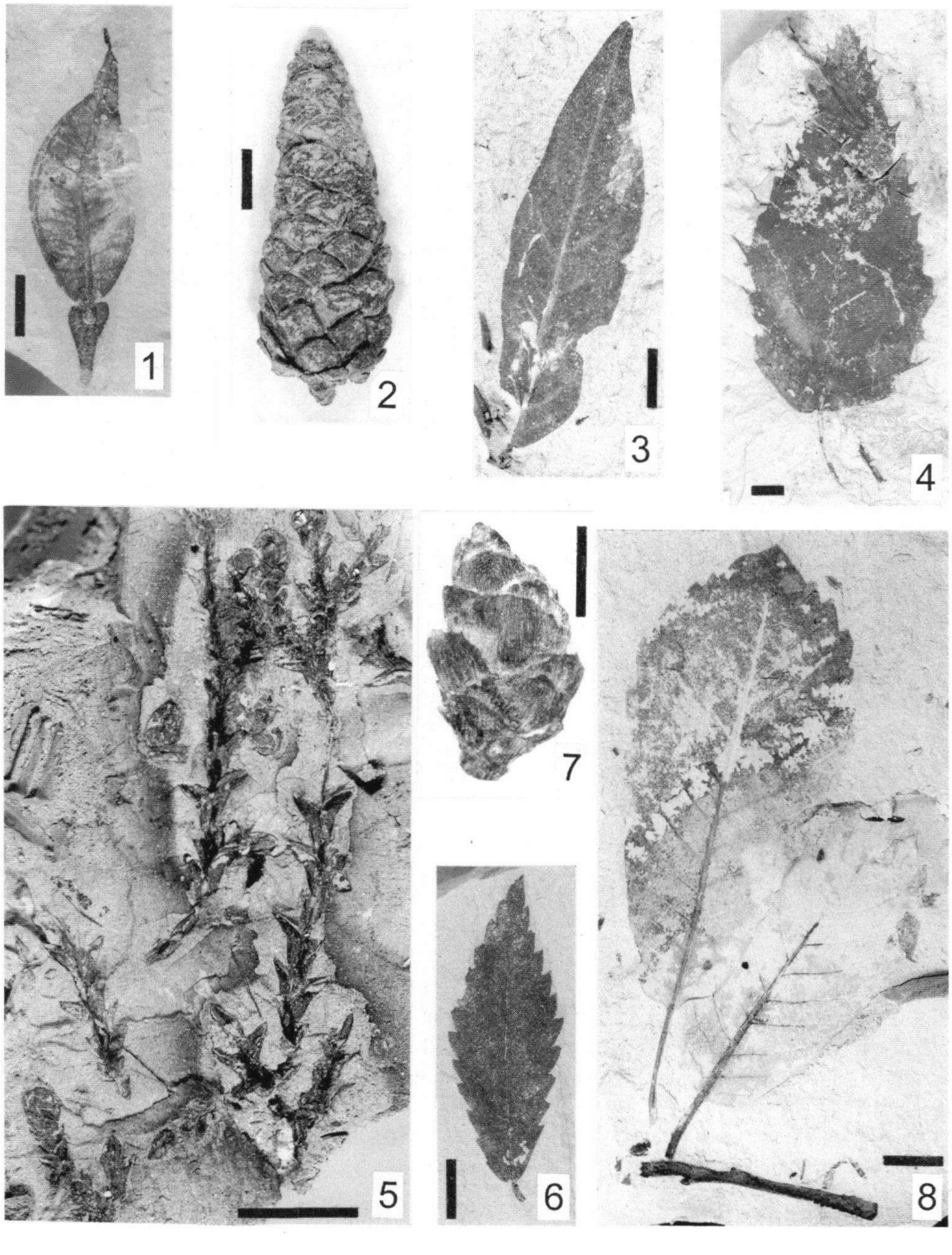

Figure 3.

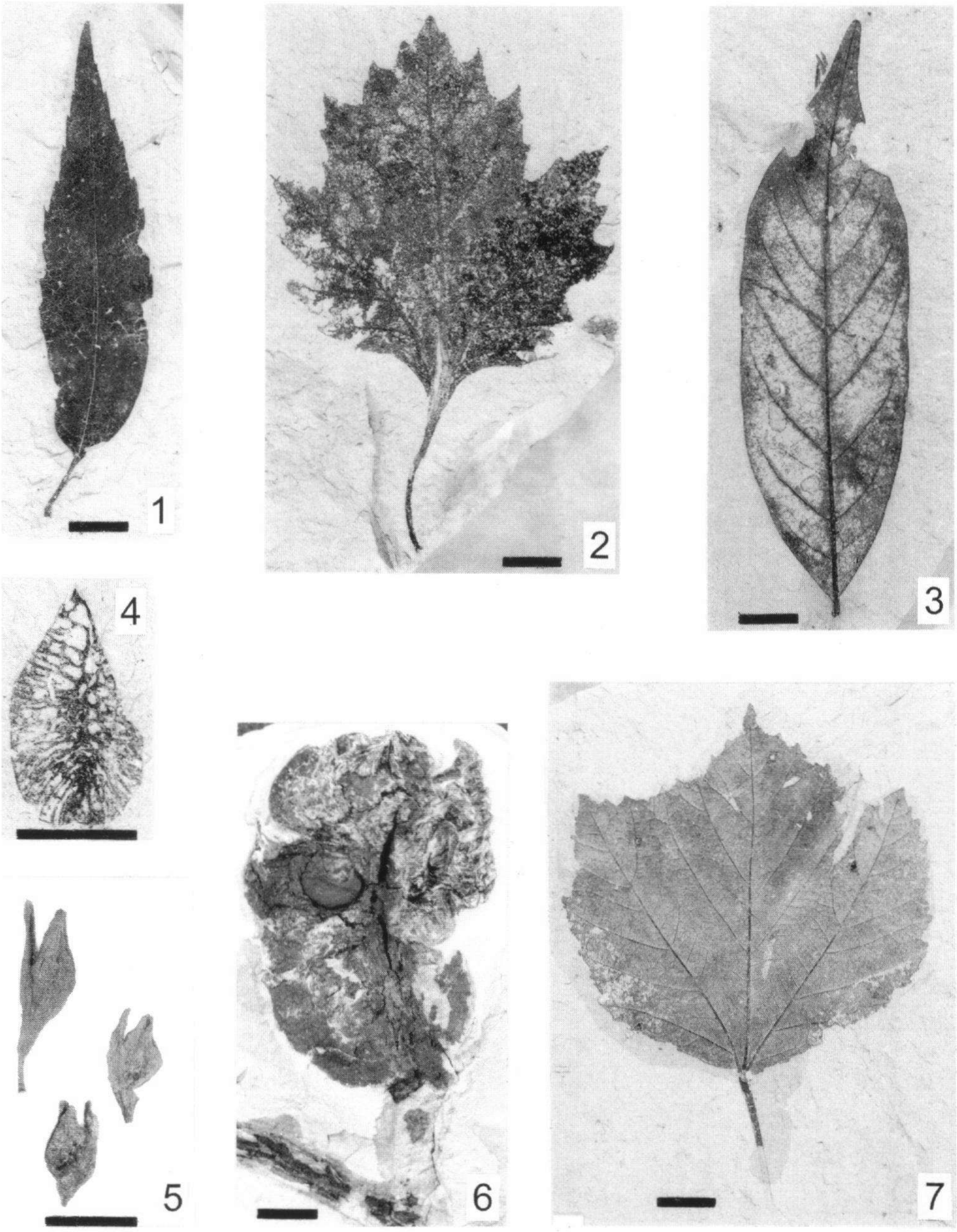

Figure 4.

