Acta Palaeobotanica 64(1), 75–108, 2024
https://doi.org/10.35535/acpa-2024-0006

e-ISSN 2082-0259
ISSN 0001-6594

Overview of Pliocene plant macrofossil localities of the Piemonte region (NW Italy) with a partial analysis of palaeobotanical and geoconservation interest

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Received 6 January 2024; accepted for publication 8 March 2024

ABSTRACT. Piemonte is widely acknowledged as a remarkable Pliocene palaeontological spot, due to its potential for the observation and study of marine and terrestrial fossils in abundant outcrops. Our observations on about 80 palaeobotanical localities, representing both terrestrial and marine sedimentary deposits, show that some of them could easily provide more significant materials than those available today. About 30 plant-bearing Pliocene sites were selected for morphological analyses on plant fossils, mainly leaf remains. The main features of each assemblage, including the systematic placement of about 400 plant samples within 52 taxa, are indexed and described in this paper, by combining analysis of palaeontological collections and field observations. The results obtained so far encourage further studies in specific areas of palaeobotanical interest, whose results could easily provide major palaeoenvironmental insights. Finally, we suggest considering more carefully the Piemonte palaeobotanical sites in the frame of geoconservation strategies and we point out the relevance of ex-situ protection of endangered plant fossil samples (collections) in order to assure their availability for future studies.

KEYWORDS: Fossil leaves, catalogue, continental, marine, conservation status, late Cenozoic

INTRODUCTION

The fossil record, even with its severe limitations and uncertainties, provides the only direct access to the chronological and palaeogeographical dimensions of biological events and processes that took place in ancient environments in completely natural conditions (Masini et al., 2002). Therefore, the analysis of the fossil record at a regional scale is fundamental to summarise the dynamics of animal and plant populations. In this paper we focus on the particularly rich Pliocene plant fossil record (e.g. Martinetto et al., 2023) of the largest administrative region of NW Italy, Piemonte (we follow Piana et al., 2017 in using the Italian name instead of the English form Piedmont). Studies during the 19th century (Sismonda, 1859, 1865; Sacco, 1889–1890; Peola, 1895, 1896a, b; Sordelli, 1896) described plant fossils from several Pliocene successions, without a comprehensive treatment. Such work was planned by Peola (unpubl.) for the floras of the whole Cenozoic, but this author only managed to publish preliminary results (Peola, 1901) and left an unpublished manuscript of his planned monograph, with sketchy but precious drawings of many specimens that were successively destroyed by a bombing during 1944. A few of the 19th century Pliocene leaf fossil assemblages originated from outcrops which are no longer exposed, such as Bra (Peola,

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1895), or not precisely located, such as San Damiano d'Asti and Pralormo (Peola, 1896a). The plant fossils from Bra are still available at the Craveri Civic Museum of Bra (Peola, 1895; Molinaro and Bergesio, 1980; Martinetto et al., 2023), whereas those from the other two localities, close to Asti, are lost (Peola, 1896a; Martinetto et al., 2023). In Piemonte plant fossils commonly occur, as usual for other basins (e.g. Reid and Reid, 1915; Szafer, 1946; Mai and Walther, 1988; Geissert et al., 1990; Teodoridis et al., 2017), in lacustrine, deltaic, fluvial, and swamp deposits; however, here they are also particularly frequent in shallow marine facies (Cavallo and Martinetto, 1996; Basilici et al., 1997; Martinetto, 2003; Ferrero et al., 2003; Martinetto et al., 2015, 2023).

During the last 30 years many new sites have been discovered and partly studied. Most of these sites, together with those cited in the older literature, were not yet evaluated in terms of possible usefulness in various palaeobotanical studies, a shortfall that we try to overcome here. The new fossil specimens we analysed, mainly consisting of leaf samples, provide complementary information to the abundant palaeofloral data obtained through previous carpological analyses (Martinetto, 1994, 2015; Cavallo and Martinetto, 1996, 2001; Basilici et al., 1997; Macaluso et al., 2018; Martinetto et al., 2018b and references therein). The abundance of seeds, fruits and infructescences can be attributed to their resistant parts (although not mineralized), that escaped decomposition processes, and were stored in anoxic sediments for millions of years, without appreciable transformations, if not a certain compression ("mummified": Martinetto, 2001; Mustoe, 2018). Compression is more evident in organic leaf material, defined as compressed leaves or leaf compressions in the palaeobotanical literature. As already pointed out by Spicer (1991), in anaerobic diagenetic conditions plant remains may maintain organic matter, which can be deeply transformed over a long time by the process of coalification. In the poorly coalified organic deposits occurring in Piemonte it is often possible to find seeds, fruits, woods and, more rarely, leaves, in such a good preservation status to allow anatomical and histological analyses. However, the sites in which the organic matter was removed, and the morphology of plant remains was only recorded through impressions on the sediment, are more abundant. The remains investigated in this paper are, in fact, mainly oxidised leaf impressions and information on organic fruit and seed material was mostly derived from papers published previously.

