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16 **Abstract**

17 In Pliocene sedimentary successions of northern and central Italy, fossil swamp forests are
18 relatively common. Most of them pertain to the Piacenzian stage and show a dominance of the
19 conifer *Glyptostrobus europaeus* as an arboreal element. A new fossil forest that recently cropped
20 out at Fossano in the Piedmont region, represents the first Zanclean assemblage of this type. Herein,
21 we describe the context of the site and report the consistent stratigraphic and palaeofloral results so
22 far obtained, also highlighting the need of more detailed future studies. Our results demonstrate that
23 the fossil stumps exposed at Fossano pertain to two superposed forest beds, and the upper one is
24 covered by a dense buried litter of *Glyptostrobus europaeus* shoots. Therefore, this conifer species
25 is reconstructed as a dominant arboreal plant also in this fossil forest. Other interesting
26 palaeontological information about the Pliocene succession of this relatively neglected area is
27 provided by under- and overlying layers. Detailed macropalaeobotanical studies on leaves, fruits
28 and seeds, provide good evidence for the palaeoecological and biochronological characterisation of
29 the succession. The integrated plant records (pollen and plant macrofossils) studied in a short
30 interval of the succession correspond with the macrofossil records of the rest of the succession and
31 point to the reconstruction of a "subtropical humid forest" grown under a very warm temperate
32 climate regime, with a small range of temperatures and abundant and well-distributed rainfall
33 throughout the year.

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1. Introduction

In northern and central Italy, the infilling of marine and fluvio-lacustrine basins during the Pliocene created favourable environments for the growth of swamp communities and for their preservation at the fossil state, thanks to a still consistent subsidence combined with sea and lake level changes. In several of these sites, such as Dunarobba (Ambrosetti et al., 1995; Martinetto, 1994a; Martinetto et al., 2014), La Cassa (Martinetto, 1994a), Le Matole in the Upper Valdarno Basin (Bertini et al., 2014; Ielpi, 2012), Nole Canavese (Martinetto, 1994a; Martinetto et al., 2007; Vassio et al., 2008), Villafranca d'Asti-RDB Quarry (Forno et al., 2015; Martinetto and Mai, 1996), the conifer *Glyptostrobus europaeus* has been detected as a dominant arboreal element. Also in the late Cenozoic swamp forests of other parts of Europe (Erdei et al., 2009; Kovar-Eder et al., 2001) *Glyptostrobus europaeus* has been recognized as a characteristic tree and some recent evidence even suggests its survival until the Holocene on the southern shores of the Black Sea (Biltekin et al., 2015).

A new fossil forest was recently detected close to the small town of Fossano (Cuneo province), in the bed of the Stura di Demonte river (Fig. 1), a site where a thick Pliocene succession crops out (Sacco, 1886a), showing a complete palaeoenvironmental trend from a shallow marine to a fluvial-alluvial environment. However, the palaeofloral context of this interesting succession had not been investigated so far. The Fossano Fossil Forest is particularly interesting for the stratigraphic context in which it crops out and for the occurrence of animal fossils (land snails) in several layers, including the palaeosols supporting the fossil stumps. Sacco (1886b) reported a diverse assemblage of continental molluscs with several extinct species from the continental layers of this succession, and more recent studies pointed out a high degree of endemism among them (Esu and Ciangherotti, 2004). Given that the continental molluscs studied in other successions of northern Italy, either older (Colombero et al., 2017) or younger (Ciangherotti et al., 2007) than Fossano's one, provided interesting palaeoenvironmental information, it would be desirable to re-evaluate their role in the characterization of this succession.

The discovery of the Fossano Fossil Forest has already attracted the attention of local people and may increase the demand for scientific investigations on this poorly studied sedimentary succession. Indeed, it convinced us to gather all the available palaeobotanical and stratigraphical information on the Fossano succession, and to present it in this report, also indicating those fields in which our data are insufficient, and new and more detailed palaeobotanical analyses are needed.

Despite the recent outcrop of the Fossano Fossil Forest (Section FF: Fig. 3), stratigraphic information has been collected more than a decade ago from the underlying and overlying layers (Cilia, 2005; Martinetto, 2015), therefore, we deem it useful to report here all the available data. Actually, the main aim of the present paper is to compare the palaeofloral and stratigraphic context of the Fossano Fossil Forest with those from similar late Cenozoic Italian sites. Conversely, the presentation of biometric and wood anatomical data on stumps and trunks, as well as the reconstruction of ancient plant community and of the whole palaeobiological context (including molluscs), are beyond the purpose of this paper.

2. Geological setting

Starting from the 19th century (Sacco, 1889-1890) until now, geologists have been studying the Neogene/Pleistocene succession of the Tertiary Piedmont Basin, making it one of the most studied outcropping areas for this stratigraphic range. After the continental evaporitic episode of the

Messinian (Dela Pierre et al., 2011), the Tertiary Piedmont Basin experienced the deposition of a thick Plio-Pleistocene sedimentary succession, represented by a transgressive-regressive cycle with offshore clay-rich sediments in its lower part (Argille Azzurre Formation), followed by the shallow marine Sabbie di Asti Formation, also including paralic sands and muds, which represent the "Fossaniano" facies (sensu Sacco, 1886a, 1889-1890). The succession is overlain by continental and deltaicdeposits: the so-called "Villafranchiano", (Caramiello et al., 1995; Carraro, 1996 and references therein). The transition between marine and continental deposits has been extensively described by Sacco (1886a, 1889-1890), both in the southern sector of Piedmont (Fossano area) and in the central part (Villafranchian type-area: Forno et al., 2015).

The Argille Azzurre Formation, often described in literature as "Argille di Lugagnano" ("Piacenziano" sensu Sacco, 1889-90), mainly consists of clay-rich sediments of grey-blue colour, generally homogeneous and mostly without an evident stratification. In outcrop, these show variable thickness, locally exceeding 100 metres. They represent offshore muddy deposits and Boni et al. (1987) attributed their lower portion, cropping out 20 km SW of Fossano, to the MPl2 foraminiferal biozone of the Lower Pliocene (Zanclean), thanks to the presence of *Globorotalia margaritae*. To the NE of the Fossano area similar deposits have been assigned to the MPl3 foraminifer biozone (Ghielmi et al., in press; Vigna et al., 2010; Violanti, 2005). Boni et al. (1987) also dated the sediments belonging to Sabbie di Asti and the overlying "Villafranchiano" deposits respectively to the "early-middle" Pliocene and to the "late Pliocene-early Pleistocene" based on the stratigraphic position, because these deposits yielded only benthic shallow marine foraminifera, hardly useful for a chronological attribution. The Sabbie di Asti ("Astiano" sensu Sacco, 1889-90; Ferrero, 1971), yellow incoherent sands only locally cemented, are interpreted as foreshore deposits (Ferrero and Pavia, 1996) controlled by strong hydrodynamic energy (waves and coastal currents). This formation, 60-80 metres in thickness, is particularly known because of its rich associations of molluscs, described in many classical outcrops in the Asti area (Caretto, 1963, 1975; Damarco, 2009; Ferrero, 1971; Ferrero et al., 1982, 1984; Pavia, 1970; Pavia and Demagistris, 1970).

The "Villafranchiano" deposits yielded mammal assemblages of confirmed Villafranchian age only in the type-area (Carraro, 1996), and not in the Fossano area, where these deposits have tentatively been assigned to the Zanclean by Ghielmi et al. (in press). The stratigraphical setting of the Plio-Pleistocene succession of the Tertiary Piedmont Basin has been only recently reviewed following the underground data provided by the ENI energy company (seismic survey and stratigraphy from a series of drillings), integrated with geological and micropalaeontological surface data (Ghielmi et al., 2002; Ghielmi et al., in press; Vigna, 2011; Vigna et al., 2010). These studies show a stratigraphic framework that is quite different from that presented in the previous literature. Three tectonic unconformities of regional significance have been detected (Ghielmi et al., 2010; Minervini et al., 2008; Rossi et al., 2002a; Roveri and Manzi, 2006), named Intra-Messinian Unconformity, Intra-Zanclean Unconformity, Base Gelasian Unconformity. These major unconformities divide the Plio-Pleistocene succession in an equal number of allogroups: LM, PL and PS (Fig. 2). These allogroups have been subdivided in a series of sequences, but sometimes correspond to relevant variations in sedimentary facies. In both the PL and PS allogroups three sequences have been detected: PL1-PL3, PS1-PS3. The PL1 sequence is divided into units designated by the "A" letter, which allows the distinction from the similar, but younger, sediments belonging to the upper sequence (PL2). PL1 includes Argille Azzurre A, Sabbie di Asti A and "Villafranchiano" A, placed in the lower and middle part of the Zanclean (early Pliocene). At the bottom of the PL1 Sequence the Pliocene transgression causes a sudden onset of the offshore sedimentation in most of the Tertiary Piedmont Basin. Soon after the transgression an important platform progradation towards deeper central-northern sector of the basin starts and is named "Pliocene Progradation" (Vigna et al., 2010). With the progressive filling of the basin, from the southern to the northern areas, a marginal-marine sedimentation starts, with the appearance of still quite coarse sandy deposits, outcropping in the Fossano area, and progressively thinner and more silty deposits to the NE. These sediments have been named Sabbie di Asti A, and they show facies and ages quite different from

the type-area of the Sabbie di Asti. The top of the Sabbie di Asti A is exposed some kilometres downstream of Fossano and represented by a sandy gravel-rich facies, typical of a fluvio-deltaic depositional system, interfingering with sandy-silty deposits of a brackish deltaic environment (with the bivalves *Ostrea* and *Cerastoderma*).

At the margin of the basin (SW of Fossano) the foregoing deposits are progressively replaced by coarse gravels and sands, interspersed with silty-clay horizons and altered gravels with clay-rich matrix, referred respectively to fluvial/lacustrine and alluvial fan environments ("Villafranchiano" A). From the integration of stratigraphic and sedimentological data it is possible to recognize in the studied area a regressive trend of the "Villafranchiano" A deposit which is locally expressed by sequences of peculiar facies. In the sector near the town of Fossano, this trend is demonstrated by the sandy gravels which overlay dominantly sandy deposits. These deposits could be interpreted as sand bars of braided rivers, formed in a more distal sector with respect to the overlaying gravels. Among the sandy-gravelly sediments there are some subordinate bodies constituted by grey clays with a lot of freshwater fossils and the Fossano Fossil Forest is placed in this facies association (Fig. 3).

The Quaternary in this area is mainly represented by terraced fluvial deposits and thin successions in the alluvial plains and river valleys. Since the time of Sacco (1887), it has been recognized that during glacial periods all fluvial terraces around the Piedmont plains formed successive flat surfaces, later cut through by streams. The direction of the waterways changed considerably during time, especially that of rivers Tanaro and Gesso. Along the Western Alps, tectonic activity was already intense during the Pliocene, and intensified during the Middle-Late Pleistocene (Rossi et al., 2002b; Pavia et al., 2004). The whole Plio-Pleistocene succession of the Tertiary Piedmont Basin has been tilted asymmetrically, more intensively at its SW corner (Biancotti and Cortemiglia, 1982; Vigna et al., 2010). In the Late Pleistocene, during the last glaciation, the geography of the region was still very different from today, since the water from the Ligurian Alps flowed to the North, through the waterlogged lowland between Cuneo and Torino, following the ancient course of the Po River (Sacco, 1889-90; Biancotti and Cortemiglia, 1982; Castiglioni, 2001). The youngest tectonic activity and concomitant climatic variations at the end of the Pleistocene determined radical modifications in this catchment network (Biancotti and Cortemiglia, 1982; Carraro, 1996; Castiglioni, 2001). The main effects have been the diversion in northward direction of the Po River course and in northeast ward direction of the Tanaro River, associated to a marked slope increase (Castiglioni, 2001, fig. 1). This phenomenon caused a geomorphological rejuvenation in the entire examined area. The main morphogenetic process since the end of the Pleistocene has been river erosion, which is still very active in the Fossano area, thus determining the recent outcrop of the Fossil Forest.