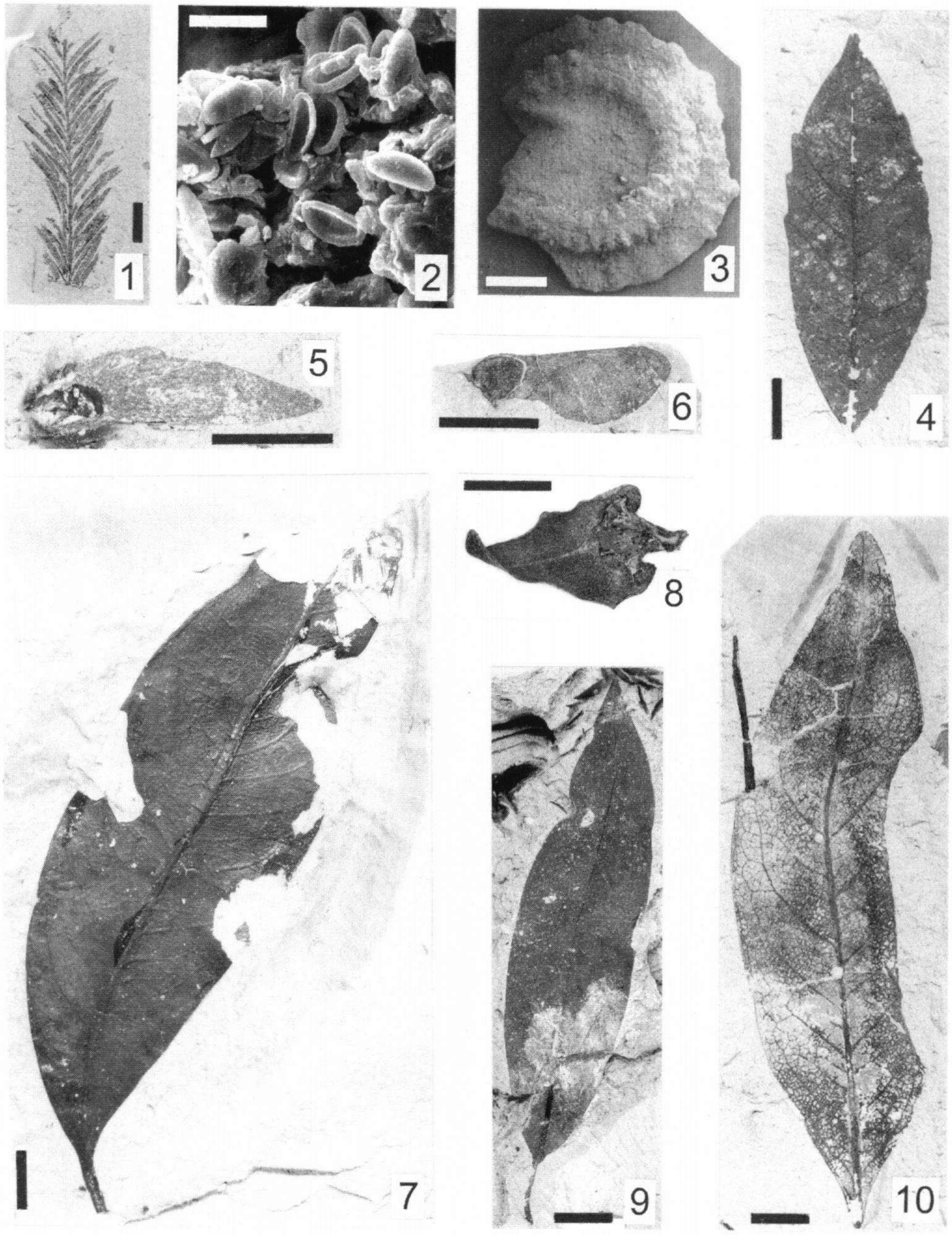

Figure 5.

Figure 3. Scale bar: 1 cm. 1: *Citrus meletensis*, 2: *Pinus hampeana*, 3: *Trigonobalanopsis rhamnoides*, 4: *Quercus czeczottiae*, 5: *Taiwania schaeferi*, 6: *Zelkova zelkovaefolia*, 7: *Cathaya vanderburghii*, 8: *Quercus pseudocastanea*.

Figure 4. Scale bar: 1 cm. 1: *Quercus drymeia*, 2: *Platanus leucophylla*, 3: *Laurophyllum* cf. *pseudoprinceps*, 4: *Craigia bronni*, 5: *Trigonobalanopsis exacantha*, 6: *Magnoliostrobus* sp., 7: *Acer ilnicense*.

Figure 5. Scale bar: 1 cm (exceptions indicated in the legend). 1: *Taxodium dubium*, 2: *Rosellinites congregatus* (scale bar: 10 µm), 3: *Sinomenium cantalense* (scale bar: 1 mm), 4: *Myrica lignitum*, 5: *Pinus* cf. *urani*, 6: *Acer* sp., 7: *Laurophyllum markvarticense*, 8: *Pseudolarix schmidtgenii*, 9: *Ocotea hradekensis*, 10: *Magnolia liblarense*.

Palaeobiogeography

The palaeobiogeographical characteristics of the macroflora have been analysed using the approach of Günther & Gregor (1989, 1990, 1992, 1993, 1997, 1998). This includes the analysis of about 500 carpofloras; only the results for the most closely related floras have been shown (Tables 5, 6). The most closely related carpofloras are from Italian Neogene localities (most significant: Candelo, Scrivia, Ca' Viettone and Castellengo), as well as from some other European Neogene sites (*e.g.* Aubenham). The palaeobiogeographical characteristics considered were the presence of the extant genus in Europe (native or exotic), the assignment to arctotertiary or palaeotropical elements (according to the concept of Engler, 1879/1882, and the affiliation lists provided by Günther & Gregor, 1990), and the geographical distribution of the extant genus. Characteristics of the taxa, such as growth form, dependence on water, and abundance were also included. The analysis was performed separately for leaf and diaspore macrofloras (Fig. 6).

Based on these characteristics, the macroflora almost exclusively comprises woody plants and plants of drier habitats, with relatively few swamp plants and water plants. Arctotertiary elements dominate the diaspores (87%) and leaves (71%) compared to palaeotropical elements. Leaf margin analyses gave comparable results. Leaves belonging to the palaeotropic taxa mostly have an entire margin whilst arctotertiary ones generally possess margins with teeth (*e.g.* Mai, 1995); leaves with a toothed margin are dominant (65%), as arctotertiary elements also are. However, there are more exotic elements (60% vs. 44%) among the diaspore flora than among the leaf flora. The weighting of extant geographical distributions of the genera identified by leaves is: holarctic > dispersed > asiatic/american > tropical/subtropical > cosmopolitan. Almost all (97% / 95%) species belong to extant genera.

Palaeoclimate

Palaeoclimate analysis has been based on the climatic requirements of the nearest related living species. This approach has been well established in palaeobotany since the 19th century (see also Mosbrugger, 1999) and was applied to Italian floras by Martinetto (2001b). All the taxa of the Meleto flora identified by macroremains were included in this analysis. When the nearest living relative indicated more than one climate, all of them were included. The results show that most diaspore and leaf taxa (79% / 57%) indicate a Cfa climate, with 13% and 28% taxa indicating a Cfb climate. Thus a Cfa-palaeoclimate has been inferred for the time of sedimentation.