The advantage of organic carpological remains is that they can be extracted from small volumes of sediment, which can be obtained without specific excavations. Conversely, the study of leaf assemblages has been hampered by the large size of the sediment samples necessary to obtain a significant level of information. In Italy, the main issue in recovering leaf fossils is not linked to their occurrence in public or private land, since in every case they are considered property of the Italian State. The main problem is that adequate sampling of a buried leaf-bearing deposit requires field work with a considerable impact on the outcrop. Such an action in Italy is assimilated to the archaeological excavations (Martinetto et al., 2018a), and implies a rather complicated procedure in order to obtain a formal permission from the Ministry of Culture, that requires a professional team for such activities. This is the reason why it is not possible to rely upon the help of volunteers, as usual in other countries (e.g. Greenwood et al., 2016), for the time-consuming process of recovery, preparation and storage of huge amounts of voluminous palaeobotanical samples. In practice, not a single planned excavation for Pliocene plant fossils was ever organised in the Piemonte region. Such a situation is detrimental for the knowledge and preservation of the palaeobotanical heritage, because the territory is too broad to be adequately monitored by the few competent professionals, and relevant findings that would have been lost otherwise (Fig. 1A, B), have been often reported to the University of Turin or to the Territorial Palaeontological Museum of Asti (MPTA) by non-professional people.

The available information was mainly obtained through occasional monitoring of non-scientific excavations (Fig. 1C) or natural erosion processes, with emergency recovery of only small samples of endangered materials (i.e. exposed fossiliferous sediments that will be destroyed by either natural or anthropic action: Fig. 1D). In particular, interesting and endangered fossil plant material was often noticed during field trips with university students (Fig. 1C), when the scheduled teaching activities do not allow to dedicate

Figure 1. Examples of plant fossil samples saved from destruction by occasional, non-professional collaborators and students. **A**. Compressed leaf of *Quercus* cf. *roburoides* C.T. Gaudin representing the single leaf specimen recovered from the Merlino Quarry of Isola d'Asti, Argille Azzurre Fm., Zanclean; MPTA13436. Photo L. Lacroce; **B**. Assemblage of oxidised leaf impressions from the lower part of the Arboschio section, Piacenzian (Arboschio-L1, Lithozone 1 of Pavia, 1970), with easily recognizable leaves of *Carpinus betulus*, *Pterocarya paradisiaca* and *Populus latior*, plus a fruit cast of *Corylus avellana*, MGPT-PU141481. Photo G. Accornero; **C**. Student excursion at Rocchetta Tanaro, in a field where blocks of leaf-bearing Pliocene sediments cropped out in abundance due to agricultural activities; **D**. Example of an endangered leaf-bearing sediment sample exposed at Rocchetta Tanaro, which would have been destroyed by successive agricultural activities or meteoric events (stored at MPTA)

enough time to an adequate recovery of the fossils. Consequently, our knowledge on the leaf assemblages of many sites is scarce to very scanty (see Supplementary File[1]).

We intended to verify if the relatively scarce material that reached the palaeontological collections in the above-mentioned ways could be significant to evaluate the potential interest of selected Pliocene plant-bearing localities in the Piemonte region. The aim of this paper is to index and describe the main scientific features and interests of a selection of Pliocene, and subordinately Early Pleistocene (Gibbard et al., 2010), plant-bearing sites of the Piemonte region. We summarise the potential palaeobotanical interest of each locality, in order to

[1] Supplementary File. Fossil samples and their affiliation to localities and formations, with notes on their conservation status

encourage further, more accurate studies. Furthermore, we call attention to palaeobotanical localities in the frame of regional geoconservation efforts. However, given that our review is restricted mainly to Pliocene sites, a definitive evaluation, selection and ranking of possible regional geosites for geoconservation purposes are beyond the scope of this paper. It will be simply discussed if the evidence collected is sufficient to indicate some plant-bearing localities as candidate geosites, in need of protection and adequate presentation to the public (Pavia et al., 2004).

GEOLOGICAL SETTING

Miocene and Pliocene sediments constitute the bulk of central Piemonte: the more elevated Turin-Monferrato and Langhe hills and the low-elevation Poirino Plateau, Astigiano-Roero and Alessandria areas (Forno et al., 2015). During the Miocene, the central Mediterranean area deeply changed its palaeogeography, leading to the definitive disappearance of the Tethys Ocean and the consequent emergence of the Mediterranean Sea, which also reached the Piemonte region. In the Messinian the Italian peninsula started to assume its present shape and the terrestrial animal communities left consistent records in Romagna, Tuscany (Rook et al., 2015) and Piemonte too (Colombero et al., 2014). After the continental episode of the late Messinian (Gelati et al., 1987; Bertini and Martinetto, 2008; Dela Pierre et al., 2011), the Piemonte region was again partly flooded by a branch of the Mediterranean Sea (Adriatic), at the beginning of the Pliocene. The resulting basin started to receive clastic sediments from the surrounding terrains, a process that led to the formation of a thick Plio-Pleistocene sedimentary succession. Its lower part is mainly rich in muddy sediments deposited in the ancient offshore zone (Argille Azzurre Formation), followed by shoreface sands, the Asti Sands Formation. The marine succession is often overlaid by continental and deltaic deposits (these also include the "Fossaniano" facies sensu Sacco, 1886, 1889–1890), which are mainly framed within the comprehensive "Villafranchiano" lithostratigraphic unit (Caramiello et al., 1996; Carraro, 1996). Ghielmi et al. (2019) subdivided this unit and the other main Pliocene lithostratigraphic units into three sequences, A, B, C, so that the Zanclean sequence A, for example, contains Argille Azzurre A, Asti Sands A and "Villafranchiano A" (we suggest the use of quotation marks to avoid confusion with the Villafranchian Mammal Unit, as already suggested in Martinetto, 1995)