3. Field observations

The long stratigraphic succession described and mapped by Sacco (1886a) at present crops out in a few places (Fig. 1), especially on the banks of the Stura di Demonte River. The strata dip rather uniformly 4° north-westward, and the river approximately runs from West to East from Section FF to Section A , so that the vertical stack of the Pliocene succession can be reconstructed by following upstream the river from the East to the West.

The discontinuity of the outcrops does not allow to measure a complete section, however, it is possible to study short portions in three sections (A, B, FF) and a longer one in the sediment samples of a 70 m thick drill core. The four logs can be assembled in a composite, c. 100 m thick section including the Fossano Fossil Forest in its middle part (Fig. 3). Some characteristic fossil-bearing layers have been labelled, from the oldest to the youngest: FO1, FO2, FO3, FO4, FOF10, FOF20, FO5. Being primarily a malacologist and stratigrapher, Sacco (1886a) did not pay much

187 attention to plant fossils, despite their palaeoenvironmental importance. Therefore, we carefully
188 looked for them and detected rich plant assemblages in the sediments he assigned to the
189 "Fossaniano" and "Villafranchiano" units. In particular, very significant palaeobotanical data have
190 been collected from Section A (UTM coord. 040153 4935665), located on the left bank of the Stura
191 di Demonte River (Fig. 1), where three sedimentary subsections have been measured (Fig. 3): A1,
192 A2 (20 m South from subsection A1) and A3. Subsection A1 is mainly composed of clay-rich
193 horizons with a progressive transition to silt-rich ones, locally with abundant molluscs (*Ostrea* and
194 *Potamides s.l.* mainly). Subsection A2 is generally richer in sand than A1, with the lowest layers
195 densely disturbed by *Thalassinoides* burrows. The top layer of the upper silt-rich portion, with
196 abundant molluscs, can be recognized also in subsection A3, where it is stratigraphically situated 5
197 metres below layer FO4, characterised by an abundance of mummified leaves. Subsection A3 is
198 composed of silty and sandy layers and in a few layers the presence of mummified roots within
199 poorly evolved hygromorphic palaeosols was observed. The top of the lowest palaeosol, labelled
200 FO1, showed a thin concentration of mummified plant material and shells of freshwater and
201 terrestrial gastropods. Just above FO1, the succession is interrupted by an erosional surface,
202 overlain by a channelized sandy deposit with bottom-up grain-size decrease and a concentration of
203 mummified plant material, labelled FO2. This deposit only cropped out for a short time in 2003, but
204 an ovelying similar deposit, labelled FO3, was still accessible in 2017. FO3 lays 2.5 m above the
205 top of FO2 and directly below FO4.
206 The part of the succession between sections A and FF is poorly exposed, so that its total thickness
207 (nearly 25 m) can be only estimated with geological mapping techniques. An outcrop in its middle
208 part allowed us to measure Section B (12 m: Fig. 3), completely composed of yellowish, coarse-
209 sandy gravels. Conversely, Section FF was visible in a c. 500 m long outcrop during 2016–2017
210 and a thickness of 690 cm was measured (Fig. 3). The most visible fossils are represented by
211 upright stumps or stump remains (radially converging roots). The dimensions of the stumps were
212 not always easy to assess because the trunk portion was often not preserved when the observations
213 were carried out, and only a circular assemblage of radially converging roots was left. The base of
214 the trunk of the largest measured specimen was c. 90 cm in diameter (Plate I, 4), and several smaller
215 specimens were 25–40 cm in diameter (Plate I, 2). We observed 18 specimens of this type so far,
216 which are rooted in two distinct palaeosol horizons (c. 520 cm and c. 630 cm in Section FF: Fig. 3).
217 The mummified roots of the tree stumps forming the lower fossil forest bed penetrate the upper part
218 of a mainly massive blackish layer, which is abruptly covered by stratified sandy silts and sands
219 (520–630 cm), still containing abundant mummified root remains (Plate I, 2). The roots are often
220 only preserved as imprints or reddish traces far away from the stumps. This blackish layer (located
221 at 510–520 cm) locally shows a concentration of leaf fragments and seeds (assemblage FOF10 in
222 Fig. 3). Additionally, a concentration of conifer shoots in muddy sediments was observed 130 cm
223 above (assemblage FOF20 in Fig. 3).
224
225 A long portion of the succession overlaying the Fossano Fossil Forest is exposed in an inaccessible
226 escarpment below the town of Fossano. From the distance one can observe mainly grey muds and
227 sands, with subordinate gravels. Direct observation and sampling of one of these layers was
228 possible in the accumulation of a landslide, where a layer rich in leaves, also yielding some fruits
229 and seeds, has been detected and labelled FO5. It can be estimated that this layer is located c. 30–50
230 m above the fossil forest bed.
231

4. Material and methods

233 Two sections of the Fossano succession (A and FF: Fig. 3) were subjected to stratigraphic
234 measurements and sediment sampling for carpological analyses. Wood samples were collected from

each upright stump and from the main horizontal trunks and twigs, and their anatomical analysis is in progress. The present paper deals with the already abundant palaeofloral data derived from carpological, palynological, leaf morphological and cuticular analyses. The analyses on freshly collected material have been combined with those on palaeobotanical material deposited in the collections MGPT-PU, mainly coming from Section A. The palaeobotanical material studied in this work includes:

- 167 leaf compressions from layer FO4, 43 shoot compression from layer FOF20 and 10 leaf compressions and impressions from layer FO5;
- more than 1000 fruits and seeds from layers FO1, FO2, FO3, FOF10, FOF20, FO5;
- a pilot palynological assemblage from layer FO3.

The description of macroscopic morphological features of the leaves (Plate II) follows Hickey and Wolfe (1975) and Wolfe (1993). Furthermore, cuticular analyses have been carried out on a few lamina fragments, sampled in the intercostal areas of the lamina. Cuticles (Plate III) have been prepared from 147 leaf samples of the FO4 layer. The leaf fragments have been treated with hydrogen peroxide for 30 minutes, to remove silt and clay residues, and, after rinsing, with 5% sodium hypochlorite to remove the mesophyll. Then, cuticle fragments have been observed under a Nikon light microscope with attention to diagnostic features like stomatal pores, disposition of epidermal cells, and the presence of glands and trichomes. After cuticle sampling, the still wet macroscopic leaf specimens have been inserted in little polyethylene bags under vacuum, although this preservation method did appeared to be not successful after a few years (Cimino et al., 2016).

In the FF Section, we paid attention to the abundance and distribution of identifiable plant remains in the field (Fig. 4). Palaeocarpological bulk sampling was carried out at the top of the palaeosol in which most stumps of the lower forest bed are rooted (see FOF10 in Fig. 3) and 130 cm above, in muddy sediments rich in conifer shoots (see FOF20 in Fig. 3). Topographically, three sampling sites were adjacent to different small in situ stumps (Plate I), whereas a sample from layer FOF10 (C9W) was located c. 20 m away from the closest visible stump. In the overlying deposit FO5 we carried out a palaeocarpological bulk sampling and we recovered 10 fossil leaves by splitting fallen-down blocks of clayey silts along bedding planes.

Pollen preparation of the sediment sample collected from layer FO3 followed a standard chemical-physical procedure at the Department of Earth Science, University of Florence. The dry sample was first weighed (20 g), and one *Lycopodium* tablet was added to provide palynomorph concentrations. The procedure included treatments with HCl (20%), HF (48%), sodium hexametaphosphate, KOH (10%) and $ZnCl_2$ density separation (solution density 2.0). Residues were sieved at 10 μm and mounted using glycerol. A pollen count of the sample was carried out under a light microscope at x750 and x1250 (oil immersion) magnification. Pollen percentages were calculated based on a main pollen sum of 263 terrestrial pollen grains.

5. Systematics of selected plant taxa

The complete list of carpological taxa of the Fossano composite section is given in Tab. 1 and includes 83 taxa, most of which have been treated in previous papers (Cavallo and Martinetto, 1996, 2001; Martinetto, 1994a, 1994b, 2001a, 2001b, 2015; Martinetto and Gregor, 1989; Martinetto et al., 2015, 2016). All the taxa documented by fossil leaves at Fossano have been listed below, and most of them were already described from other Neogene sites of Italy (Martinetto, 2003; Martinetto et al., 2000; Teodoridis et al., 2015).

In this chapter, we provide additional information, not reported in previous papers, on a few selected fossil-species represented by leaves or carpological remains, whose occurrence at Fossano is of special importance from a palaeoenvironmental (and/or biochronological) point of view. The

282 summary for each species describes its occurrence in Italy, and the locality names correspond to
283 those listed in Bertini and Martinetto (2008) and Martinetto (2015).

284

285 6.1 Gymnospermae

286 Family Cupressaceae

287 *Glyptostrobus europaeus* (Brongniart) Unger
288 Plate I, 5
289 1994a *Glyptostrobus europaeus* (Brongniart) Unger – Martinetto: pl. 1, figs 1–4. (Dunarobba,
290   Fossil Forest of the Stura di Lanzo River, and La Cassa).
291 1994b *Glyptostrobus europaeus* (Brongniart) Unger – Martinetto: pl. 1, figs 1, 2. (Fossil Forest of
292   the Stura di Lanzo River).
293

294 1996 *Glyptostrobus europaeus* (Brongniart) Unger – Cavallo and Martinetto, p. 11, pl. 4, fig. 2
295   (Pocapaglia).
296 1998 *Glyptostrobus europaeus* (Brongniart) Unger – Martinetto: pl. 2, figs 1–4. (Dunarobba,
297   Fossil Forest of the Stura di Lanzo River, and La Cassa).
298 *Occurrence*: Northern Italy: several Miocene sites (see Sordelli, 1896; Bertini and Martinetto,
299 2008); Pocapaglia (Zanclean); Candelo, Sento II (supposed Zanclean); Baldichieri-Fornace
300 (Zanclean-Piacenzian transition); Villafranca d'Asti-RDB Quarry, Fossil Forest of the Stura di
301 Lanzo River (Piacenzian); Barbania, Front, La Cassa, Momello-Lanzo (supposed Piacenzian);
302 Central Italy: Le Matole (Piacenzian); Dunarobba, Cava Toppetti I (supposedly Piacenzian). At
303 Fossano only in layer FOF10: abundant shoots, 2 cones, 3 seeds.
304 *Description and remarks*: The shoots of *Glyptostrobus europaeus* have been observed in large
305 quantity in the Pliocene of Italy on several square metres of bedding planes of the Dunarobba, La
306 Cassa, Le Matole, Momello-Lanzo and Stura di Lanzo fossil forests (Martinetto, 1994b; Martinetto
307 et al., 2007; Vassio et al., 2008; Martinetto et al., 2014; Bertini et al., 2014). Nowhere in Italy
308 shoots with elongated leaves have been observed; however these occurred, attached to the more
309 common cupressoid shoots, in some Neogene European localities (e.g., Balatonszentgyörgy: Hably,
310 2013, pl. 3, fig. 5). The abundant shoots of Fossano's layer FOF20 show a much reduced
311 heterophylly: all the leaves are helically arranged, scale-like and mostly very short (rarely up to 13
312 mm long in large shoots), partly to fully adpressed, bluntly pointed and amphistomatic.
313 *Glyptostrobus europaeus* was originally described (Brongniart, 1833) from the lower Miocene of
314 Allonisos (as Île d'Iliodroma), an island of the Northern Sporades (Velitzelos et al., 2014). Remains
315 of *Glyptostrobus* are among the commonest fossils in the Cenozoic of Europe up to the top of the
316 Pliocene, which is justified by its habitat: it was a dominant element of the swamp vegetation
317 covering many Cenozoic depositional sites. In several Italian sites (Barbania, Dunarobba, La Cassa,
318 Fossil Forest of the Stura di Lanzo River) it is easy to collect shoots with attached cones which still
319 contain seeds. For this reason it is preferable to use a single name for all these remains (*G.*
320 *europaeus*), even if the separate seeds could be named *G. brevisiliquata* (Ludwig) Mai.
321 In northern Italy *Glyptostrobus* forests were particularly well-developed in the Piacenzian
322 (Martinetto, 1994a). Despite the late occurrences of other exotic conifers (*Amentotaxus*, *Sequoia*,
323 *Taxodium*) in the Calabrian or Middle Pleistocene of Georgia (Chochieva, 1975) and central Italy
324 (Follieri, 2010), not a single shoot, cone or seed of *Glyptostrobus* is known from Early Pleistocene
325 or younger sediments in Europe (see Velitzelos et al., 2014 for an unreliable middle Pleistocene
326 record by Boyd, 2009). The possible last occurrence is represented by wood of the fossil-genus
327 *Glyptostroboxylon* in the Calabrian sediments of Leffe (Ravazzi and Van der Burgh, 1994). This is