Comparison with other Neogene floras and age of the leaf flora

For comparison with the leaf flora, 21 other floras from the whole Mediterranean realm were chosen. Ten well studied floras (based on the species number and level of investigation) were compared in detail: Gabbro, Senigallia, Carbonara Scrivia, "Valdarno", Coiron, Vegora, Montevarcchi, Arboschio, Ceyssac and Perrier. For the comparisons, emphasis was mainly laid on the dominant taxa at Meleto: *Acer*, legumes, *Zelkova*, and also the abundant taxa *Laurophyllum*, *Trigonobalanopsis*, *Fagus*, *Taxodium*, *Daphnogene*, *Platanus*, *Pterocarya*, *Magnolia*, *Quercus drymeia* Unger, 1845, *Quercus* sp. (lobed leaves, roburoid) and *Quercus* sp. (serrate leaves). The relative abundance of the taxa was also taken into account, as well as the presence or absence of rare taxa.

Comparing the Mediterranean leaf floras, similarities with the Italian Upper Miocene floras of Gabbro (Tuscany; Berger, 1957), Senigallia (Marken; Massalongo & Scarabelli, 1858/1859) and also Carbonara Scrivia (Alessandria; Brambilla *et al.*, 1982; Knobloch, 1997) are striking. The classic floras of "Valdarno" (Tuscany; published as Upper Miocene; Gaudin & Strozzi, 1858, 1859, 1862; Ristori, 1886; Knobloch, 1997) are most similar to the Meleto flora as might be expected, but they are composed of material from various localities of unknown stratigraphic position and hence are less valuable for comparisons. The relative abundance of taxa appears to be comparable for the floras, although there are differences in the presence or absence of some taxa. Palm leaves are present in the "Valdarno" (Gaudin & Strozzi, 1859), whereas only palm pollen have been recorded from Meleto. *Magnolia* and *Betula* are missing in the Gabbro flora whilst *Trigonobalanopsis* is present in both the Gabbro and Meleto floras. The Senigallia flora also has rare elements which have been found in the Meleto flora, such as *Citrus* (*Hesperidophyllum*), *Sapindus*, *Grewia* and *Ocotea*. Conifers such as *Tsuga*, *Pinus*, *Sequoia*, *Taxodium* and *Glyptostrobus* have been described from Carbonara Scrivia flora and these are also present at Meleto. *Cornus* and *Corylus* are additionally present at Carbonara Scrivia but not at Meleto. Some rare elements, such as *Sapindus*, are common to Carbonara Scrivia and Meleto.

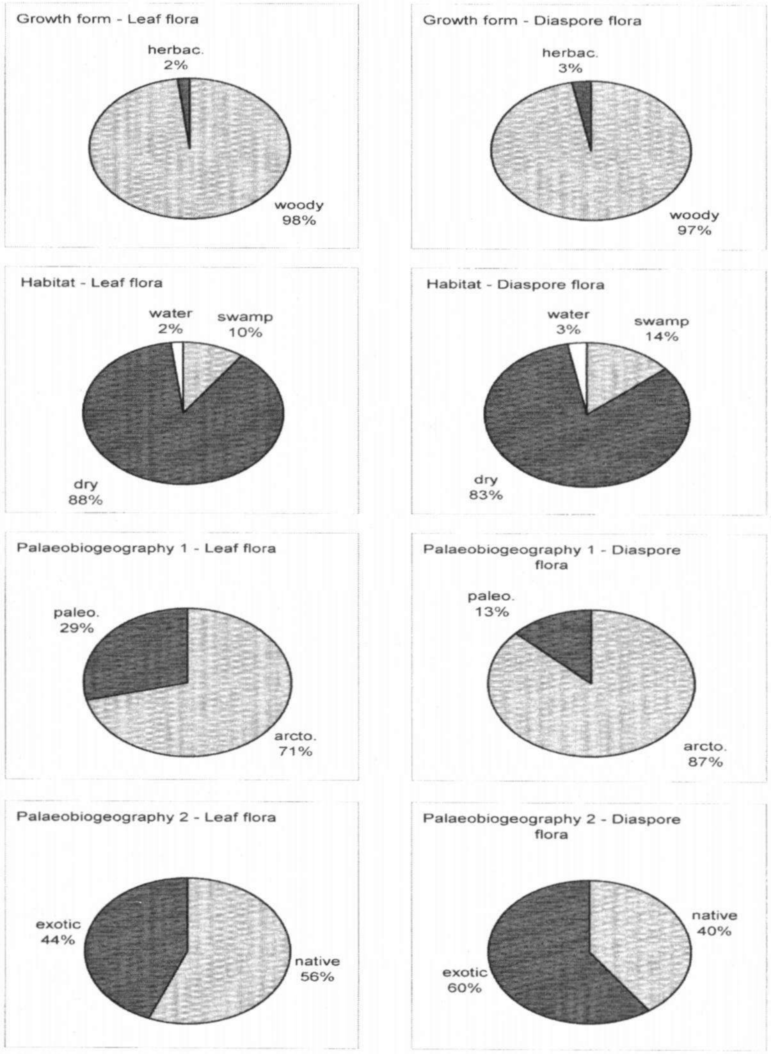

Figure 6-1. Palaeobiogeographical and further characteristics of species identified as diaspores or leaves in Meleto. Abbreviations: Growth form: tree (woody), herbac. (herbaceous plant); habitat: swamp, dry, water; palaeobiogeography 1: arcto.: arctotertiary, palaeo.: palaeotropical; palaeobiogeography 2: native, exotic; palaeobiogeography 3: american/asiatic, dispers, holarctic, cosm.: cosmopolitan; trop./subtr.: tropical/subtropical; extinction status: fossil, extant; climate: percentages of nearest living relatives indicating the respective palaeoclimate.

The Upper Miocene locality at Coiron (Ardèche), located near to the Rhone valley, has been well studied (also palynologically; Grangeon, 1958; Mai, 1995) and its age has been confirmed (Suc & Zagwijn, 1983) by radiometrical methods at 8 – 8.5 Ma (Tortonian; Iskandar, 1990). In contrast to the Meleto flora, the genera *Ulmus, Celtis* and *Cornus* have been reported from Coiron, which could be interpreted as a more arctotertiary influence. *Taxodium, Trigonobalanopsis, Myrica, Sassafras* and *Smilax* are all missing in Coiron. However, the most abundant taxa are common to both floras.

The flora of Vegora (Greece) recently described in detail by Kvaček *et al.* (2002), is also strikingly similar to the Meleto flora and has been radiometrically dated to the Upper Miocene (Pontian/Messinian, 5.97 Ma; Gersonde & Velitzelos, 1978; Steenbrink *et al.*, 2001 (cited in Kvaček *et al.*, 2002). Leaf taxa common to both Meleto and Vegora are *Taxodium, Pinus, Laurophyllum, Sassafras, Daphnogene, Fagus, Quercus, Alnus, Betula, Platanus, Pterocarya, Zelkova, Populus* and *Acer*. With the exception of *Ginkgo, Ulmus*, and *Hedera* all Vegora leaf taxa are also present in Meleto.