The transition between marine and continental deposits was broadly described in the 19th century by Sacco (1886, 1889–1890), with recent updates concerning the NW (Basilici et al., 1997; Martinetto et al., 2007, 2018b), NE (Martinetto, 2001; Fantoni et al., 2005) and southern (Forno et al., 2015; Irace et al., 2017; Ghielmi et al., 2019) sectors of Piemonte.

In conclusion, Piemonte (Piana et al., 2017) is widely acknowledged as a remarkable Pliocene palaeontological spot, due to abundant outcrops of fossil-bearing sediments of this epoch in a broad and accessible area. The Pliocene palaeogeography of the area, with a marine gulf encircled by the Alps, drained by several rivers, can probably explain the richness of its palaeobotanical record.

MATERIAL AND METHODS

This work is primarily based on the analysis of palaeobotanical samples which were recovered in emergency throughout years of field excursions (Fig. 1C) to different Pliocene (and subordinately Pleistocene) localities within the area shown in Fig. 2. Since the quantity of material was too large in relation to the planned work, the analysis was restricted to a delimited part, with the intention to extend the work to the whole set in the future. All of the samples which were analysed received a temporary museum number (RobCal0001-0377: Supplementary File), and are mainly housed at the Museum of Geology and Palaeontology of Turin University, where some of them received the definitive museum number with acronym MGPT (Pavia et al., 2017). We also analysed samples at the Regional Museum of Natural Sciences of Turin (acronym MRSNT) and at the Territorial Palaeontological Museum of Asti (acronym MPTA). A few samples from Valsesia are stored at the Museo Calderini of Varallo Sesia (Fantoni et al., 2005) and a few others from the Cuneo Province at the Eusebio Civic Museum of Alba (acronym MCEA) and Sacco Museum of Fossano. Several samples needed cleaning and size adjustment operations, which were carried out at the Palaeontological Archive of MGPT (Pavia et al., 2017). The taxonomic classification of the fossils was supported by a rich array of previous publications, mostly referenced in Martinetto (2003) and Martinetto et al. (2023). Some useful suggestions for the leaf-morphological study were provided by Bůžek et al. (1996), Denk et al. (2005), Ellis et al. (2009), Kvaček et al. (2020), but also by the unpublished graduation thesis of Leidi (2004).

For the sites of origin of the samples that we analysed, we tried to provide, besides basic information, highlights on the main palaeobotanical potentialities, hoping to stimulate various types of research in the future. We also included information about localities that provided carpological remains stored in the CENOFITA palaeocarpological collection (acronym CCN), which is managed in synergy between the Museum of Geology and Palaeontology of Turin University and the Regional Museum of Natural Sciences of Turin. Each site was assigned a preliminary numerical code (∑01–80), and, additionally, the code GCTM (+number) was indicated for those sites which were already treated by Pavia et al. (2004). In order to cope with the lack of up-to-date information about many localities, even those already reported in the literature, we revisited most of the described sites, listed in Table 1. The summarised observations are reported in a kind of catalogue of the potential flora-bearing Pliocene sites of the Piemonte region, subdivided in four geographic sectors (Fig. 2). Those sites which are known for having provided fossil plant material in the past, but were not revisited by us or are currently inaccessible, are listed as "other sites" at the end of the catalogue dealing with each of the four geographic sectors. We only omitted from our analysis those sites that evidently yielded poorly relevant plant remains or single specimens (e.g. Cava Merlino of Isola d'Asti, Fig. 1A). The analytic results are reported in two documents: the first (Table 1) gathers bibliographical and on-site information, dating back to our last visit to each site, while the second (Supplementary File) is a list resulting from the morphological analysis, which often allowed us to propose a preliminary systematic classification of individual plant fossils.

For the cartography data the source was the Technical Regional Cartography of the Piemonte region. To obtain a uniform and coherent lithostratigraphy, we referred to Piana et al. (2017). The chronostratigraphic framing of the fossil-bearing sites, established referring to Martinetto et al. (2007, 2015, 2018b, 2023) or Ghielmi et al. (2019), is reported in Table 1. A key information included in Table 1 consists in the evaluation of each site according to categories of potential interest: leaf physiognomic analysis, cuticular analysis, CO_2 values reconstruction, assessment of palaeofloral diversity, Whole-Plant Concept (Kvaček, 2008), plant-animal interactions, assessment of local plant palaeocommunity features, marine-continental correlation.