328   in strong contrast with the pollen evidence used to proof the survival of *Glyptostrobus europaeus*
329   until to the Holocene on the southern shores of the Black Sea (Biltekin et al., 2015).

330

331   *Tetraclinis salicorniodes* (Unger) Kvaček
332   Fig. 4; Plate II, 8
333   1997   *Tetraclinis salicorniodes* (Unger) Kvaček – Basilici et al.: pl. 1, figs 3-6 (Sento II).
334   2001   *Tetraclinis salicorniodes* (Unger) Kvaček – Martinetto: pl. 1, fig. 1; pl. 2, fig. 1
335   (Dunarobba).
336   2015   *Tetraclinis salicorniodes* (Unger) Kvaček – Teodoridis et al.: pl. 2, figs 2-3 (Tossignano
337   and Monte Tondo, Vena del Gesso Basin, Romagna Apennines, Northern Italy).
338   *Occurrence*: Northern Italy: several upper Miocene sites (see Bertini and Martinetto, 2008;
339   Teodoridis et al., 2015); Breolungi, Crava di Morozzo I, Sezzadio-Rio della Lupa (Zanclean); Boca,
340   Ca' Viettone, Crava di Morozzo II, Sento II (supposedly Zanclean); Central Italy: Dunarobba
341   (supposedly Piacenzian). At Fossano abundant shoots and cones in layer FO3, less abundant in FO4
342   and FO10.
343   *Description and remarks*: Short shoots consisting of cladode-like flattened segments (cladodium) of
344   fused flat decussate leaves, up to 18 mm long, leaf base truncate to rounded, apex obtuse with two
345   lateral incisions. Lateral leaves do not overlap between adjacent nodes, and the facial leaves overlap
346   only slightly. The articulated shoots found in layer FO4, up to 60 mm long, represent the most
347   complete canopy remain of this ancient plant in Italy, otherwise represented by disarticulated
348   elements. Shorter articulated shoots were also detected in layers FO3 and FOF10, which suggests
349   that this ancient plant repeatedly grew in (or close to) the Fossano depositional palaeoenvironment.
350   The valvate seed cones (abundant in layer FO3) are composed of 4 (rarely 3) verticillate unequal
351   scales, 4-11 mm broad and c. 6 mm long. Cone scales are thick and woody, widely ovate with a
352   cordate base and rounded apex, length 3–8 mm width 4–10 mm; the scale surface is wrinkled and
353   bears a mucro. Seeds not found.
354   The problematic nomenclature and taxonomy of Cenozoic shoots and cones of *Tetraclinis* have
355   been discussed by Mai (1994), who suggested using different specific names for these two types of
356   remains, even when they are found in the same layer. Here, the Italian material is designated with
357   the single, widely used, name *Tetraclinis salicornioides*. As in other Neogene sites (Teodoridis et
358   al., 2015), the type of *Tetraclinis* occurring at Fossano is clearly different from the xeromorphic *T.*
359   *brachyodon* (Brongniart) Mai et Walther in having flat and broad leafy segments.
360   In central Europe this species does not occur in the Pliocene (Mai, 1997), whereas it is rather
361   common in the Lower Pliocene of NW Italy (Martinetto, 1999), and Pliocene remains of *Tetraclinis*
362   are also reported from Greece (Velitzelos et al., 2014). The fossils of Dunarobba II prove that this
363   species survived in central Italy at least until the Piacenzian, and its absence in the younger floras
364   seems to indicate that later it either disappeared or became very rare.

365

366   6.2 Angiospermae

367   Family Alangiaceae

368   *Alangium deutschmannii* Geissert et Gregor
369   Plate IV, 3, 4
370   1997   *Alangium* sp. – Basilici et al.: pl. 3, fig. 11 (Sento II).
371   1998   *Alangium deutschmannii* Geissert et Gregor – Martinetto: pl. 4, fig. 7 (Sento II).

372   *Occurrence*: Single endocarps of this species were known from three supposedly Zanclean sites of
373   northern Italy (Benasso, Sento II and Ronco Biellese) and a small fragment of an *Alangium*
374   endocarp was recovered from Dunarobba (supposedly Piacenzian) in central Italy, but its state of
375   preservation did not allow a specific identification. The Fossano material consists of 38 endocarps,
376   which provide a good record of the morphology and its variation.
377   *Description and remarks*: Endocarp bilocular with one locule much smaller than the other, ovate in
378   face view, laterally flattened, base rounded, apex truncated and grooved. Endocarp surface
379   completely smooth, with a peripheral furrow between the two carpels, bordered by two series of pits
380   and crossed by scarcely apparent transverse ridges. On the external surface the largest carpel is 5.4–
381   8.6 mm long and 4.2–5.6 wide, the shorter one 2.9–5.8 mm long and 2.0–3.2 wide. As these
382   endocarps are thick-walled and bilocular, with one locule larger than the other, they can be assigned
383   to sect. *Marlea* Baillon (Eyde, 1968; Manchester, 1994).
384   In Italy, many Cenozoic fossil leaves (e.g., Principi, 1940) have been assigned to this genus, but leaf
385   identification is problematic and a careful revision is needed. Several species of *Alangium* are well
386   documented by fossil endocarps in the Cenozoic of Europe (Geissert et al., 1990; Mai, 1970).
387   Endocarps of *A. deutschmannii* have been compared with those of living species (c. 20) by Geissert
388   and Gregor (1981), who pointed out the Asian species *A. longifolium* Merrill and *A. lamarcki*
389   Thwaites as the nearest living relatives. These plants are mainly trees, but also shrubs and lianas
390   (Manchester, 1994).

391   Family Cornaceae

392   *Cornus roshkii* (Negru) Martinetto
393   Plate IV, 2
394   2015   *Cornus roshkii* (Negru) Martinetto – Martinetto, p. 70.
395   *Occurrence*: Single endocarps occurred at Sento I (late Zanclean) and Sento II (supposedly late
396   Zanclean: Basilici et al., 1997), but only Fossano's layer FO3 provided abundant material (Tab. 1).
397   The fossil leaves of *Cornus* sp. occurring in layer FO4 may be a product of the same ancient plant.
398   *Description and remarks*: Endocarp globose, bilocular, coarsely pitted on sides 4.8 mm long, 5.1
399   mm wide, 0.96-1.17 l/w ratio, c. 1.5 mm thick, being laterally flattened by the sediment load during
400   fossilization. Apical cavity often broad; vascular bundles raised, surface very rough, conspicuously
401   reticulately-ribbed, apex and base flat. The endocarps have a structure similar with *C. sanguinea*,
402   but largely differ for the sculpturing. The elevation of the ribs and the shape show a consistent
403   variation. This fossil-species was only recorded in the Miocene of Moldavia (Negru, 1972), whereas
404   another record in Kovar-Eder and Krainer (1988) is problematic.

405

406   Family Lauraceae

407   *Laurus abchasica* (Kolakovskii et Shakryl) Ferguson
408   Plate III, 1
409   *Occurrence*: Single leaf from Fossano.
410   *Description and remarks:* Incomplete simple leaf, lamina ovate, 110 mm long and 28 mm wide,
411   base cuneate with fragmentary petiole, apex not preserved probably acuminate and blunt, margin
412   entire, venation brochidodromous, midrib strong, moderate, secondary veins thinner, straight,
413   looping by margin, alternate, originating at 30–50°, tertiary veins perpendicular, straight to sinuous,
414   venation of the higher orders regular polygonal reticulate, areolation well developed, 4-sided,
415   veinlets dichotomous to dendritic branching. Leaves hypostomatic; texture coriaceous, adaxial and
416   abaxial epidermis composed of polygonal irregularly disposed cells, 20–45 μm in diameter,

417 anticlines curved to undulate, stomatal complexes paracytic, shape rhomboidal, very dense,
418 subsidiary cells largely overlapping the sunken guard cells; guard-cell pair c. 16–20 μm long.
419 According to Kürschner and Kvaček (2009), *Laurus abchasica* is an evergreen element of the
420 Lauraceae, representing the direct ancestor of two extant laurels distributed today in the
421 Mediterranean (*L. nobilis* L.) and Canary Islands (*L. azorica* (Seubert) Franco). It is easily
422 recognizable by the abaxial cuticle containing rhomboidal stomatal complexes and the omega-
423 shaped fine undulation of the cuticle which covered the anticlinal walls). European occurrences are
424 known from the Lower Miocene to Pliocene (e.g., Bůžek et al., 1996; Ferguson, 1971, 1974;
425 Knobloch and Kvaček, 1976; Knobloch and Kvaček, 1996; Kolakovskii, 1958; Kovar-Eder and
426 Meller, 2001; Kvaček and Bůžek, 1966; Teodoridis and Kvaček, 2006; Uzunova, 1995).