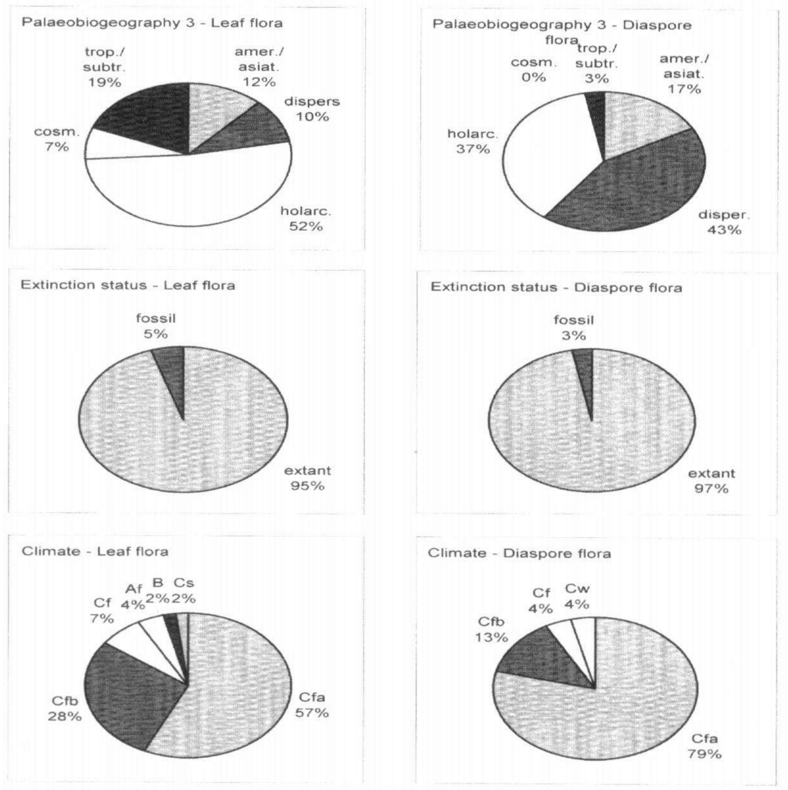

Figure 6-2.

All Meleto *Fagus* leaves belong to *Fagus haidingeri* (Denk, pers. comm.), which has been shown in a recent revision of Cenozoic *Fagus* species (Denk, 2004) to be characteristic for Upper Miocene floras.

Comparing the Meleto flora with the Lower Pliocene Montevarcchi flora (Valdarno; Billi, 1980; Knobloch, 1997), the absence of *Zelkova*, Leguminosae, *Fagus*, *Daphnogene*, *Pterocarya*, *Magnolia*, as well as *Taxodium* and roburoid *Quercus* at Montevarcchi has been noticed. In both floras, the genera *Trigonobalanopsis*, *Laurophyllum*, *Platanus*, *Sassafras*, *Acer*, *Betula*, *Salix*, *Populus* and *Smilax* have been found. For all Upper Pliocene floras from Italy and France, such as those from Arboschio (Cantarana; Knobloch, 1997), Ceyssac (Puy-en-Velay, Haute Loire; Depape, 1922; Bout & Marty 1936; Mai, 1995), as well as Perrier (Puy-de-Dome; Bout & Marty, 1936) the "old" taxa, such as *Trigonobalanopsis*, *Laurophyllum*, *Myrica*, *Sapindus*, *Quercus drymeia*, *Q. ilicoides* and *Magnolia* have not been documented whilst "young" elements, such as *Ulmus* and *Corylus*, *Picea*, *Abies*, *Salix* are important. There is less congruence with the Meleto leaf flora. The Upper Pliocene small flora from Perrier consists (with the exception of *Laurus*) only of native elements.

Thus, with the exception of the floras of the Valdarno itself, the Meleto flora has more similarities with Upper Miocene floras of the Mediterranean (including radiometrically dated ones) than with the corresponding Pliocene floras. This is in contrast to the palaeomagnetically determined early Late Pliocene age of the Meleto sequence (Napoleone *et al.*, 2003). The same discrepancy in age determination is found by interpretation of the diaspore flora (below and Discussion).

Diaspore flora

The diaspore floras of the Meleto silts and clays, respectively, were compared to the dataset of more than 500 Neogene European floras (including well investigated middle European floras like those of Reuver and Tegelen) using the method described by Günther & Gregor (1989, 1990, 1992, 1993, 1997, 1998). The European diaspore floras identified by this means that are most closely related to the Meleto silt and clay flora are shown in Tables 5 and 6. In general, the Meleto flora has few similarities with other diaspore floras (up to 36%); but the most similar floras (Candelo, Scrivia, Ca'Viettone, Castellengo, Sento, "Valdarno", Val Chiusella, Castellina) are all from Italian localities and mostly of Late Miocene to Early Pliocene age.

Discussion and conclusions

The investigation of the fossil flora of Meleto led to the identification of 160 fossil taxa (Tables 1-3), many of which had not been described before from the Valdarno basin. Furthermore, the abundance and excellent preservation of the fossils allowed detailed description and studies to be made, including the identification of a new species. Since many taxa have been identified from different types of macro- and microfossils it seems that the material is a good representative of the Pliocene flora. Moreover, the Meleto flora can serve as a reference flora for other sites in central Italy as it comprises all classes of macro- and microremains, each represented by several taxa. Furthermore, the co-occurrences of diaspores, leaves, and pollen and spores allow conclusions for tentative identification of the biological species.

The Meleto flora is clearly dominated by woody plants from drier habitats, although a few taxa belong to wetlands (*e.g. Glyptostrobus*). The rareness of waterplants (*Ceratophyllum*, *Trapa*) suggests that the aquatic flora was limited, except for algae. Although waterplants leaves have a low preservation potential, since they are not shed and have thin cuticles, fruits and seeds should have been preserved if water plants had been present. The lack of macrofossils from non-aquatic herbaceous plants might also be due to a low preservation potential of their vegetative organs as well as their fruits or seeds. Such a phenomenon has been reported from many fossil sites (*e.g.* Meller & Hofmann, 2004, Table 3). Several herbaceous plants were only identified by pollen; pollen of wind-pollinated taxa like Graminae and Cyperaceae may have been transported long distances. The same phenomenon has been observed for conifers which are adapted to drier habitats: *Abies*, *Picea*, *Cedrus*. Most likely, they grew at higher altitudes and at some distance from the lake. Therefore, their pollen is present, but the corresponding macrofossils are missing. However, most of the species belonged to the different habitats that would have surrounded a lake. This is in accordance with the topography inferred for the Neogene Valdarno half graben: a basin with surrounding hills.

The Cfa-climate reconstructed from the Meleto flora agrees with other analyses of more or less contemporaneous floras from the Italian Neogene (Martinetto, 1996).

Comparison of the carpoflora with other Mediterranean assemblages suggests a Late Miocene to Early Pliocene age. In contrast, the leaf flora strongly suggests that the Meleto flora has more similarities with Upper Miocene floras rather than Upper Pliocene floras. Leaf floras from the Italian Upper Pliocene like Arboschio and Cantarano (Knobloch, 1997; Martinetto, 2001b) are generally scarce. The analysis of the diatom flora (Witkowsky *et al.*, 2001) resulted in a putative Late Miocene to Early Pliocene age. However, current magnetostratigraphical investigations indirectly concluded an early Late Pliocene age for the Meleto clay (Napoleone *et al.*, 2003), which is closer to our results. Together with Martinetto's results, which correlate Italian Neogene floras and interpret Central Italy as a centre of refuge for thermophilous plants (Martinetto, 2001c), the apparently older ages may be a result of using palaeobotanical techniques for age estimations in a refuge area .

The rich fossil floras of the Valdarno clearly need extensive stratigraphical investigations that use several different methods of age determination. Beyond the classical descriptions by Gaudin and Strozzi (1858, 1859, 1862) as well as Ristori (1886), further fossil floras should be collected, be determined according to modern nomenclature, and be stratigraphically correlated. This would allow either correction of the age determination of the Meleto sediments or would support the interpretation of Central Italy as a centre of refuge for thermophilous plants during the Neogene. Furthermore, it would most likely result in further identification of yet unknown fossil taxa.