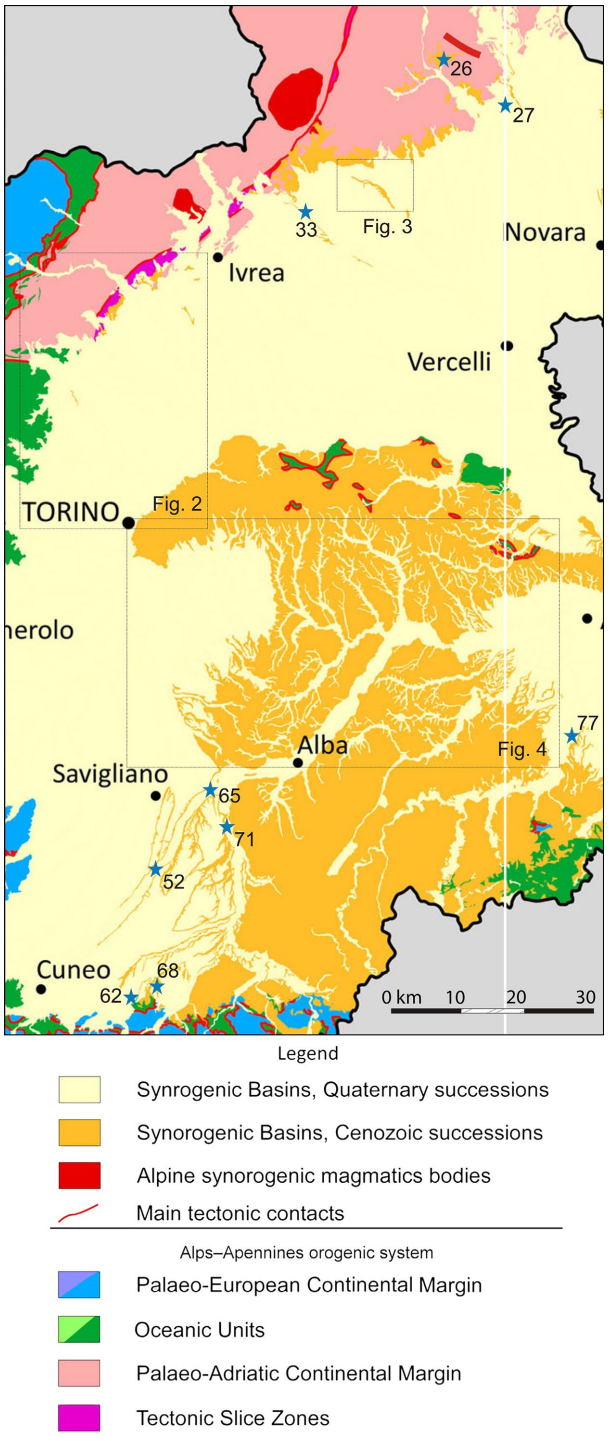

Figure 2. Portion of the geological map of the Piemonte region showing the three main sectors with Pliocene plant-bearing localities, each enlarged in a specific figure below (modified from Piana et al., 2017). The location of nine isolated plant-bearing sites, whose numbers correspond to those preceded by "∑" above and in Table 1, is directly shown in this map. 26.Valduggia, 27. Boca, 33. Cerrione-Cascina Galanta, 52. Fossano, 62. Carrù-Mondovì, 65. Cherasco-Stura, 68. Breolungi and Crava di Morozzo, 71. Madonna di Galizia of Benevagienna, 77. Sezzadio-Rio della Lupa

PLIOCENE PLANT MACROFOSSIL SITES OF THE PIEMONTE REGION

This section details the results of the analysis of a selected part of the Pliocene plant fossils that reached the palaeontological collections of the Piemonte region, mostly thanks to recovery of endangered materials. The data gathered in the following catalogue (Table 1) concern single sites (with a single acronym) or groups of sites (with more than one acronym) framed within four geographic sectors shown in Fig. 2. At the end of the section concerning each sector, a list of all the known plant-bearing sites, with an eventual reference to their publication, is provided.

Table 1. List of localities/layers with summary of relevant information. The scientific potential of each site is indicated with reference to eventual suitability for: leaf physiognomic analysis /assessment of palaeofloral diversity/ Whole-Plant Concept / cuticular analysis/ CO_2 values reconstruction/ plant-animal interactions/assessment of local plant palaeocommunity features/ marine-continental correlation. The sampling effort has been expressed by six states: just-a-glance/very scarce/scarce/moderate/almost accurate/accurate