427

428 *Laurophyllum pseudoprinceps* Weyland et Kilpper
429 Plate II, 2; Plate III, 2, 3
430 2015   cf. *Laurophyllum pseudoprinceps* Weyland et Kilpper – Teodoridis et al.: pl. 2, figs 15–16,
431   Pl. 3, figs 1–2.
432 *Occurrence*: Messinian of Tossignano and Monte Tondo (Vena del Gesso Basin: Teodoridis et al.,
433 2015), Early Miocene flora of Meleto (Valdarno Superiore: Fischer and Butzman, 2000).
434 *Description and remarks*: Incomplete leaves simple, petiolate, lamina elliptic to ovate, up to 55 mm
435 long and 31 mm wide, base cuneate, apex not preserved probably acuminate and blunt, margin
436 entire, venation brochidodromous, midrib strong, moderate, straight or slightly curved, secondary
437 veins thinner, straight, looping by margin, alternate, originating at 30–50°, tertiary veins
438 perpendicular, straight to sinuous, venation of the higher orders regular polygonal reticulate,
439 areolation well developed, 4-sided, veinlets dichotomous to dendritic branching. Leaves
440 hypostomatic, texture coriaceous, adaxial and abaxial epidermis composed of polygonal irregularly
441 disposed cells 20–40 μm in diameter, anticlines curved to undulate, with bead-like thickenings,
442 stomatal complexes amphibrachyparacytic, with larger outer subsidiary cells and central sunken
443 guard-cell pair c. 20–30 μm long and narrow pair of inner subsidiary cells, stomatal ledges thick,
444 surface of the guard cells finely granular, lens-shaped oil cells preserved in the mesophyll.
445 This apparently extinct and very common fossil lauroid was correlated with various members of
446 *Ocotea* without very satisfactory evidence as to the generic affinity. Indeed, *Laurophyllum*
447 *pseudoprinceps* is similar in the stomatal pattern to *Ocotea* (Bůžek et al., 1996; Palamarev and
448 Petkova, 1987 as *Ocotea oblanceolata* Palamarev et Petkova (Uzunova and Stojanova, 1999), but at
449 the same time, also to other genera, e.g., *Aniba*, *Cryptocarya*, which should also be taken into
450 consideration (Kvaček, 1971, Kürschner and Kvaček, 2009). According to Kürschner and Kvaček
451 (2009), the direct lineage of the fossil towards an extant species, as is the case for *Laurus abchasica*
452 and *Ocotea hradekensis* (Kvaček et Bůžek) Kvaček (Bůžek et al., 1996), is broken at the Pliocene,
453 when *L. pseudoprinceps* became extinct in Europe. The *Laurophyllum pseudoprinceps* complex
454 consists of two to three morphotypes sometimes considered as independent (sub)species (Weyland
455 and Kilpper, 1963, Kvaček in Knobloch et al., 1996) and may be interpreted as a typical element of
456 the subtropical evergreen humid forest types.

457

458 Family Oleaceae

459 *Olea moldavica* Negru
460 Plate IV, 1
461 *Occurrence*: only a few endocarps from Ca' Viettone (newly detected in the material described by
462 Martinetto and Vassio, 2010), and 2 endocarps from Fossano (Tab. 1).

463 *Description and remarks*: The Fossano endocarps are ellipsoidal, unilocular, anastomosedly ribbed
464 on sides, 9,1 mm long, 5.9 mm wide, l/w ratio 1.54, c. 1.3 mm thick, being laterally flattened only
465 due to the sediment load during fossilization. This fossil-species was described from the Sarmatian
466 (middle Miocene) of Moldavia (Negru, 1972) and the Miocene of Germany (Gregor, 1986). The
467 fruit stone morphology was possibly never compared accurately with that of several modern
468 Oleaceaus genera, so that the generic assignment would better be confirmed, also because some
469 pollen grains found in the same deposit of Fossano show an affinity to *Phyllirea*. However, we were
470 able to compare the fossil endocarp with the modern ones of two species of *Osmanthus*, two species
471 of *Phyllirea*, and *Olea europaea*, and the endocarps of *Olea* resulted the most similar to the fossils
472 with regard to their shape, dimensions, structure and venation, but the endocarp wall is more
473 strongly lignified. Medail et al. (2001) also pointed out a considerable variability of stone characters
474 within *Olea europaea*. Another fossil-species, *Olea oleastroides*, described from the Miocene of
475 Poland (Zabłocki, 1930) as being very similar to *O. europaea*, has been questioned (Geissert et al.,
476 1990) as a real representative of *Olea*. This first occurrence in Italy is definitely remarkable.

477

478 Family Staphyleaceae

479 *Turpinia ettingshausenii* (Engelhardt) Mai
480 Plate IV, 6, 8
481 1997   *Turpinia ettingshausenii* (Engelhardt) Mai – Basilici et al.: pl. 3, figs 3, 4 (Sento II).
482 *Occurrence*: Just a few seeds of this species were found so far in northern Italy at Boca, Ca'
483 Viettone, Sento II (supposed Zanclean). In central Italy only one seed at Santa Barbara-Gregor's
484 outcrop (Piacenzian). The richest Italian assemblage is represented by the nine seeds from Fossano's
485 layer FO2 and FO3.
486 *Description and remarks*: Miocene seeds of this fossil-species have recently been described by
487 Holý et al. (2012). The nine seeds available from Fossano agree in the irregular outline, mostly
488 ovoid to elongate ovoid, 7.4 to 8.0 mm long, 5.3 to 5.5 mm wide, l/w ratio 1.54–1.51, at base
489 obliquely cut, blunt, on sides irregularly flattened, hilum subapical deeply sunken, up to 2.8 mm
490 long on base, with a funnel-shaped hole on the bottom for the vascular bundles of raphe, which
491 enter the testa tissue within hilum. A few specimens show dehiscence along the peripheral suture in
492 the widest part of the seed. The outer surface is densely punctate but not particularly lustrous. The
493 above described seeds are identical with those described by Mai (1964, p. 97), Holý (1975, pp. 68–
494 69, pl. 13, figs 1–6) and Holý et al. (2012). Mai (1964) assessed the similarity of the fossil seeds
495 with those produced by the living *Turpinia montana* (Blume) Kurz and *T. formosana* Nakai from
496 eastern Asia.

497

498 Family Vitaceae

499 *Tetrastigma chandlerae* Kirchheimer
500 Plate IV, 7
501 1997   *Tetrastigma* sp. – Basilici et al.: pl. 3, fig. 13 (Sento II).
502 *Occurrence*: Just a few seeds of this species were found so far in northern Italy at Boca, Ca'
503 Viettone, Sento II (supposedly Zanclean). One seed from Fossano's layer FO2.
504 *Description and remarks*: Miocene seeds of this fossil-species have been recently described by
505 Holý et al. (2012). The single seed available from Fossano agrees in the ovoid outline with flat
506 sides, 6.9 mm long, 5.0 mm wide, 1.38 l/w ratio, apex rounded with a deeply cut furrow of raphe,
507 base gradually narrowed into a short conical micropylar tubercle, dorsal side with elliptic chalaza

508 and short furrows radiating from there, two furrows running from the keel dividing the surface into
509 transversal lobes. The seeds described by Holý (1975) correspond to the records common in Upper
510 Lusatia, particularly from Wiesa near Kamenz (Mai, 1964). Kirchheimer (1938) indicated *T.*
511 *lanceolarium* (Roxburgh) Planchon as a comparable living species, distributed mostly in lowland
512 evergreen forests of Thailand, Indonesia, Myanmar, Vietnam and India (Holý et al., 2012). Habib et
513 al. (2017) pointed out the systematic-phylogenetic importance of seed characters in *Tetrastigma*.

514

515 *Vitis teutonica* A. Braun
516 Plate IV, 5
517 1996 *Vitis teutonica* A. Braun – Cavallo and Martinetto, p. 26, pl. 6, figs 6–8.
518 *Occurrence*: Northern Italy: A probable record in the Messinian (Bertini and Martinetto, 2014);
519 Benevagienna, Breolungi, Pocapaglia, Sento I (Zanclean); Ca' Viettone, Ronco Biellese, Sento II
520 (supposedly Zanclean). Thirty-nine seeds from Fossano's layers FO2, FO3 and FOF10.
521 *Description and remarks*: The abundant seeds from Fossano correspond with the description
522 provided by Unger (1866) (*seminibus parvis 3-5 mm. longis ovato-acuminatis rugulosis, externe*
523 *convexis longitudinaliter sulcatis, interne lateribus compressis*) for the type material from the
524 German lignites, found associated with leaves assigned to *Vitis*. The Fossano specimens are 3.5–5.5
525 mm long, 3.0–3.5 mm wide, l/w ratio 1.0–1.5, obovate, abruptly narrowed into the basal beak, inner
526 face with short shallow pits, outer surface convex and smooth, longitudinally sulcate with a narrow
527 pyriform chalaza.
528 Seeds of *Vitis* are very common in the Pliocene and Early Pleistocene deposits of northern-central
529 Italy. Rich populations of several tens to hundreds of seeds show a considerable variation, which
530 has not yet sufficiently studied, also because in recent years more accurate studies of seed shape and
531 variation have been carried out (Gong et al., 2010; Chen and Manchester, 2011; Ucchesu et al.,
532 2015), with a reconsideration of the taxonomy of such fossils. The taxonomic frame of the Italian
533 material is still unclear, but some seed populations were accurately compared, together with D.H.
534 Mai, with analogous rich material from Germany, including the types of different fossil-species, in
535 particular *V. globosa*, *V. lusatica*, *V. parasylvestris* and *V. teutonica*. Part of the Italian material was
536 actually assigned to the last two species in previous papers (Martinetto, 1994b, 1995).
537 Several fossil seed populations from the Zanclean to the Holocene show distinct similarities to the
538 wild Mediterranean grape *V. vinifera* ssp. *sylvestris* (Martinetto, 1994b; Basilici et al., 1997;
539 Cavallo and Martinetto, 2001). However, other rich populations from the Zanclean or supposed
540 Zanclean sites are morphologically distinguishable for the generally smaller dimensions, smoother
541 seed surface, narrowly obovate chalaza and narrow basal beak. These populations can be assigned
542 to the fossil-species *V. teutonica*.

543

6. Palaeobotanical results

545 In Section A, the analysis of carpological assemblage FO1 (Tab. 1) yielded a poorly diverse flora
546 dominated by wetland plants. Carpological assemblages FO2 and FO3 indicated a considerable
547 taxonomic diversity, with respectively 27 and 70 taxa, among which the occurrence of *Alangium*
548 *deutschmannii*, *Cornus roshkii*, *Olea moldavica*, *Tetrastigma chandlerae*, *Turpinia ettingshausenii*,
549 *Vitis teutonica* is particularly remarkable.
550 Thanks to the macroscopic morphological analysis of leaves and to the microscopic study of
551 cuticles (Plate II, III), 13 species of terrestrial plants were identified within layer FO4. The leaf
552 assemblage shows an excellent preservation (Plate II, 1) and is dominated by coriaceous
553 laurophyllic (evergreen) taxa (mainly Lauraceae: *Daphnogene* sp., *Laurus abchasica* (Plate III, 1),

Laurophyllum pseudoprinceps (Plate II, 2; Plate III, 2, 3), *Ocotea heeri*, and Loranthaceae: *Viscum morlotii*), whereas chartaceous leaves of deciduous trees are less common, and allowed us to identify: *Acer integerrimum* (Plate II, 9), *Alnus gaudinii*, *Berchemia multinervis* (Plate II, 4), *Celtis* sp. (Plate II, 5), *Cornus* sp. (Plate II, 6), *Liriodendron* sp., *Platanus leucophylla, Pungiphyllum cruciatum* (Plate II, 7).

The preliminary pollen analysis of layer FO3 yielded 45 pollen taxa, with a concentration of 6106 pollen grains per gram. The pollen flora is characterized by the dominance of arboreal taxa (80.2%), especially Pinaceae. Among the latter *Pinus* attains the higher values (13.7%) followed by *Cathaya* (7.6%) plus *Pinus haploxylon* (0.4%). Mesothermic gymnosperms such as *Cedrus* (5.7%) and *Tsuga* (3.8%), interpreted as mid to high elevation forest taxa, are quite abundant, but also the microthermic *Picea* (4.9%) and *Abies* (1.9%), interpreted as high elevation forest taxa, are well represented. *Betula* (1.9%) and *Fagus* (1.9%) are broad-leaved deciduous forest taxa that could accompany these conifers at high palaeoelevation. Taxa typical of the "subtropical humid forest" (Bertini and Martinetto, 2011) are especially abundant and, among them, *Taxodium/Glyptostrobus* type (9.5%) is the most abundant, followed by *Sciadopitys* (3.0%) and *Engelhardia* (1.1%). Other taxa occur with values below 1%: Apocynaceae, cf. *Morella*, Rutaceae, Sapotaceae, cf. *Trigonobalanopsis*. Temperate broad-leaved deciduous forest taxa are also well represented, especially *Quercus* (4.9%), followed with decreasing pollen percentage by *Liquidambar, Pterocarya*, cf.