Acknowledgements

We gratefully acknowledge the support we received for this work. Dr. H.-J. Gregor (Naturmuseum Augsburg) discovered the Meleto landslide as a palaeobotanical locality, guided our first field trip to the site and supported us with species determinations, literature discussion, and manuscript correction. K.-J. Meyer (Niedersächsisches Landesamt für Bodenforschung, Hannover) provided the palynological analysis, Prof. Dr. Z. Kvaček (Charles University, Prague) and Dr. J. Kvaček (National Museum, Prague) did cuticular analyses for some problematical leaves. H. Schmitt (Dietramszell) provided most drawings of leaves. P. Ghetti (Siena) and E. Gliozzi (Roma) kindly permitted the reproduction of the structural map from their publication. Furthermore we are grateful to Dr. B. Meller, Dr. H. Rice (both University Vienna, correction of the manuscript), Dr. G. Miotti (ENEL-Corporation, Santa Barbara), Dr. T. Denk (Swedish Museum of Natural History, Stockholm), C. Mayr (Fürstenfeldbruck), Dr. E. Martinetto (University Torino), O. Obermeier (Donauwörth), A. and E. Hepfer (Ulm), Dr. H. Rampf (München), Dr. M. Sachse (Naturhistorisches Museum Mainz), Dr. F. Schuhwerk and M. Werner (LM-Universität München), T. Günther (München), Dr. E. Knobloch † (Czech Geological Survey, Prague), Prof. emer. Dr. R. Hantke (Zürich), U. Butzmann (München) and all members of the PBA (Paläobotanische Arbeitsgruppe, Augsburg, Günzburg) for their support. We acknowledge the helpful comments of the reviewers J. van Konijenburg-van Cittert (Leiden) and J. van der Burgh (Utrecht).

References

Albianelli, A. 1995. *Caratteri magnetici e magnetostratigrafici dei sedimenti anossici fluviolacustri e marini coevi*, Parma (University Parma) (unpublished MSc thesis).

Azzaroli, A. & Lazzeri, L. 1977. I laghi del Valdarno Superiore. *Centro Studi Geologia Appennino CNR (Università di Firenze) Pubbl.* 26, 1-4.

Berger, W. 1957. Untersuchungen an der obermiozänen (sarmatischen) Flora von Gabbro in der Toskana. *Palaeontographica Italica* 51 (21), 1-96.

Bertini, A. 1994. Palynological investigations on Upper Neogene and Lower Pleistocene sections in Central and Northern Italy. *Memorie Società Geologica Italiana* 48, 431-443.

Bertoldi, R. & Martinetto, E. 1995. Ricerche paleobotaniche (palinologiche e paleocarpologiche) sulla successione "Villafranchia" del Rio Ca'Viettone (Torino, Italia). *Il Quaternario* 8 (2), 403-422.

Billi, G. 1980. Conoscere il Valdarno. *Commune di Cavriglia*, 1-155.

Billi, P., Magi, M. & Sagri, M. 1991. *Pleistocene lacustrine fan delta deposits of the Valdarno.*

Bout, M. & Marty, P. 1936. Flore astienne de Perrier (Puy-de-Dôme). *Annales du Musée d'Histoire naturelles de Marseille* 28 (1), 5-36.

Brambilla, G., Ronchetti, G. & Vittadini Zorzoli, M. 1982. Semi e filliti delle argille messiniane (Miocene superiore) di Carbonara Scrivia (Alessandria). *Atti dell'Istituto Botanico e del Laboratorio Crittogamico dell'Universitá di Pavia* 7 (1), 31-40.

Burgh, J. van der 1983. Allochthonous seed and fruit floras from the Pliocene of the Lower Rhine Basin. *Review Palaeobotany and Palynology* 40, 33-90.

Burgh, J. van der 1987. Miocene floras in the Lower Rhenish Basin and their ecological interpretation. *Review Palaeobotany and Palynology* 52, 299-366.

Capellini, G. 1874. La formazione gessosa di Castellina marittima e suoi fossili. *Mem. Acc. Sc. Inst. Di Bologna Ser. III, Tom. IV.*

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

Denk, T. 2004. Revision of *Fagus* from the Cenozoic of Europe and Southwestern Asia and its phylogenetic implications. *Documenta Naturae* 150, 1-72.

Depape, P. 1922. Recherches sur la flore pliocène de la vallée du Rhône. Flores de Saint Marcel d'Ardèche et des environs de Théziers (Gard.). *Annales sciences naturelles, Botanique* 10 (4), 73-266.

Dorofeev, P.I. 1963. The tertiary floras of western Siberia (in Russian). 345 pp. *Izd. Nauka Moskva-Leningrad.*

Engler, A. 1879/1882. Versuch einer Entwicklungsgeschichte der Pflanzenwelt, insbesondere der Florengebiete, seit der Tertiärperiode I-II. 588 pp. Leipzig (Wilhelm Engelmann).

Ettingshausen, C. 1888. Die Flora von Leoben in der Steiermark. I. Theil. *Denkschrift der Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Classe* 54, 1-384.

Fischer, T.C. & Butzmann, R. 1998. *Citrus meletensis* (Rutaceae), a new species from the Pliocene of Valdarno (Italy). *Plant Systematics and Evolution* 210, 51-55.

Fischer, T.C., Butzmann, G. & Butzmann, R. 1998. Review of fossil *Citrus* leaves from the Cretaceous and the Tertiary. *In*: Gregor, H.-J., *Flora Tertiaria Mediterranea* 9 (5), 1-10, Documenta Naturae.

Fischer, T.C. & Butzmann, R. 2000. Die mediterrane neogene Flora von Meleto (Valdarno, Italien). Paläobotanik, Paläoökologie und Paläoklima. *In*: Gregor, H.-J. (ed.) *Flora Tertiaria Mediterranea.* Die tertiären Floren des Mittelmeergebietes. Vegetationsgeschichte, Phytostratigraphie, Paläoökologie, Paläoklimatologie, Paläogeographie. 5 (6), 1-187, Documenta Naturae.

Gaudin, C.T. & Strozzi, C. 1858. Mémoire sur quelques gisements de feuilles fossiles de la Toscane. *Neue Denkschrift der allgemeinen Schweizerischen Gesellschaft für die gesamte Naturwissenschaften.* B. 16, 1-47.

Gaudin, C.T. & Strozzi, C. 1859. Contribution à la flore fossile italienne (Val d'Arno). *Neue Denkschrift der allgemeinen Schweizerischen Gesellschaft für die gesamte Naturwissenschaften.* B. 17, 1-59.

Gaudin, C.T. & Strozzi, C. 1862. Contribution à la flore fossile italienne. *Neue Denkschrift der allgemeinen Schweizerischen Gesellschaft für die gesamte Naturwissenschaften.* B. 20, 1-32.

Gersonde, R. & Velitzelos, E. (1978). Diatomeenpaläoökologie im Neogenbecken von Vegora (N-W Mazedonien). *Annales Géologie Pays Helléniques.* 30, 373-382.

Ghetti, P., Anadón, P., Bertini, A., Esu, D., Gliozzi, E., Rook, L. & Soulié-Märsche, I. 2002. The early Messinian Velona basin (Siena, central Italy): paleoenvironmental and paleobiogeographical reconstructions. *Palaeo* 187, 1-33.

Gossmann, R. in Mai, D.H. 1994, Fossile Koniferenreste in der meridionalen Zone Europas. *Feddes Repertorium* 98 (1-2), 105-126.

Grangeon, P. 1958. Contribution à l'étude de la paléontologie végétale du Massif du Coiron (Ardèche). *Mémoires de la Société d'Histoire Naturelle d'Auvergne* 6, 1-299.

Gregor, H.-J., Pingen, M., Butzmann, R., Fischer, T.C., Mayr, Ch. & Schmitt H. 1998. Die neogene Makrofloren-Abfolge im Tagebau Hambach der Rheinbraun AG Köln. *Documenta Naturae* 104 (2), 1-83.