Site Nr.	Locality	Province	Coordinates	Layer / sediment	Palaeoenvironment	Fossil assemblage description	Preservation status
∑01	Fiano-Layer FI1	TO	Omitted to avoid site damage	Outcrop in a 1 m tall wall along the Ceronda stream / sandy silt	Alluvial plain	Oligotypic assemblage with dominance of *Acer tricuspidatum* ssp. *lusaticum*	Oxidised leaf impressions with medium-quality detail of venation and margin hard to see for specimens' layering
∑02	Stura di Lanzo Fossil Forest	TO	45°13′0.80″N 7°33′45.88″E	Clayey silt to sandy silt	Swamp	Oligotypic assemblages, mostly with dominance of *Alnus gaudinii* or *A. cecropiifolia*	Oxidised leaf impressions with medium to high-quality detail of venation and margin hard to see for specimens' layering
∑03	Varisella	TO	45°12′42.92″N 7°29′41.85″E	Fine-grained lens in conglomerate / sandy silt	Channel in alluvial fan	Low-diversity allochthonous plant assemblage	Oxidised leaf and cone impressions with medium-quality detail of morphology
∑04	Vastalla	TO	45°12′39.05″N 7°33′48.57″E	Outcrop in a 7 m tall wall along a small brook, layer in the upper part / sandy silt	Channel in alluvial plain	Oligotypic assemblage with dominance of *Salix* and *Ulmus*	Oxidised leaf impressions with medium-quality detail of venation and margins hard to see for specimens' layering
∑06	Vauda inferiore -Locality FN1	TO	45°17′11.34″N 7°38′57.91″E.	Outcrop in a 20 m tall wall along the Fandaglia stream, sandy silt layer in the lower part	Alluvial plain	Oligotypic assemblage with dominance of Cyperaceae	Oxidised leaf impressions with medium-quality detail of venation and margin hard to see for specimens' layering
∑23	Canton Iuli near Castelletto Cervo -Layer CC30	BI	45°30′46.11″N 8°13′37.07″E	Layer CC30 (see CENOFITA) / sandy silt	Alluvial plain	Terrestrial plant leaves and aquatic plant seeds	Leaf compressions with medium- to low-quality detail of venation and margins
∑23	Canton Iuli near Castelletto Cervo (CC8)	BI	45°30′52.15″N 8°13′30.24″E	Layer CC8 (not yet registered in CENOFITA, but nearly the same area and stratigraphy of CC30) / sandy silt	Alluvial plain	Oligotypic assemblage with *Acer tricuspidatum* ssp. *lusaticum*	Oxidised leaf impressions with medium-quality detail of venation and margins hard to see for specimens' layering
∑24	Castellengo-Locality TC1	BI	Omitted to avoid site damage	Layer TC1 (see CENOFITA) / fine sand	Marine, Shoreface	Rich marine invertebrate assemblages and poor allochthonous plant remains	Anatomically preserved cones, fruits, leaves and woods
∑24	Castellengo-Layer TC20	BI	Omitted to avoid site damage	Tall wall on the right bank of the Cervo River, 1 km N of the Cossato bridge, close to TC1	Tidal flat	High-diversity allochthonous leaf assemblage	Oxidised leaf impressions with medium-quality detail of venation and margins
∑25	Cossato-Layer CO2	BI	Omitted to avoid site damage	Layer CO2 (see CENOFITA) / very fine silty sand	Channel in tidal flat	High-diversity allochthonous leaf assemblage	Oxidised leaf impressions with medium- to low-quality detail of venation but well-defined margins
∑26	Valduggia -Molino Rastelli	VC	45°43′15.38″N 8°18′16.53″E	Outcrop in a 5 m tall wall behind a factory / very fine sand	Marine, shoreface to offshore	Allochthonous leaf assemblage of unknown diversity due to limited sampling	Oxidised leaf impressions with good detail of venation and margin
∑40	Arboschio-L7	AT	Omitted to avoid site damage	Layer A5 (see Carraro, 1996; Lithozone 7 by Pavia, 1970) / clayey silt	Estuary/ lagoon	Diverse allochthonous leaf assemblage	Oxidised impressions of various plant parts with good quality detail of venation and margin
∑40	Arboschio-L4	AT	44°54′1.16″N 8°2′23.27″E	Layer A4 (see Carraro, 1996; Lithozone 4 by Pavia, 1970) / clayey silt	Swamp	Oligotypic assemblage with dominance of *Alnus gaudinii*	Oxidised leaf impressions with medium-quality detail of venation and margin hard to see for specimens' layering