Craigia, Carpinus, *Buxus*. The consistent frequency of *Alnus* (4.2%) suggests the local occurrence of carr and/or swamp vegetation. The scanty occurrence of Cupressaceae (possibly *Tetraclinis*) and cf. *Phillyrea* needs to be examined with the macrofossil record for a possible palaeovegetational interpretation.

Non-arboreal pollen is definitely subordinate to the arboreal pollen. Poaceae (9.5%) dominate, followed in very low percentages by Fabaceae, *Plantago*, Brassicaceae, Amaranthaceae, Caryophyllaceae, Asteraceae Asteroideae and Cichorioideae, *Rumex*, Rosaceae and Cannabaceae.

Among the other palynomorphs, Pteridophyta (Osmundaceae and monolete spores) as well as sparse Fungi are also present (Tab. 2).

In Section FF, the combination of field observations and bulk sample analysis provided interesting palaeofloral data for two layers. Layer FOF10 yielded several carpological remains (Tab. 1), including *Vitis teutonica* and *Tetraclinis salicornioides*, the last one showing a dominance of delicate articulated shoots (Fig. 4). The assemblage FOF20 is almost exclusively composed of *Glyptostrobus europaeus* shoots forming a buried litter (Plate I, 5). Only a few fruits and seeds point out the presence of other plants, e.g., *Ampelopsis ludwigii, Liquidambar europaea* and *Meliosma wetteraviensis*.

The poor palaeofloral data obtained from the FO5 assemblage (Tab. 1) are, however, relevant for the occurrence of *Saurauia* sp. and for the dominance of a lauraceous leaf type (*Laurophyllum* sp.), which is most likely connected to the very abundant endocarps of *Litsea sonntagii*.

7. Discussion

In this paper, we summarize the available palaeofloral data and the preliminary stratigraphic and palaeontological information obtained for the c. 100 m thick Pliocene succession including the Fossano Fossil Forest in its middle part. The large-scale palaeoenvironmental framework and trend is provided by studies on the underlying deposits (Violanti, 2005; Vigna et al., 2010; Ghielmi et al., in press). These studies show that the uppermost offshore muddy deposits of the Fossano area belong to the MPl3 foraminifer biozone. This indicates that the studied area was characterized by an outer shelf palaeoenvironment at least until 4.5 Ma. The shallow marine sands (Ghielmi et al., in press; Vigna et al., 2010) at the top of the offshore muddy deposits, directly underlying our Section

602   A (Fig. 3), yielded invertebrate assemblages (Sacco, 1886a, 1889-1890) which suggest a transition
603   to a shoreface depositional environment.
604   The layers with brackish water molluscs (i.e. *Potamides* sp.) at the base of Section A (Fig. 3) point
605   to the successive gradual transition to a coastal lagoon or a brackish estuary. The presence of
606   fossilized terrestrial vegetation (roots) and poorly evolved palaeosols, first occurring in the middle
607   part of Section A, testifies for the subsequent establishment of continental environments. Evidence
608   like this, even more frequent in the overlying portion of the succession, proves that continental
609   conditions persisted for a long time.
610   Channelized sandy-gravelly deposits with bottom-up grain size decrease, observed from 10–96 m of
611   the studied composite section, can be attributed to the occupation of the Fossano palaeolandscape
612   by inland waterways. One of these deposits was observed 2.5 m below the fossil forest bed, and the
613   fining upward trend of the overlying beds (Fig. 3) indicates that the Fossano Fossil Forest settled in
614   a phase of decreasing fluvial influence, when the palaeoenvironment was characterized by wetlands,
615   including swamps with dense arboreal cover. The dominance of delicate articulated shoots of
616   *Tetraclinis salicornioides* in layer FOF10 indicates an autochthonous/parautochthonous deposition
617   (but see below for the ecology of *Tetraclinis*), and the same indication is provided by the buried
618   litter of *Glyptostrobus europaeus* shoots in layer FOF20, which also indicates that the ancient
619   swamp forest was dominated by this plant.
620   The complex of the herein observed characteristics is useful for a palaeoenvironmental and
621   chronostratigraphic comparison of the succession with better studied ones of NW Italy. The
622   Fossano Fossil Forest has indeed consistent analogies in the facies, and sometimes vertical stack of
623   facies, with other NW Italian successions, such as Ceresole d'Alba, La Cassa, Fossil Forest of the
624   Stura di Lanzo River and Villafranca d'Asti-RDB Quarry (Martinetto, 1994a, 1994b; Ciangherotti et
625   al., 2007; Martinetto et al., 2007; Vassio et al., 2009; Forno et al., 2015).
626   However, the palaeofloral data collected from the whole Fossano succession do not support a
627   palaeoclimatic and chronological equivalence to any of the above successions. A comparison of the
628   integrated pollen-macrofossil record of Fossano with that of the Villafranchian type-area points out
629   consistent floristic differences, in particular for the presence of several, mostly thermophilous plants
630   that lack in the second site (*Alangium*, *Cyclea*, *Saurauia*, *Tetraclinis*, *Tetrastigma*, *Turpinia*,
631   *Zanthoxylum*). From the palaeoclimatic point of view, the high number of "humid thermophilous
632   plant taxa of East Asian affinity" (HUTEA: Martinetto et al., 2016) identified in several layers,
633   spanning over 50 m of the Fossano composite section (Fig. 5), testifies for the long-lasting
634   persistence of mesic plant communities with a strongly thermophilous character (Bertini and
635   Martinetto, 2011). This feature distinguishes the Fossano palaeofloral assemblages from those of
636   other *Glyptostrobus* fossil forests of the Piacenzian of northern Italy, where the taxa originating
637   from mesic plant communities are also recorded, but the thermophilous elements are not so
638   abundant. In this respect the Fossano palaeoflora is analogous to those of other Zanclean or
639   supposed Zanclean sites of northern Italy. The differences between these and the Piacenzian floras
640   are not huge, since they share a large number of common taxa, and only a minor, but significant
641   group of taxa, lacks in the Piacenzian floras (Group 1), and highlights the palaeofloral differences.
642   Actually, in northern Italy the zonal vegetation during both Zanclean and Piacenzian seems to be
643   constantly of "subtropical humid forest" type (Bertini and Martinetto, 2011). Even the occurrence of
644   low pollen percentages of Cupressaceae (possibly *Tetraclinis*) and cf. *Phillyrea* (possibly the pollen
645   of *Olea moldavica*) at Fossano cannot univocally be interpreted as the record of a sub-humid
646   Mediterranean type sclerophyllous forest. Rather, the fossil occurrences of *Tetraclinis*
647   *salicornioides* and *Olea moldavica* at a European scale (Geissert et al., 1990; Gregor, 1986; Kvaček
648   et al., 2000; Negru, 1972) suggest that these extinct elements, although having extant Mediterranean
649   relatives, were actually adapted to the "subtropical humid forest". Kvaček (2007) indicated two
650   kinds of humid habitat for *Tetraclinis salicornioides*: subtropical humid forests and broad-leaved
651   deciduous forests. Additionally, our finding of authochtonous remains (see above) of this species in
652   Fossano's bed FOF10 would suggest that this plant also tolerated swamp conditions. As a whole, the

653 integrated plant records (fruits and seeds, leaves, pollen) of the adjacent layers FO3 and FO4 allow
654 us to reconstruct a warm temperate climate regime, with a small range of temperature and abundant,
655 well-distributed rainfall throughout the year. Such climatic conditions are typical for the entire
656 Zanclean interval in northern Italy, but they have been pointed out also for some Piacenzian warm
657 intervals (Combourieu-Nebout et al., 2015). Nevertheless, they are separated by important cooling
658 events (De Schepper et al., 2014), probably affecting the abundance or even the existence of some
659 humid thermophilous plant taxa of East Asian affinity taxa. In conclusion, even if these taxa are still
660 well represented in the Piacenzian assemblages, they are more numerous and frequent in the
661 Zanclean ones (Martinetto et al., 2016).
662 From the chronological point of view, we can exploit the biochronological relevance of several
663 Groups of carpological taxa defined by Martinetto et al. (2015, but see also Martinetto et al., 2016)
664 for the interpretation of the Fossano assemblages. In particular, several elements of Group 1 have
665 been detected in the samples of Fossano's Section A, and a few ones also occur in the less diverse
666 assemblages of Section FF and layer FO5 (Fig. 5). Group 1 was defined as comprising those taxa
667 which, in northern Italy, occur only in the Zanclean (and pre-Zanclean). However, there are no
668 precise constraints fixing the local extinction of these taxa to the end of the Zanclean, so that in this
669 work we introduce a more cautious approach, admitting a Zanclean-earliest Piacenzian distribution
670 of Group 1. Therefore, the abundance of Group 1 elements (Martinetto et al., 2015) in Fossano's
671 Section A (e.g., *Alangium deutschmannii*, *Cornus roshkii*, *Symplocos minutula*, *Tetrastigma*
672 *chandlerae*, *Turpinia ettingshausenii*, *Vitis teutonica*: Plate IV), the occurrence of a few ones in
673 Section FF (*Vitis teutonica*, *Tetraclinis salicornioides*, *Saurauia* sp.), and the persistence of the
674 Group 1 species *Saurauia* sp. in layer FO5, suggest the assignment of a long portion of the studied
675 succession (from Layer FO1 up to layer FO5: Fig. 3) to the Zanclean-earliest Piacenzian interval.
676 At the state-of-the-art the sequence stratigraphic framework (Ghielmi et al., in press; Vigna et al.,
677 2010) would indicate that the whole Fossano pre-Quaternary succession (Fig. 3) lays below a major
678 regional Intra-Zanclean Unconformity. In the deepest part of the basin this unconformity lays in
679 between marine sediments respectively assigned to the MPL3 and MPL4a biozones (late Zanclean)
680 (Vigna et al., 2010). The Fossano continental deposits overlay the MPL3 foreshore muds, and are
681 truncated by the pre-MPL4a Intra-Zanclean Unconformity (above), which constrains their age to the
682 late Zanclean (Fig. 2). However, further palaeontological evidence would be needed for a
683 confirmation of the chronological framing of the Fossano succession, in particular for its upper part,
684 where the single biochronologically significant taxon is *Saurauia* sp. It should be noticed that other
685 swamp fossil forests of NW Italy, including the ones detected in the Villafranchian type-area, were
686 dated to the Piacenzian (Forno et al., 2015; Martinetto et al., 2007), so that the Fossano Fossil
687 Forest would be the oldest assemblage of this type in the study area.
688
689 **8. Conclusion**
690 The assemblage of upright mummified stumps recently cropped out in a small area at Fossano
691 suggests the existence of two successive fossil forest beds. The data so far collected allow us to
692 point out the palaeofloral and stratigraphic context of these ancient forests. Only the upper forest
693 bed shows an abundance of remains of *Glyptostrobus europaeus*, the dominant conifer in other
694 Italian late Cenozoic fossil forests. Both sequence stratigraphic and palaeobotanical results prove
695 that the continental deposits of Fossano, assigned to the stratigraphic sequence PL1, do not have
696 any chronological link with the sediments of the Villafranchian type-area (Carraro, 1996; Forno et
697 al., 2015). These belong to the overlying sequence PL3, even if they were apparently deposited in
698 similar palaeoenvironmental conditions. The settlement of the Fossano palaeoswamp, where the
699 trees grew, possibly occurred around 4.1–4.0 Ma, during the first formation of a coastal plain in the
700 western Po Basin after the post-Messinian marine ingression, and falls, from the climatic point of
701 view, within the "Early Pliocene warmth" (Fedorov et al., 2013). This is well supported by the
702 thermophilous character of the Fossano palaeofloras, from the base to the top of the studied section,

which points to a stable, very warm temperate climate. The successive eastward progradation of the coastal plain determined the establishment of similar continental environments in the Villafranchian type-area, about one million years later, already under the effects of the first Piacenzian climatic deterioration.