Günther, Th. & Gregor, H.-J. 1989. Computeranalyse neogener Frucht- und Samenfloren Europas. Band 1, Fundorte und deren Florenlisten. *Documenta Naturae* 50 (1), 1-180.

Günther, Th. & Gregor, H.-J. 1990. Computeranalyse neogener Frucht- und Samenfloren Europas. Band 2, Florenmerkmale und ihre stratigraphisch-geographischen Abhängigkeiten. *Documenta Naturae* 50 (2), 1-159.

Günther, Th. & Gregor, H.-J. 1992. Computeranalyse neogener Frucht- und Samenfloren Europas. Band 3, Übereinstimmungen von Florenlisten und ihre stratigraphisch-geographischen Beziehungen. *Documenta Naturae* 50 (3), 1-244.

Günther, Th. & Gregor, H.-J. 1993. Computeranalyse neogener Frucht- und Samenfloren Europas. Band 4, Carpofloren, Carpofloren-Komplexe und Carpofloren-Phasen. *Documenta Naturae* 50 (4), 1-190.

Günther, Th. & Gregor, H.-J. 1997. Computeranalyse neogener Frucht- und Samenfloren Europas. Band 5, Artennachweise und stratigraphische Problematik. *Documenta Naturae* 50 (5), 1-150.

Günther, Th. & Gregor, H.-J. 1998. Computeranalyse neogener Frucht- und Samenfloren Europas. Band 6, Fundorte und deren Florenlisten. *Documenta Naturae* 50 (6), 1-154.

Heer, O. 1856. *Flora tertiaria Helvetiae.* II. Theil, 1-110, Winterthur.

Hummel, A. 1983. The Pliocene leaf flora from Ruszów near Żary in Lower Silesia, SW Poland. *Prace Muzeum Ziemi Z.*

36.

Iljinskaja, I.A. 1968. *Neogene floras of the Transcarpathian region of the U. S. S. R*, 121 pp., Nauka, Leningrad (russ.).

Iskandar, D. 1990. La diatomite miocène de la Montagne d' Andance, carrière de Saint Bauzile (Ardèche, France). *Documents des Laboratoires de Géologie de Lyon* 110, 1-173.

Knobloch, E. 1988. Neue Ergebnisse zur Flora aus der Oberen Süßwassermolasse von Aubenham bei Ampfing (Krs. Mühldorf a. Inn). *Documenta Naturae* 42, 2-27.

Knobloch, E. 1997. Bemerkungen zu den jungtertiären und quartären Blätterfloren Italiens. *In*: Gregor, H.-J., *Flora Tertiaria Mediterranea* 5 (2), 1-27, Documenta Naturae.

Kvaček, Z. & Walther, H. 1988. Revision der mitteleuropäischen Fagaceen nach blattepidermalen Charakteristiken. II. Teil -*Castanopsis* (D. Don) SPACH, *Trigonobalanus* Forman, *Trigonobalanopsis* Kvaček et Walther. *Feddes Repertorium* 99 (9), 395-418.

Kvaček, Z., Velitzelos, D. & Velitzelos, E. 2002. *Late Miocene flora of Vegora N. Greece*. 175 pp., Athens (Korali Publications, University of Athens).

Magi, M. 1989. *Carta geologica della Conoide di Loro Ciuffenna (Valdarno Superiore). Firenze (Selca).*

Mai, D.H. 1995. *Tertiäre Vegetationsgeschichte Europas*. 691 pp., Jena (Fischer).

Martinetto, E. 1995. Significato cronologico e paleoambientale dei macrofossili vegetali nell' inquadramento stratigrafico del "Villafranchiano" di alcuni settori del Piemonte (Italia NW). Tesi di dottorato, Universita di Torino, Dipartimento di Scienze della Terra, Torino.

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

Martinetto, E., Pavia, G. & Bertoldi, R. 1997. Fruit and seed floras rich in exotic and subtropical elements from two Lower Pliocene successions of Italy. *Meded. Nederlands Inst. Toegepaste Geowet. TNO* 58, 237-244.

Martinetto, E. 1998. A. *Guide to the field conference. Pliocene plants, environments and climate of North-Western Italy. Mottalciatta, Biella, Italy - April 27-30th, 1998, Torino* (Dipartimento Di Scienze Della Terra Di Torino, Università Torino) (unpublished field guide).

Martinetto, E. 1998b. East Asian elements in the Plio-Pleistocene floras of Italy. *In*: Aoluo, Z. & Sugong, W. (eds.), *Proceedings of the International Symposium on Floristic Characterisation of the Diversity of East Asian Plants*, 71-87, Berlin (Springer).

Martinetto, E. 2001a. Studies on some exotic elements of the Pliocene flora of Italy. *Palaeontographica* B 259, 149-166.

Martinetto, E. (ed.) 2001b. Pliocene plants, environment and climate of northwestern Italy. *In*: Gregor, H.-J. (ed.), *Flora Tertiaria Mediterranea* 5 (8), 1-88, Documenta Naturae.

Martinetto, E. 2001c. The role of central Italy as a centre of refuge for thermophilous plants in the late Cenozoic. *Acta Palaeobotanica* 41 (2), 299-319.

Massalongo, A. & Scarabelli, G.F. 1858/59. *Studii sulla Flora Fossile e Geologia Stratigrafica del Senigalliese*, 506 pp., Imola (Premiata Lit Penufi Verona).

Meller, B. & Hofmann, C.-C. 2004. Paläökologische Interpretation von Diasporen- und Palynomorphen-Vergesellschaftungen aus obermiozänen Seesedimenten (Mataschen bei Fehring, Oststeiermark, Österreich). *Joannea – Geologie und Paläontologie* 5.

Merla, G. & Abbate, E. 1967. *Note illustrative della Carta Geologica d'Italia. Foglio 114*, 52 pp., Arezzo (Serv. Geol. Ital.).

Mielke, K. & Müller, H. 1981. Palynologie. *In*: Bender, F. (ed.). *Angewandte Geowissenschaften Band I*, 393-407, Stuttgart (Enke).

Mosbrugger, V. 1999. The nearest living relative method. *In*: Jones, T.P. & Rowe, N.P (eds.). *Fossil Plants and Spores: Modern Techniques*. Geological Society, London, 261-265.

Napoleone, G., Albianelli, A. & Azzaroli, A., 2003. Dating of the late Villafranchien (Pliocene) vertebrate collections of the Upper Valdarno (Tuscany, Italy) by the magnetochronologic framework of the basin fill. *Bollettino della Società Paleontologica Italiana* 42 (3), 301-313.

Reid, El. E. 1920. Recherches sur les graines du pliocène inférieur du Pont-De-Gail (Cantal). *Bulletin Société Géologique France* 4, 20, 48-87.

Rérolle, L. 1884-1885. Études sur les végétaux fossiles de Cerdagne. *Revue Société Naturelle Montpellier* 3, 4, 167-191, 252-298, 368-386.

Ristori, G. 1886. Contributo alla flora fossile del Valdarno Superiore. *Atta della Società Toscana de Scienze Naturali.* Mem. Vol. 7, 143-189.

Rossmässler, E.A. 1840. *Die Versteinerungen des Braunkohlesandsteins aus der Gegend von Altsattel in Böhmen*. Arnoldische Buchhandlung, 42 pp. Dresden-Leipzig.

Schloemer-Jaeger, A. 1858. Alttertiäre Pflanzen aus der Brögger-Halbinsel Spitzbergens. *Palaeontographica*, B, 104, 39-103.

Ströbitzer-Hermann, M. 2002. *Systematik, Variabilität, regionale und stratigraphische Verbreitung sowie Ökologie der Gattung Acer L. in Mitteleuropa vom Oligo- bis Pliozän.* 149 pp., Vienna (University Vienna) (unpublished MSc thesis).