Table 1. Continued

Site Nr.	Year and status during last visit	Scientific potential	Further sampling requirements	Sampling effort	Piana et al., 2017 formation
∑01	2017, wall along a river, still well exposed	Assessment of local plant palaeocommunity features. The assemblage is scarcely suitable for leaf physiognomic analysis	Available for new sampling	Scarce	"Villafranchiano B" – La Cassa Unit
∑02	2023, wall along a river, still well exposed	Assessment of local plant palaeocommunity features / Whole-Plant Concept	New sampling not necessary	Accurate	"Villafranchiano B" – La Cassa Unit
∑03	2005?, wall along a stream, still well exposed	Assessment of local plant palaeocommunity features	New sampling not necessary	Very scarce	"Villafranchiano B" – La Cassa Unit
∑04	2007, wall along a river, still exposed	Assessment of local plant palaeocommunity features. The assemblage is scarcely suitable for leaf physiognomic analysis	Hard to locate the leaf-bearing stratum, excavation difficult due to vegetation cover	Moderate	"Villafranchiano B" – La Cassa Unit
∑06	2017, wall along a stream, deeply covered by detritus and vegetation	Assessment of local plant palaeocommunity features.	New sampling not necessary	Scarce	"Villafranchiano B" – La Cassa Unit
∑23	2015, leaf-bearing deposit covered by river gravels	Cuticular analysis / CO_2 values reconstruction / poor opportunity for leaf physiognomic analysis / assessment of local plant palaeocommunity features.	New sampling not possible	Very scarce	"Villafranchiano B"
∑23	2015, wall along a river, now deeply covered by detritus	Assessment of local plant palaeocommunity features. The assemblage is scarcely suitable for leaf physiognomic analysis	New sampling not necessary	Scarce	"Villafranchiano B"
∑24	2015, poorly-exposed in the river bed; 2024, well exposed	Marine-continental correlation	New sampling not necessary	Accurate	Asti Sands B
∑24	2015, wall along a river, still well exposed	The little available information suggests good opportunity for leaf physiognomic analysis and assessment of palaeofloral diversity	Rock-fall danger; excavation difficult due to steep wall	Just-a-glance	Asti Sands B
∑25	2018, leaf-bearing deposit still well-exposed	Very good opportunity for leaf physiognomic analysis and assessment of palaeofloral diversity	New sampling not necessary	Accurate	Asti Sands B
∑26	2023, covered wall behind a factory	The little available information suggests good opportunity for leaf physiognomic analysis and assessment of palaeofloral diversity	New sampling not possible, but available at the more interesting Crabbia site	Just-a-glance	Asti Sands B
∑40	2024, outcrop partly covered by vegetation	Opportunity for leaf physiognomic analysis and assessment of palaeofloral diversity. Unique types of fossils as for taxonomy and preservation can be yielded by this deposit	New sampling would require a specific preparation for hand excavation	Moderate	San Martino unit, "Villafranchiano B"
∑40	2018, outcrop covered by vegetation	Assessment of local plant palaeocommunity features, good indications for an *Alnus gaudinii-Taxodium dubium* swamp	New sampling would require a specific budget for excavation with caterpillar, and it would not add much information	Accurate	San Martino unit, "Villafranchiano B"

Table 1. Continued

Site Nr.	Locality	Province	Coordinates	Layer / sediment	Palaeoenvironment	Fossil assemblage description	Preservation status
∑41	Asti-Cascina Risso (Vallescura)	AT	44°55′58.05″N 8°14′7.02″E	Very fine silty sand	Transition marine-continental	High-diversity allochthonous leaf assemblage	Oxidised leaf impressions with good detail of venation and margin
∑42	Baldichieri -Fornace	AT	44°54′13.48″N 8°6′23.13″E	Fine sand	Marine, shoreface	Allochthonous leaf assemblage of possibly high diversity	Oxidised leaf impressions with poor to medium detail of venation and margin
∑43	Baldichieri -North	AT	44°54′37.74″N 8°4′52.94″E	Fine sand	Marine, shoreface to tidal	Allochthonous leaf assemblage of possibly high diversity	Oxidised leaf impressions with poor to medium detail of venation and margin
∑44	Cantarana -Graveyard	AT	44°54′0.24″N 8°1′41.56″E	Layer in the middle part of the outcrop / very fine silty sand	Transition marine-continental	High-diversity allochthonous leaf assemblage	Oxidised leaf impressions with good detail of venation and margin
∑44	Cantarana -Locality Martinetto	AT	44°53′52.88″N 8°1′24.91″E	Clayey silt	Fluvial/ deltaic channel	Monotypic assemblage with dominance of *Salix*	Oxidised leaf impressions with medium-quality detail of venation and margin hard to see for specimens' layering
∑45	Casa Barbarino of Bruno	AT	44°47′31″N 8°26′35″E	Layer in the middle part of the outcrop / fine-middle sand	Transition marine-continental	Allochthonous leaf assemblage of possibly high diversity	Oxidised leaf impressions with very poor detail of venation, margin better preserved
∑47	Castagnole Monferrato	AT	44°57′3.43″N 8°17′33.07″E	Outcrop in a large quarry, layer in the upper part / silty sand	Marine, offshore	scattered, but rather frequent leaves	Oxidised leaf impressions with medium-quality detail of venation but well-defined margins
∑48	Castelnuovo Belbo -Graveyard	AT	44°48′24.26″N 8°24′26.14″E	Layer in the lower part of the outcrop / fine sand	Marine, shoreface	Allochthonous leaf assemblage of unknown diversity due to limited sampling	Oxidised leaf impressions with good detail of venation and margin
∑50	Castelnuovo Bormida-Lens 7	AL	44°45′24.28″N 8°33′55.89″E	Silt	Channel in alluvial fan	Terrestrial leaves and aquatic plant assemblage	Oxidised leaf impressions with medium- to low-quality detail of venation but well-defined margins
∑50	Castelnuovo Don Bosco-Layer CDB1	AT	45°1′37.12″N 7°58′10.19″E	Layer CDB1 (see CENOFITA) / clayey silt	Swamp	Oligotypic assemblage with dominance of *Taxodium dubium*	Leaf compressions with cuticles and medium-quality detail of venation and margin hard to see for specimens' layering
∑52	Fossano -Section A -layer FO4	CN	Omitted to avoid site damage	Layer FO4 (see CENOFITA) / sandy silt	Fluvial/ deltaic channel	High-diversity allochthonous leaf assemblage	Leaf compressions with good detail of cuticle, venation and margin
∑52	Fossano-Layer FO5	CN	44°33′33.61″N 7°44′38.32″E	Layer FO5 (see CENOFITA) / silt	Alluvial plain	Poorly diverse leaf assemblage	Leaf compressions with good detail of cuticle
∑53	Fubine	AL	44°57′57.89″N 8°25′39.91″E (town coordinates)	Sandy silt	Fluvial/ deltaic channel	High-diversity allochthonous leaf assemblage	Oxidised leaf impressions with medium-quality detail of venation and margin
∑54	Gherba	AT	44°50′47.74″N 7°58′49.40″E	Small outcrop to the east of the large quarry, but in the woodland, about 2/5 from the base of the succession / very fine silty sand	Transition marine-continental	Allochthonous leaf assemblage of unknown diversity due to limited sampling	Oxidised leaf impressions with good detail of venation and margin
∑55	Mombercelli	AT	44°48′38.73″N 8°15′35.85″E	Silt	Marine, offshore	Scattered, rare leaves	Oxidised leaf impressions with medium- to low-quality detail of venation but well-defined margins
∑57	Roatto-Cascina Melona-Layer A	AT	44°57′22.51″N 8°1′8.98″E	Layer in the upper part of the outcrop / clayey silt	Swamp	Monotypic assemblage with dominance of *Alnus gaudinii*	Oxidised leaf impressions with medium-quality detail of venation and margin hard to see for specimens' layering
∑57	Roatto Cascina Melona (Roatto)-Layer B	AT	44°57′22.51″N 8°1′8.98″E	Layer in the lower part of the outcrop / clayey silt	Alluvial plain	Allochthonous leaf assemblage of possibly high diversity	Oxidised leaf impressions with medium-quality detail of venation