Abbreviations - MGPT-PU: Museo di Geologia e Paleontologia, Università degli Studi di Torino.

Captions

Fig. 1.A. Historical geological map by Sacco (1887) with the location of the Fossano Fossil Forest and our stratigraphic Section A. In the lower right corner: Location of the Fossano site and the Piedmont region on a physiographic map Italy.

Fig. 1.B. Detailed geological map based on observations carried out in the years 2000-2017 with the location of the Fossano drill core (D) and stratigraphic sections A, B and FF.

Fig. 2. Sequence stratigraphic scheme of the Pliocene and Pleistocene successions of the Fossano area, based on integrated subsoil and outcrop data illustrated in Ghielmi et al. (in press). GPTS, Geomagnetic Polarity Time Scale, chronostratigraphy after Gibbard et al. (2010). The stratigraphic position of the Fossano Fossil Forest is indicated by the arrow (FF).

Fig. 3. From left to right, respectively: detail of Section A, Section FF andcomposite stratigraphic section of the Fossano Fossil Forest succession, based on the integration of data collected in sections A, B and FF with those of a long drill core log (Fossano landslide, see Fig. 1). The position of the main fossil-bearing layers is indicated by the labels FO1, FO2, FO3, FO4, FOF10, FOF20, FO5.

Fig. 4. Detail of the natural outcrop of a bedding surface of the Fossano Fossil Forest at ca. 505 cm of section FF (layer FOF10) with naturally exposed remains of *Tetraclinis salicornioides* (Unger) Endlicher; A. small articulated shoot; B. cone.

Fig. 5. Scheme summarizing the biochronological distribution of selected carpological records of plant taxa occurring in the Fossano composite section. The Groups 1-5 are defined in Martinetto et al. (2015). Mes = Messinian; MP = Middle Pleistocene.
The biochronological distribution of each taxon is deduced from the whole N-Italian CENOFITA database (Martinetto and Vassio, 2010; Martinetto, 2015; Martinetto et al., 2015). The age range for

each species is indicated by black bars, for the records originating from reliably dated localities: Lugagnano (5.1–4.5 Ma), Pocapaglia (4.5–3.8 Ma), Breolungi (5.1–3.8 Ma), Morozzo (5.1–3.8 Ma), Sento I (3.8–3.6 Ma), Candelo (4.5–3.6 Ma), Roatto (3.3–3.2 Ma), Villafranca d'Asti-RDB Quarry (3.3–3.0 Ma), Fossil Forest of the Stura di Lanzo River (3.1–3.0 Ma), Casnigo (2.1–1.9 Ma), Santerno (1.8–1.7 Ma), Leffe (1.7–1.5 Ma), Stirone-LA1 (1.1–1.0 Ma), Enza-EZ38 (1.1–1.0 Ma), Ranica (1.1–1.0 Ma), Oriolo (1.0–0.8 Ma), Stirone-LA3 (1.0–0.8 Ma). Hatched bars indicate records from the following poorly dated localities (see Martinetto, 1999): Ca' Viettone (late Zanclean, 3.8–3.6 Ma); Sento II (late Zanclean, 3.8–3.6 Ma); Front (Piacenzian, 3.3–3.0 Ma); Momello-Lanzo (Piacenzian, 3.6–3.0 Ma); Castelletto Cervo I (late Piacenzian, 2.8–2.6 Ma); Castelletto Cervo II (Gelasian, 2.6–2.0 Ma); San Pietro di Ragogna (Gelasian, 2.6–1.8 Ma); Buronzo (Gelasian, 2.2–1.8 Ma); Steggio (Calabrian, 1.8–0.9 Ma). The dashed lines indicate the presence of records in central Italy, considered a refuge area in the Piacenzian-Calabrian (Martinetto, 2001; Martinetto et al., 2016).

Tab. 1. List of carpological remains identified in the samples of the Fossano succession (sections A, FF and layer FO5). The labels used for the sampled layers (e.g., FO3) are also used for indicating carpological samples, with the addition of a conventional code of 3 characters which designates all the carpological records of each individual sample in the CENOFITA database (Letter–Number–Letter; e.g., B6N). The numbers in brackets represent the abundance of the carpological remains of each taxon in the sample specified.

Tab. 2. Percentage pollen spectrum of layer FO3 including Arboreal (AP) and Non Arboreal Pollen (NAP).

Plate I. Outcrop of the Fossano Fossil Forest in the bed of the Stura di Demonte River. 1. General overview of the outcrop, with a stump in the foreground and another one in the background; 2, 3, 4. Detail of some stumps. Notice in 2 the sediments which entirely cover a small stump and the presence of diagenetic concretions around roots on the right, and in 3 the deepening of roots in the palaeosol, which testifies the living position of the stumps. 5. Buried litter in layer FOF20 with massive occurrence of *Glyptostrobus europaeus* shoots.

Plate II. Examples of leaf compressions from bed FO4 of Fossano Section A. Scale bar 10 mm. 1. MGPT-PU 105951, bedding surface of bed FO4 with several compressed leaves; 2. MGPT-PU 105952, *Laurophyllum pseudoprinceps* Weyland et Kilpper, cluster of three leaves; 3. MGPT-PU 105953, *Laurophyllum* sp.; 4. MGPT-PU 105954, *Berchemia multinervis* (A. Braun) Heer; 5. MGPT-PU 105955, *Cornus* sp.; 6. MGPT-PU 105956, *Celtis* sp.; 7. MGPT-PU 105957, *Pungiphyllum cruciatum* (A. Braun) Frankenhäuser et Wilde; 8. MGPT-PU 105958, *Tetraclinis salicornioides* (Unger) Endlicher; 9. MGPT-PU 105959, *Acer integerrimum* (Viviani) Massalongo.

Plate III. Examples of leaf compressions with details of their cuticles. Scale bar 10 mm (thick), 20 µm (thin). 1. MGPT-PU105700, *Laurus abchasica* (Kolakovsky et Shakryl) Ferguson: incomplete leaf lamina (1a), detail of the figure 1a (1b) and abaxial cuticle with dense paracytic rhomboidal stomata epidermal polygonal cells with curved to undulate anticlines (1c, d). 2. MGPT-PU105168, *Laurophyllum pseudoprinceps* Weyland et Kilpper: detail (2a) of one of the leaves of Plate II, 2, abaxial cuticle with amphibrachyparacytic stomata and epidermal polygonal cells with undulate anticlines and bead-like thickenings (2b). 3. MGPT-PU105218, *Laurophyllum pseudoprinceps* Weyland et Kilpper: incomplete leaf lamina (3a), abaxial cuticle with amphibrachyparacytic stomata and epidermal polygonal cells with curved to slightly undulate anticlines (3b, c).

Plate IV. Examples of carpological material from Section A. Scale bar 1 mm. 1. MGPT-PU 105960, *Olea moldavica* Negru: endocarp from layer FO2 in lateral (1a), ventral (1b) and dorsal