Steenbrink, J., Hilgen, F.J., Krijgsman, W., Wijbrans, J.R. & Meulenkamp, J.E. 2001. Late Miocene to Early Pliocene depositional history of the intramontane Florina-Ptolemais-Servia Basin, NW Greece: interplay between orbital forcing and tectonics. *In*: Steenbrink, J. *Orbital signatures in lacustrine sediments. The Late Neogene intramontane Florina-Ptolemais-Sevia Basin, northwestern Greece. Geologica Ultraiectina* 205, 167 pp., Utrecht.

Stuchlik, L., Szynkiewicz, A., Lancucka-Srodoniowa, M. & Zastawniak, E. 1990. Results of the hitherto palaeobotanical investigations of the Tertiary brown coal bed "Belchatow" (Central Poland). *Acta Palaeobot.* 30 (1,2), 259-305.

Suc, I.P. & Zagwijn, W. 1983. Plio-Pleistocene correlation between the northwestern Mediterranean region and northwestern Europe according to recent biostratigraphic and paleobotanic data. *Boreas* 12, 153-166.

Teodoridis, V. & Gregor, H.-J. 2001. A new Pliocene leaf flora from the Meleto clay in the opencast mine Santa Barbara, Upper Valdarno. *In*: Gregor, H.-J. (eds.) *Flora Tertiaria Mediterranea*. Die tertiären Floren des Mittelmeergebietes. Vegetationsgeschichte, Phytostratigraphie, Paläoökologie, Paläoklimatologie, Paläogeographie. 5 (9), 1-28, Documenta Naturae.

Thewalt, U. & Gregor, H.-J. 2001. Vivianit, ein Phosphatmineral, auf "blauen" Blättern aus pliozänen Sedimenten von Meleto im Valdarno (Italien). *Documenta Naturae* 137 (1), 13-23.

Torre, D., Albianelli, A., Azzaroli, A., Ficcarelli, G., Magi, M., Napoleone, G. & Sagri, M. 1993. Palaeomagnetic calibration of late Villafranchian mammalian faunas from the Upper Valdarno, Central Italy. *Memorie Società Geologica Italiana* 49, 335-344.

Unger, F. 1841-1847. *Chloris protogaea*. CX, 150 pp. Leipzig (Engelmann).

Witkowsky, A., Bak, M. & Wawrzyniak-Wydrowska, B. 2001. Silicious Microfossils (Diatoms-Bacillariophyceae) from neogene deposits of the Valdarno Area (Tuscany, Italy) Preliminary results. *In*: Gregor, H.-J., *Flora Tertiaria Mediterranea* 5 (5), 1- 47, Documenta Naturae.

Bryophyta	
Hepaticae	
Musci	
Gymnospermae	
Pinaceae	
Pinus sp. 1	+C, +M
Pinus sp. 2	+C, +M
Taxodiaceae	
Glyptostrobus europaeus	+C, +M
Taiwania schaeferi	+C, +M
Taxodium dubium	+C, +M
Angiospermae	
Dicotyledonae	
Aceraceae	
Acer pyrenaicum	+C, +M
Acer tricuspidatum	+C, +M
Acer intergerrimum	+C, +M
Betulaceae	
Alnus cecropiaefolia	+C, +M
Betula insignis	+C, +M
Betula subpubescens	+C, +M
Carpinus suborientalis	+C, +M
Ceratophyllaceae	
Ceratophyllum tertiarium	
Fagaceae	
Fagus haidingeri	+C, +M
Quercus drymeia	+C, +M
Quercus czeczottiae	+C, +M
Quercus ilicoides	+C, +M
Quercus pseudocastanea	+C, +M
Quercus roburoides	+C, +M
Trigonobalanopsis rhamnoides	+C
Juglandaceae	
Dicotylophyllum sp. 1	
Pterocarya paradisiaca	+C, +M
Lauraceae	
Daphnogene polymorphum	
Lauraceae	
Laurophyllum cf. *pseudoprinceps*	
Laurophyllum markvarticense	
Ocotea hradekensis	
Sassafras ferretianum	
Leguminosae	
Leguminosae	+C
Magnoliaceae	
Magnolia liblarense	+C, +M
Myricaceae	
Myrica lignitum	+M
Oleaceae	
Chionanthus sp.	
Platanaceae	
Platanus leucophylla	+M
Platanus sp.	+M
Rutaceae	
Citrus meletensis	
Salicaceae	
Populus populina	
Salix sp.	+M
Sapindaceae	
Sapindus falcifolius	
Smilacaceae	
Smilax weberi	
Tiliaceae	
Grewia cf. *staubi*	
Ulmaceae	
Zelkova zelkovaefolia	+M
Zelkova sp.	+M
Viscaceae	
Viscum cf. *morlottii*	
Viscum sp.	
Monocotyledonae	
Monocotyledon	
Incertae sedis	
Sapotacites cf. *minor*	
Dicotylophyllum sp. 2-11	

Table 1. Leaf flora of the Meleto locality (leaves, needles, twigs). +C and +M indicate, that the genus is (or at least may be) also represented in the carpoflora or microflora, respectively.

Fungi		
Cenococcum geophilum	S	
Rosellinites congregatus	S	
Gymnospermae		
Cupressaceae		
Cupressoconus cf. *weylandi*	C	+M
Pinaceae		
Pinus hampeana	C	+L, +M
Pinus cf. *urani*	C	+L, +M
Cathaya vanderburghii	S	+M
Pseudolarix schmidtgenii	S	
Tsuga europaea	S	+M
Taxodiaceae		
Glyptostrobus europaeus	C	+L, +M
Taiwania schaeferi	S	+L, +M
Taxodium dubium	S	+L, +M
Sequoia abietina	C	+M
Angiospermae		
Dicotyledonae		
Aceraceae		
Acer sp.	C	+L, +M
Altingiaceae		
Liquidambar magniloculata	C	+M
Betulaceae		
Alnus sp.	C, S	+L, +M
Betula sp.	C	+L, +M
Carpinus grandis	C	+L, +M
Carpinus pyramidalis	C	+L, +M
Fagaceae		
Trigonobalanopsis exacantha	C, S	+C
Hamamelidaceae		
Hamam. gen. et sp. indet.	S	
Juglandaceae		
Palaeocarya macroptera	C	+M
Pterocarya sp.	C	+L, +M
Leguminosae		
Leguminocarpum sp.	C	+L
Magnoliaceae		
Magnoliostrobus sp.	C	+L, +M
Menispermaceae		
Sinomenium cantalense	S	
Oleaceae		
Fraxinus stenoptera	C	+M
Styracaceae		
Rehderodendron ehrenbergii	C	+M
Tiliaceae		
Craigia bronnii	C	
Tilia gieskei	S	+M
Trapaceae		
Trapa sp.	C	
Vitaceae		
Vitis sp.	S	+M
Incertae sedis		
Carpolithus sp. 1-8	S	

Table 2. Carpoflora of the Meleto locality (diaspores: fungal fruiting structures, seeds, fruits, cones). +L and +M indicate, that the genus is (or at least may be) also represented in the leaf flora or microflora, respectively. C indicates occurrence in the clay, S silt. *Cathaya vanderburghii* is a *nomen nudum* (Gossmann in Mai, 1994).