Table 1. Continued

Site Nr.	Year and status during last visit	Scientific potential	Further sampling requirements	Sampling effort	Piana et al., 2017 formation
∑41	2001, scarcely exposed wall close to a farm	Leaf physiognomic analysis / assessment of palaeofloral diversity	Hard to locate the leaf-bearing stratum, excavation difficult due to vertical wall	Scarce	Asti Sands B
∑42	1994, quarry abandoned and covered	The assemblage could have been suitable for leaf physiognomic analysis and assessment of palaeofloral diversity	New sampling not possible	Scarce	Asti Sands B
∑43	2003, quarry abandoned and covered	The assemblage could have been suitable for leaf physiognomic analysis and assessment of palaeofloral diversity	New sampling not possible	Scarce	Asti Sands B
∑44	2003, scarcely exposed wall close to the village's graveyard	Leaf physiognomic analysis / assessment of palaeofloral diversity	Hard to locate the leaf-bearing stratum, excavation difficult due to vegetation cover	Just-a-glance	Ferrere unit, "Villafranchiano B"
∑44	2003, well-exposed wall behind a farm	Assessment of local plant palaeocommunity features	Hard to locate the leaf-bearing stratum, probably at present the excavation would be difficult due to vegetation cover	Just-a-glance	Ferrere unit, "Villafranchiano B"
∑45	2017, wall behind a farm, still well exposed	Suitable for leaf physiognomic analysis and assessment of palaeofloral diversity	Leaf-bearing stratum possibly covered by vegetation	Scarce	Ferrere unit, "Villafranchiano A?"
∑47	2022, poorly exposed, leaf bearing layer difficult to locate and covered by vegetation	Leaf physiognomic analysis / assessment of palaeofloral diversity	Status of the outcrop in 2018 not known, leaf-bearing stratum possibly no more accessible	Scarce	Argille Azzurre B
∑48	2003, well-exposed, 15 m wall to the E of the Graveyard	The little available information suggests good opportunity for leaf physiognomic analysis and assessment of palaeofloral diversity	Hard to locate the leaf-bearing stratum, rock-fall danger; excavation difficult due to vertical wall	Just-a-glance	Asti Sands B
∑50	2015, leaf-bearing deposit covered by discharge earth	Poor opportunity for leaf physiognomic analysis but good condition for assessment of Whole-Plant Concept of aquatic plants	New sampling not possible	Scarce	Asti Sands B
∑50	2000, leaf-bearing deposit covered by discharge earth	Cuticular analysis / CO_2 values reconstruction / assessment of local plant palaeocommunity features	New sampling would require a specific budget for excavation with caterpillar, and it would not add much information	Scarce	San Martino unit, "Villafranchiano B"
∑52	2017, wall along a river, still well exposed	Leaf physiognomic analysis / assessment of palaeofloral diversity / Whole-Plant Concept / cuticular analysis / CO_2 values reconstruction	Available for new sampling	Almost accurate	"Villafranchiano A"
∑52	2017, no more exposed	Whole-Plant Concept / cuticular analysis / CO_2 values reconstruction	New sampling not necessary	Scarce	"Villafranchiano A"
∑53	2001?, small quarry; 2022, small outcrop closed by a fence	The little available information suggests good opportunity for leaf physiognomic analysis and assessment of palaeofloral diversity	Many difficulties for a new sampling, but it could be useful	Very scarce	Ferrere unit, "Villafranchiano B"
∑54	2003, poorly-exposed outcrop in a woodland close to a large quarry; 2024, totally hidden	The little available information suggests good opportunity for leaf physiognomic analysis and assessment of palaeofloral diversity	Hard to locate the leaf-bearing stratum, due to vegetation cover	Just-a-glance	Ferrere unit, "Villafranchiano B"
∑55	2001?, large quarry	Plant-animal interactions	Leaf-bearing stratum possibly no more accessible	Just-a-glance	Argille Azzurre B
∑57	1994, already sampled underground	Important only for the Whole-Plant Concept of *Alnus gaudinii* and *Alnus* sp. infructescences	Not necessary, new sampling would not add much information, anyway the artificial outcrop most probably almost disappeared	Scarce	San Martino unit, "Villafranchiano B″
∑57	2003, scarcely exposed wall behind a farm	Leaf physiognomic analysis / assessment of palaeofloral diversity	Not possible, the artificial outcrop most probably almost disappeared	Scarce	San Martino unit, "Villafranchiano B″