787 (1c) view. Notice the damage of probable animal origin in 1b. 2. MGPT-PU 105961, *Cornus roshkii*
788 (Negru) Martinetto: endocarp from layer FO3 viewed from two opposite faces (2a, 2b) and in apical
789 view (2c). 3. MGPT- PU 105962, *Alangium deutschmannii* Geissert et Gregor: endocarp from layer
790 FO3 in lateral (3a), ventral (3b) and dorsal (3c) view. 4. MGPT-PU 105963, *Alangium*
791 *deutschmannii* Geissert et Gregor: endocarp from layer FO3 in ventral (4a), dorsal (4b) and lateral
792 (4c) view. 5. MGPT-PU 105964, *Vitis teutonica* A. Braun: seed from layer FO3 in lateral (5a),
793 ventral (5b) and dorsal (5c) view. 6. MGPT-PU 105965, *Tetrastigma chandlerae* Kirchheimer:
794 endocarp from layer FO2 in lateral (6a), ventral (6b) and dorsal (6c) view. 7. MGPT-PU 105966,
795 *Turpinia ettingshausenii* (Engelhardt) Mai: endocarp from layer FO2 in ventral (7a), lateral (7b) and
796 inner (7c) view. 8. MGPT-PU 105967, *Turpinia ettingshausenii* (Engelhardt) Mai: endocarp from
797 layer FO2 viewed from the dorsal side (8a) and from two opposite faces (8b, c).
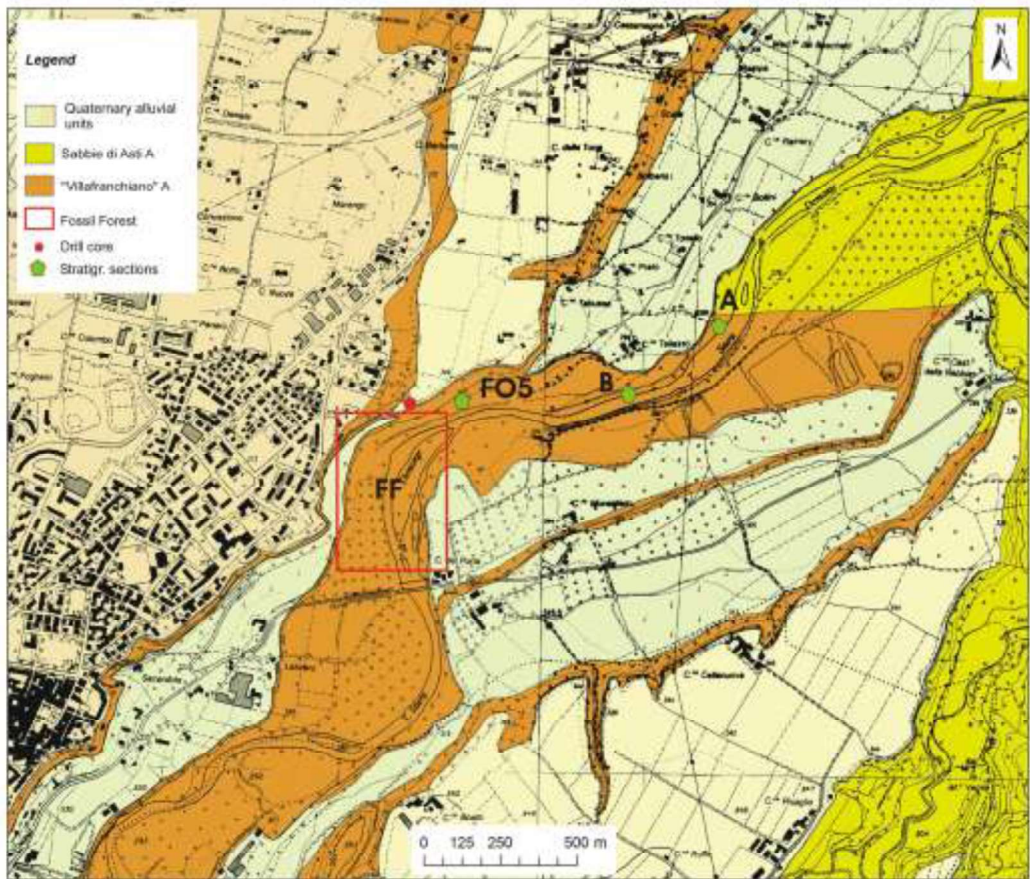
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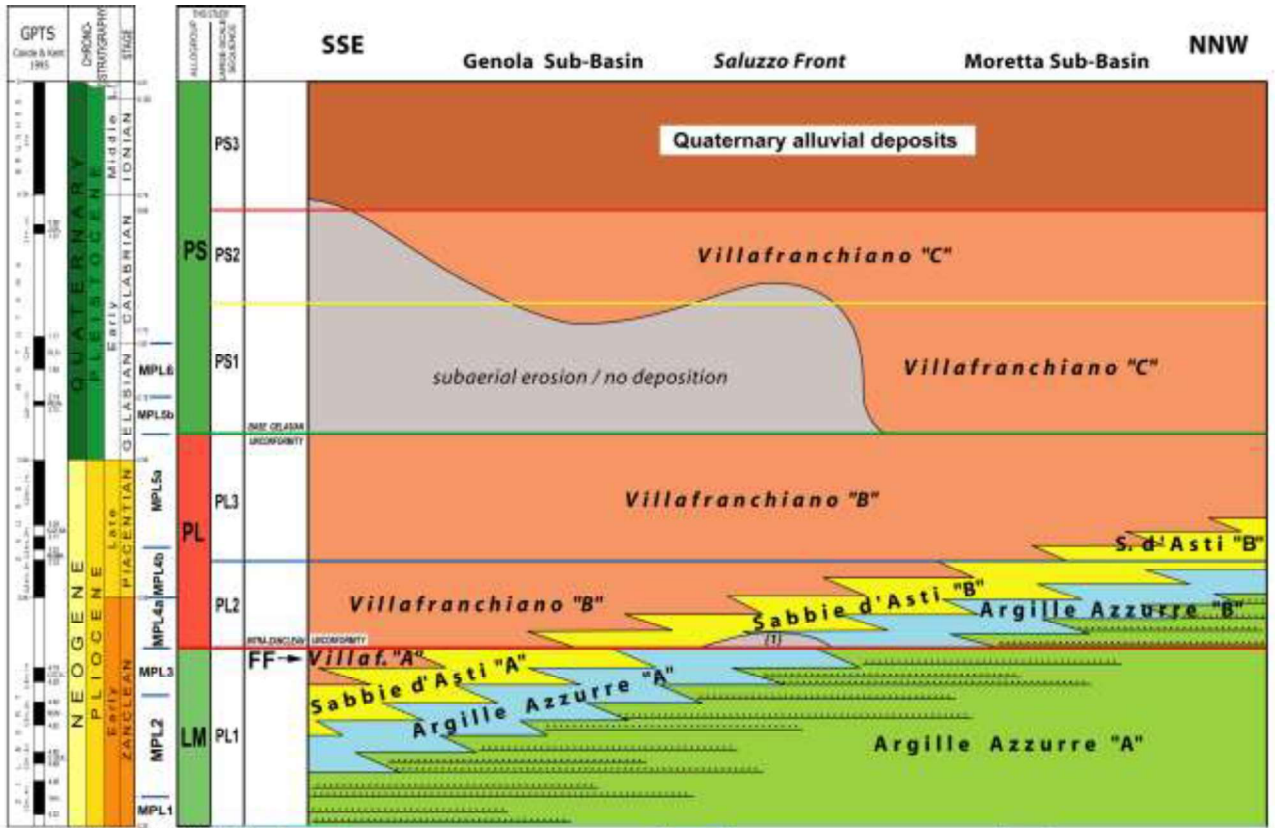
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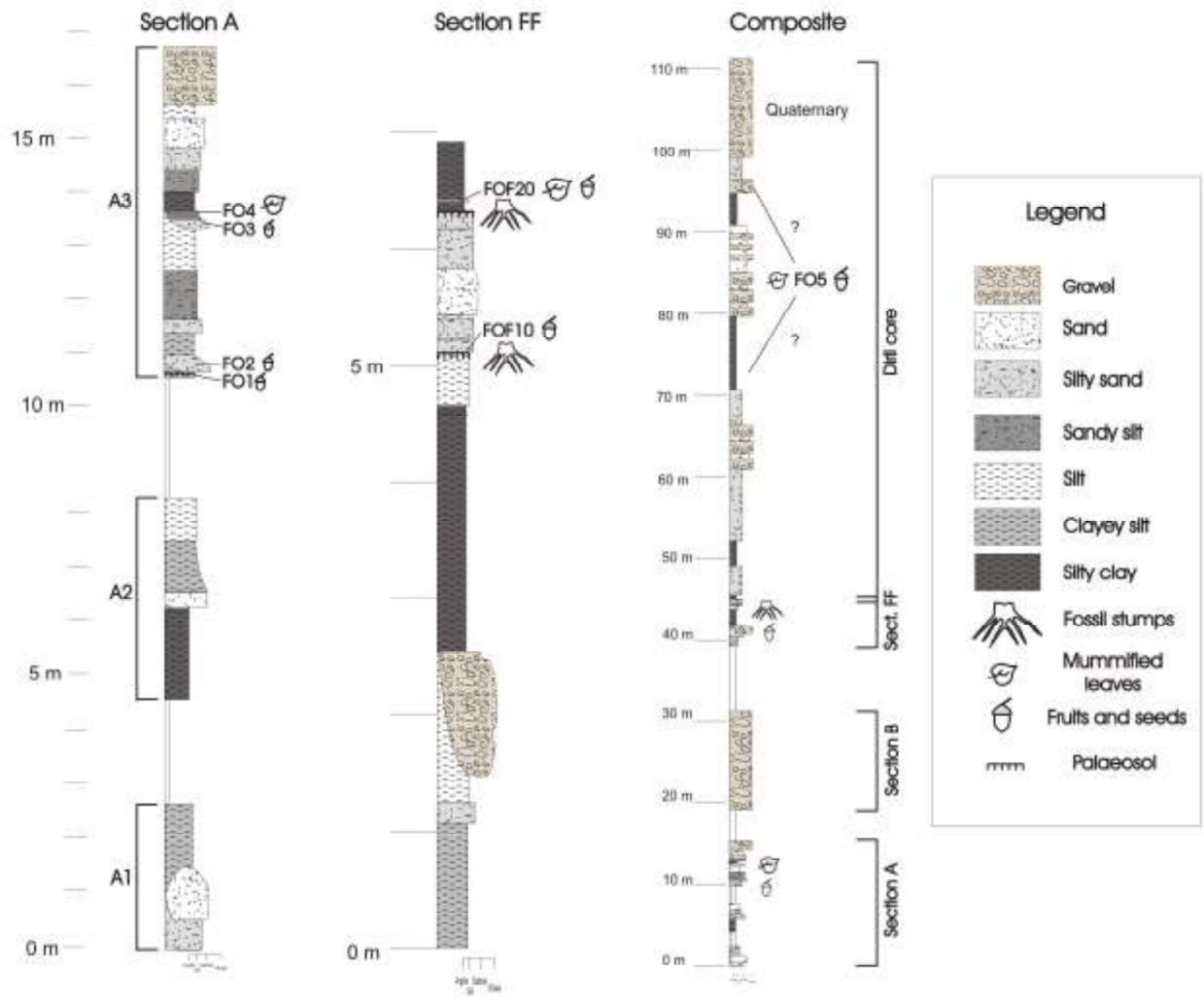
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Fossano

Milan

Fossano

ITALY

Rome

100 km

A

FO5

B

FF

0 125 250   500 m

GPTS Cande & Kent 1995

SSE — NNW

Genola Sub-Basin — Saluzzo Front — Moretta Sub-Basin

Quaternary alluvial deposits

Villafranchiano "C"

Villafranchiano "C"

subaerial erosion / no deposition

BASE CELASIAN
UNCONFORMITY

Villafranchiano "B"

S. d' Asti "B"

Villafranchiano "B"

Sabbie d'Asti "B"

Argille Azzurre "B"

INTRA-ZANCLEAN UNCONFORMITY

FF → Villaf. "A"

Sabbie d'Asti "A"

Argille Azzurre "A"

Argille Azzurre "A"

(T) condensed sedimentation or erosion on intrabacinal submarine structural high

| Alluvial Fan and Fluvio-Glacial Deposits | Shelfal Sandstone Lobes | Basinal Sandstone Lobes |
| Alluvional Fan, Fluvial, Flood-Plain and Deltaic Deposits | Slope Deposits | Basinal Fine-grained Deposits |

Section A

Section FF

Composite

A3

FO4
FO3

A2

FO2
FO1

A1

15 m

10 m

5 m

0 m

FOF20

FOF10

5 m

0 m

110 m

100 m

90 m

80 m

70 m

60 m

50 m

40 m

30 m

20 m

10 m

0 m

Quaternary

?

FO5

?

Drill core

Sect. FF

Section B

Section A

Legend

Gravel

Sand

Silty sand

Sandy silt

Silt

Clayey silt

Silty clay

Fossil stumps

Mummified leaves

Fruits and seeds

Palaeosol

Whole N-Italian CENOFITA dataset

Column headers (top):
- Series and stage
- Records
- Age (Ma)
- Marine biozones
- Magnetic polarity
- Intervals covered by dated carpofloras
- Main Köppen climate type

Age / series divisions:
- MIO — Mes — 7.5–5.3 / 5.3
- PLIOCENE — Zanclean (MPL2 MPL3 — 3.8) — Placenzian (MPL4, MPL5)
- PLEISTOCENE — Gelasian (2.6 to 1.8) — Calabrian (1.8 to 0.8)
- MP

Taxa (rows, top to bottom):
- Alangium deutschmannii Geissert et Gregor
- Cornus rostikii Negru
- Ehretia europaea E. M. Reid
- Symplocos minutula (Sternberg) Kirchheimer
- Tetrastigma chandlerae Kirchheimer
- Vitis teutonica A. Braun
- Ilex saxonica Mai
- Orcotea sp. A
- Sauvagia
- Tetraclinis salicornioides (Unger) Kvacek
- Trigonobalanopsis exacantha (Mai) Kvacek & Walther
- Turpinia ettingshausenii (Engelhardt) Mai
- Vismea germanica Menzel
- Zanthoxylum allanthoniforme (Gregor) Gregor
- Cyclea palaeohasti-bavaridae Gregor
- Litsea sporensis Gregor
- Magnolia ludwigii Ettingshausen
- Mallotus mail Martinetto
- Rehderodendron ehrenbergii (Kirchheimer) Mai
- Symplocos schereri Kirchheimer
- Toddalia antistifoliata (Ludwig) Gregor
- Magnolia allasoniae Martinetto
- Ficus potentilloides Mai
- Meliosma wetteraviensis (Ludwig) Mai
- Cinnamomum costatum (Mai) Plingen et al.
- Euya stigmosa (Ludwig) Mai
- Sparganium nanum Dorofeev
- Chronenium cantalense (E.M. Reid) Dorofeev
- Toddalia menaria Gregor
- Symplocos casparyi Ludwig
- Actinidia faveolata C. & E.M. Reid
- Ampelopsis ludwigii (Al. Braun) Kirchheimer
- Boehmeria lithuanica Dorofeev
- Styrax maximus (Weber) Kirchheimer
- Juglans bergomensis (Balsamo-Crivelli) Massalongo
- Liriodendron geminata Kirchheimer
- Pseudolarix elegans (C. et E.M. Reid) C. et E.M. Reid
- Pterocarya limburgensis C. & E.M. Reid