Chlorophyta	
Botryococcus sp.	
Pediastrum fsp.	
Pteridophyta	
Selaginellaceae	
Echinatisporis longechinus	
Muerrigerisporis sp.	
Selaginella sp.	
Pteridaceae	
Polypodiaceoisporites sp.	
Polypodiaceae	
Polypodiaceae div. fsp.	
Leiotriletes triangulus	
Gymnospermae	
Cupressaceae	
Cupressaceae	+C
Pinaceae	
Pinus div. fsp.	+C, +L
Cathaya-type + *Pinus hapl.*	+C
Tsuga sp.	+C
Abies sp.	
Cedrus sp.	
Picea sp.	
Pseudotsuga-type	
Taxodiaceae	
Taxodiaceae	+C, +L
Sciadopitys sp.	
Sequoia sp.	+C
Podocarpaceae	
Podocarpus-type	
Angiospermae	
Dicotyledonae	
Aceraceae	
Acer sp.	+C, +L
Altingiaceae	
Liquidambar sp.	+C
Aquifoliaceae	
Ilex sp.	
Araliaceae	
Araliaceae	
Betulaceae	
Alnus sp.	+C, +L
Betula sp.	+C, +L
Carpinus sp.	+C, +L
Ostrya-type	
Buxaceae	
Buxus sp.	
Caryophyllaceae	
Caryophyllaceae	
Cercidiphyllaceae	
Cercidiphyllum sp.	
Chenopodiaceae	
Chenopodiaceae	
Compositae/Tubuliflorae	
Compositae/Tubuliflorae	
Ericaceae	
Empetrum-type	
Ericaceae	

Fagaceae	
Fagus sp.	+L
Quercus div. spp.	+L
Tricolpopollenites microhenrici	
Tricolporop. cingulum oviformis	
Geraniaceae	
Geraniaceae	
Hederaceae/Araliaceae	
Hedera sp.	
Juglandaceae	
Engelhardia sp.	+C
Pterocarya sp.	+C, +L
Carya sp.	
Magnoliaceae	
Magnolia sp.	+C, +L
Myricaceae	
Myricaceae	+L
Nyssaceae	
Nyssa sp.	
Oleaceae	
Fraxinus sp.	+C
Tricolporop. microreticulatus (= Oleaceae div. fspp.)	
Platanaceae	
Platanus sp.	+L
Potamogetonaceae	
Potamogeton sp.	
Salicaceae	
Salix sp.	+L
Styracaceae	
Styracaceae	+C
Tiliaceae	
Tilia sp.	+C
Ulmaceae	
Ulmus sp./*Zelkova* sp.	+L
Umbelliferae	
Umbelliferae	
Valerianaceae	
Valerianaceae	
Vitaceae	
Vitispollenites tener	+C
Tricolporopoll. marcodurensis (*Parthenocissus*-Type)	
Monocotyledonae	
Palmae	
Palmae	
Gramineae	
Gramineae	
Cyperaceae	
Cyperaceae	
Incertae sedis	
"Ephedra fragilis"	
Tricolporop. pseudolaesus	
Varia	

Table 3. Microflora of the Meleto locality (except Bacillariophyta, diatoms). +C and +L indicate, that the genus is (or at least may be) also represented in the carpoflora or leaf flora, respectively. Abbreviation: *Tricolporop.* = *Tricolporopollenites*

Species versus vegetational unit	1	2	3	4	5	6	7	8	9
Gymnosperms									
Cathaya vanderburghii			I				I		I
Cupressoconus cf. *weylandii*							I		
Glyptostrobus europaeus			I						
Pinus cf. *urani*			I				I		I
Pinus hampeana			o				o		o
Pseudolarix schmidtgenii						I			
Sequoia abietina			I						
Taiwania schaeferi						I			
Taxodium dubium			o						
Tsuga europaea						I			
Angiosperms									
Acer ilnicense				oo	oo	oo			
Acer intergerrimum				I	I	I			
Acer tricuspidatum				I	I	I			
Alnus cecropiaefolia			o						
Betula insignis			I	I	I	I	I		
Betula subpubescens			I	I	I	I	I		
Carpinus grandis					I				
Carpinus pyramidalis					o				
Carpinus suborientalis					o				
Craigia bronni									
Ceratophyllum tertiarium	I								
Citrus meletensis						I			
Daphnogene polymorphum			o	o					
Fagus haidingeri						o			
Fraxinus stenoptera			o						
Grewia cf. *staubi*				I	I	I			
Laurophyllum cf. *pseudoprinceps*			o	o					
Laurophyllum markvarticense			I	I					
Leguminocarpum sp.					I	I			
Leguminosae					oo	oo			
Liquidambar magniloculata			oo						
Magnolia liblarense			o						
Magnolia lignitica			I						
Myrica lignitum			o						o
Ocotea hradekensis			o	o					
Palaeocarya macroptera			o						
Platanus leucophylla						o			
Platanus sp.						I			
Populus populina			o	o	o				
Pterocarya paradisiaca				o					
Pterocarya sp.				o					
Quercus ilicoides					I	I	I		
Quercus czeczottiae					o	o	o		
Quercus drymeia					o	o	o		
Quercus pseudocastanea					o	o	o		
Quercus roburoides					o	o	o		
Rehderodendron ehrenbergii				I	I	I			
Salix sp.			I						
Sapindus falcifolius				I	I				
Sapotacites cf. *minor*						o			
Sassafras ferretianum			o	o					
Sinomenium cantalense				I	I				
Smilax weberi			I	I	I	I			
Tilia gieskei			I		I	I			
Trapa sp.	I								
Trigonobalanopsis exacantha						oo			
Trigonobalanopsis rhamnoides						o			
Viscum cf. *morlottii*			I	I	I				
Viscum sp.			I	I	I				
Vitis sp.			I		I				
Zelkova sp.						o			
Zelkova zelkovaefolia						oo			
Sum	2	0	27	20	24	29	11	0	4

Table 4. Assignment of the plant species to vegetational units and their respective abundance. Vegetational units: 1, open water vegetation; 2, streamside vegetation; 3, wetland forest; 4, forest border-scrub vegetation; 5, flood plain forest; 6, upland forest; 7, coniferous forest; 8, heath; 9, peat bog. Abundances: I, 1 specimen; o, 2-10 specimens, oo, 11-100 specimens.

Locality	Congruence %	Stratigraphy	Lithology	Species	Basic publication
Valdarno 1-4	25	Pliocene	Clay/Marl	8	Gaudin 1859
Sento 1-3	22	Lower Pliocene	Sand	10	Martinetto 1997
Val Chiusella1-F	19	Pliocene	Sand	13	Martinetto 1995
Castellina 1-1	18	Middle Miocene	Clay/ Marl	3	Capellini 1874
Castellengo 1-1	18	Pliocene	Sand	14	Martinetto 1995
Hambach 4-08	18	Lower Pliocene	Sand	3	Gregor 1998
Ruszow 1-1	18	Upper Miocene	Unknown	3	Hummel 1983
Belchatow 1-9	18	Lower Miocene	Sand	3	Stuchlik 1990

Table 5. Comparison of the Meleto silt diaspore flora with other diaspore floras.

Locality	Congruence %	Stratigraphy	Lithology	Species	Basic publication
Candelo 1-1	36	Pliocene	Sand	17	Martinetto 1995
Scrivia 1-1	33	Upper Miocene	Limestone	7	Brambilla 1982
Ca' Viettone 1-1	33	Lower Pliocene	Sand	13	Martinetto 1995
Castellengo 1-1	32	Pliocene	Sand	14	Martinetto 1995
Sento 1-1	29	Lower Pliocene	Sand	17	Martinetto 1997
Ca' Viettone 1-A	29	Lower Pliocene	Clay/ Marl	24	Martinetto 1995
Aubenham 1-1	29	Upper Miocene	Clay/ Marl	10	Knobloch 1988

Table 6. Comparison of the Meleto clay diaspore flora with other diaspore floras