Right-hand occurrence columns:
| Fossano I FO2-FO3 | Fossano FOF10-FOF20 | Fossano II FO5 | Breolungi | Pocapaglia | Sento I | Ca' Viettone | Sento II | Chiavenna CVE1-2 | Front FR1-2 | Stura FF | Villafranca RDB | HUTEA/CTEA |

Groups with biochronological relevance:
long-lasting | Gr. 5 | Gr. 4 | Group 3 | Group 2 | Group 1

Taxon	Sample	Family	Part
Acer ex sect. Campestria	FO3 B6N (2)	Sapindaceae	endocarp
Acer ex sect. Platanoidea	FO3 B6N (1); FO3 B5T (11)	Sapindaceae	endocarp
Acer ex sect. Rubra	FO3 C9Y (1)	Sapindaceae	endocarp
Actinidia faveolata	FO3 B5T (5); FOF10 C9W (4)	Actinidiaceae	seed
Alangium deutschmannii	FO2 B5P (3); FO3 B5T (28); FO3 B6N (7)	Alangiaceae	endocarp
Alnus cf. *lusatica*	FO3 B5T (3); FO3 C9Y (1)	Betulaceae	fruit
Ampelopsis ludwigii	FO1 B2P (3); FO2 B5P (2); FO3 B5T (8); FOF10 C9W (5)	Vitaceae	seed
Apium prograveolens	FO3 C9Y (1)	Apiaceae	fruit
Boehmeria cf. *lithuanica*	FO3 C9Y (1)	Urticaceae	seed
Caldesia cf. *proventita*	FO1 B2P (13); FO3 C9Y (1)	Alismataceae	fruit
Carex cf. *pseudocyperus*	FO3 C9Y (1)	Cyperaceae	utricle
Carex strigosoides	FO3 C9Y (1)	Cyperaceae	achene
Carex sp.	FO1 B2P (30); FO3 B5T (1)	Cyperaceae	achene
Carex plicata	FOF20 (4)	Cyperaceae	achene
Carya globosa	FOF10 (2)	Juglandaceae	endocarp
Cephalanthus pusillus	FO5 B2M (100)	Naucleaceae	endocarp
Ceratophyllum submersum	FO5 B2M (22)	Ceratophyllaceae	fruit
Chamaecyparis europaea	FO3 C9Y (1)	Cupressaceae	seed
Cinnamomum costatum	FO2 B5P (5); FO3 C9Y (1)	Lauraceae	endocarp
Cladium sp.	FO3 B5T (6); FO5 B2M (4)	Cyperaceae	endocarp
Cornus roshkii	FO3 B5T (30); FO3 B6N (6)	Cornaceae	endocarp
Craigia bronnii	FO3 C9Y (1); FOF10 C9W (37); FOF10 C9V (3)	Malvaceae	immature fruit
Cyclea palatinati-bavariae	FO3 B5T (1)	Menispermaceae	endocarp
Ehretia europaea	FO3 C9Y (1)	Boraginaceae	endocarp
Engelhardia macroptera	FO3 C9Y (1)	Juglandaceae	endocarp
Euphorbia sp.	FO3 C9Y (1)	Euphorbiaceae	seed
Eurya stigmosa	FO1 B2P (7); FO2 B5P (21); FO3 B5T (4); FOF10 C9W (1)	Pentaphylacaceae	seed
Fagus cf. *deucaliois*	FO2 B6R (1)	Fagaceae	cupule
Ficus potentilloides	FO3 B5T (12); FO3 B6N (14); FO5 B2M (1)	Moraceae	endocarp
Frangula sp.	FO3 B6N (1)	Rhamnaceae	endocarp

Hamamelis sp.	FO2 B5P (2); FO2 B6R (8); FO3 C9Y (1)	Hamamelidaceae	seed, fruit
cf. *Hydrangea*	FO3 B6N (7); FO3 C9Y (10)	Hydrangeaceae	fruit
Ilex saxonica	FO3 B6N (1)	Aquifoliaceae	seed
Ilex thuringiaca	FO2 B5P (1)	Aquifoliaceae	seed
Ilex wisaensis vel *I. cantalensis*	FO2 B5P (4); FO3 B5T (5); FO3 C9Y (1)	Aquifoliaceae	seed
Juglans bergomensis	FO2 B6R (1)	Juglandaceae	immature endocarp
Lamium cf. *lusaticum*	FO3 C9Y (1)	Lamiaceae	nutlet
Liquidambar europaea	FO3 B5T (21); FOF20 (2)	Altingiaceae	infrutescence
Liriodendron geminata	FO2 B5P (1); FO3 B5T (100); FO3 B6N (35)	Magnoliaceae	seed
Litsea sonntagii	FO3 B5T (2); FO5 B2M (100); FO5 B4M (30)	Lauraceae	endocarp
Magnolia allasoniae	FO2 B5P (5); FO2 B6R (2); FO3 B5T (100); FO3 B6N (50); FOF10 C9V (3); FOF10 C9W (7); FO5 B2M (5)	Magnoliaceae	seed
Magnolia ludwigii	FOF10 C9W (2)	Magnoliaceae	seed
Mahonia staphyleaeformis	FO3 B5T (9)	Berberidaceae	seed
Mallotus maii	FO2 B5P (16); FO3 B6N (5); FO3 B5T (1); FOF10 C9W (8)	Euphorbiaceae	seed
Meliosma wettaraviensis	FOF10 C9W (1); FOF20 (1)	Sabiaceae	endocarp
Morus germanica	FO3 B5T (7); FO3 C9Y (1)	Moraceae	endocarp
Ocotea sp.	FO3 C9Y (1)	Lauraceae	cupule
Olea moldavica	FO2 B5P (2)	Oleaceae	endocarp
Paulownia cantalensis	FO3 C9Y (1)	Paulowniaceae	seed
Phellodendron cf. *elegans*	FO2 B5P (2); FO2 B6R (3); FO3 B5T (19); FO3 B6N (1); FO5 B2M (1); FOF10 C9W (4)	Rutaceae	seed
Pilea sp.	FO3 C9Y (1)	Urticaceae	broken nutlet
Pinus hampeana	FO3 B6N (2)	Pinaceae	cone
cf. *Platanus*	FO3 B6N (2)	Platanaceae	infrutescence
Potamogeton sp.	FO5 B2M (2)	Potamogetonaceae	endocarp
Proserpinaca reticulata	FO3 C9Y (1)	Haloragaceae	endocarp
Pseudotsuga sp.	FO2 B6R (2); FO3 B5T (1)	Pinaceae	cone
Pterocarya limburgensis	FO3 B6N (3); FO5 B2M (12)	Juglandaceae	endocarp
Quercus subgen. *Cerris*	FO3 C9Y (1)	Fagaceae	cupule
Ranunculus sceleratus	FO5 B2M (1)	Ranunculaceae	fruit
Rehderodendron ehrenbergii	FO2 B6R (1); FO2 B5P (1); FO3 B5T (2)	Ericaceae	endocarp
Rubus sp.	FO3 C9Y (1)	Rosaceae	endocarp
Rubus cf. *semirotundatus*	FO3 C9Y (1)	Rosaceae	endocarp
Sabia europaea	FO3 C9Y (1); FO3 B6N (2); FO3 B5T (4)	Sabiaceae	endocarp
Salvinia cf.	FO5 B2M (5); FO5 B4M (4)	Salviniaceae	megaspore

miocenica		ae	
Sambucus pulchella	FO3 C9Y (1)	Adoxacee	endocarp
Sarcococca sp.	FO3 B6N (1)	Buxaceae	seed
Sassafras cf. *ludwigii*	FO2 B5P (3); FO3 B6N (5); FO3 C9Y (1)	Lauraceae	cupule
Saurauia sp.	FO3 B5T (1); FOF20 (1); FO5 B2M (3)	Actinidiaceae	seed
Sinomenium cantalense	FO3 B5T (23); FO3 B6N (1); FOF10 C9W (12)	Menispermaceae	endocarp
Sparganium nanum	FO1 B2P (100); FO3 B5T (7); FOF20 (3)	Sparganiaceae	endocarp
Styrax sp.	FO2 B6R (11); FO3 B5T (2)	Styracaceae	endocarp
Symplocos casparyi	FO2 B5P (2); FO2 B6R (21); FO3 B5T (4); FO3 B6N (1)	Symplocaceae	endocarp
Symplocos minutula	FO3 B5T (1)	Symplocaceae	endocarp
Symplocos schereri	FO3 B5T (1)	Symplocaceae	endocarp
Symplocos herzogenrathensis	FO2 B6R (1); FO3 B5T (1)	Symplocaceae	endocarp
Taiwania sp.	FO3 C9Y (1)	Cupressaceae	shoot
Taxus sp.	FO3 B5T (2)	Taxaceae	seed
Tetraclinis salicornioides	FO2 B5P (2); FO3 B5T (56); FO3 B6N (48); FOF10 C9V (4)	Cupressaceae	cone
Tetrastigma chandlerae	FO2 B6R (1)	Vitaceae	seed
Toddalia latisiliquata	FO2 B5P (5); FO3 B5T (1); FOF10 C9W (2)	Rutacee	seed
Toddalia rhenana	FO2 B5P (1); FO3 B5T (53), FO3 B6N (1); FOF10 C9V (1), FOF10 C9W (10)	Rutacee	seed
Trigonobalanopsis exacantha	FO2 B6R (1)	Fagaceae	cupule
Turpinia ettingshausenii	FO2 B5P (2); FO2 B6R (6); FO3 B5T (1)	Staphyleaceae	seed
Visnea germanica	FO3 B5T (2)	Pentaphylacaceae	fruit
Vitis teutonica	FO2 B5P (9); FO3 B5T (19), FO3 B6N (4); FOF10 C9V (1), FOF10 C9W (6)	Vitaceae	seed
Zanthoxylum ailanthiforme	FOF10 C9W (17)	Rutacee	seed

Categories		QUOTE/TAXA (%)	
Arboreal pollen (sum = 80.20 %)	Conifers	*Pinus*	13,69
		Taxodium/Glyptostrobus-type	9,51
		cf. *Cathaya*	7,6
		Cedrus	5,7
		Picea	4,94
		Tsuga	3,8
		Sciadopitys	3,04
		Pinaceae sacc. indiff.	2,28
		Abies	1,9
		Inaperturated	1,52
		Cupressaceae	1,14

		Pinus haploxylon-type	0,38
	Arboreal angiosperms	*Quercus*	4,94
		Alnus	4,18
		Liquidambar	3,04
		Betula	1,9
		Fagus	1,9
		Engelhardia	1,14
		Carpinus	0,76
		Myrica	0,76
		Rutaceae	0,76
		cf. *Trigonobalanopsis*(?)	0,38
		Pterocarya	0,38
		Parrotia	0,38
		Phillyrea	0,38
		Tilia /Craigia	0,38
		Buxus	0,38
		Rubiaceae p.p.	0,38
		Sapotaceae	0,38
	Non Arboreal Pollen (sum = 19.77 %)	Poaceae	9,51
		Spore monolete	4,94
		Brassicaceae	1,52
		Fabaceae	1,52
		Plantago	1,52
		Caryophyllaceae	0,76
		Chenopodiaceae	0,76
		Asteraceae Asteroideae	0,76
		Cyperaceae	0,76
		Apocynaceae	0,38
		Borraginaceae	0,38
		Asteraceae Cichorioideae	0,38
		Polygonaceae	0,38
		Rumex	0,38
		Rosaceae	0,38
		Cannabaceae	0,38
		Osmunda	0,38
	Others	Indeterminable	2,28
		Spore varie	0,38
		LYCOPODIUM	8,75