Table 1. Continued

Site Nr.	Locality	Province	Coordinates	Layer / sediment	Palaeoenvironment	Fossil assemblage description	Preservation status
∑57	Roatto Cascina Melona (Roatto)-Layer RT1	AT	44°57′22.51″N 8°1′8.98″E	Layer RT1 (see CENOFITA) / clayey silt	Swamp	Single sample	Leaf compressions, poorly preserved
∑58	Valmanera -Cascina Ignota	AT	44°56′30.79″N 8°11′26.33″E	Very fine silty sand	Transition marine-continental	High-diversity allochthonous leaf assemblage	Oxidised leaf impressions with good detail of venation and margin
∑59	Villafranca RDB Quarry -Layer R1	AT	44°54′54.01″N 8°1′19.48″E	Layer R1 (see Carraro et al., 1996, named RDB1 in CENOFITA) / clayey silt	Swamp	Oligotypic assemblage with dominance of *Taxodium dubium*	Leaf compressions with cuticles and medium-quality detail of venation and margin hard to see for specimens' layering
∑59	Villafranca RDB Quarry -Layer R4	AT	44°54′54.56″N 8°1′17.02″E	Layer R4 (see Carraro et al., 1996, named RDB8 in CENOFITA) / clayey silt	Swamp	Oligotypic assemblage with dominance of *Alnus gaudinii*	Oxidised leaf impressions with medium-quality detail of venation and margin hard to see for specimens' layering
∑59	Villafranca RDB Quarry -R5-8	AT	44°54′54.56″N 8°1′17.02″E	Layers R5-8 (see Carraro et al., 1996) / clayey silt	Swamp	Oligotypic assemblages with dominance of *Acer tricuspidatum*, *A. gaudinii*	Oxidised leaf impressions with medium-quality detail of venation and margin hard to see for specimens' layering
∑60	Villafranca-Rio Stavanasso -Layer SV1	AT	44°54′58″N 8°0′06″E	Outcrop in a 10 m tall wall along the Stanavasso brook, layer in the middle part / clayey silt	Swamp	Oligotypic assemblage	Leaf compressions with cuticles and medium-quality detail of venation and margin hard to see for specimens' layering

The characteristic palaeobotanical taxa are cited for each locality, and a complete list of the determined fossil samples is reported in Supplementary File.

The location of the sites in the areas with denser coverage is shown in detail in Fig. 3 for the NW Sector, in Fig. 4 for the NE Sector and in Fig. 5 for the Southern Sector. Finally, the location of five isolated sites is directly shown in Fig. 2. We decided to include in Table 1 more detailed information, such as coordinates and present accessibility, only for those sites in which plant-bearing deposits are no more exposed and for those sites whose position was precisely reported in previous publications. This choice was driven by our intention to facilitate the reconsideration of the lost sites in future studies, hoping that the release of permissions for scientific sampling will become less complicated than today. In the last 30 years we have not detected any damage to the Pliocene plant fossils due to collection by fossil enthusiasts, even in the best known and precisely located sites. However, we preferred to omit any information useful to locate the problematic, presently accessible sites, and we stored it in the archives of MPTA.

NW SECTOR (CANAVESE AND SURROUNDINGS)

Materials were analysed from six sites (∑01–05 and ∑12), but we also evaluated the consistency of materials yielded by all the other Pliocene sites known in this sector (see below), shown in Fig. 3. The sites selected are located in the part of the NW Sector which hosts the sedimentary and geomorphological products of the Stura di Lanzo river. This brought from the Alps a huge quantity of sediments that filled a Pliocene basin and later, during the Pleistocene, formed a broad alluvial fan that covered the whole area delimited today by the courses of the Ceronda and Malone rivers (Sacco, 1888). The subsequent tectonic uplift of this sector and, probably, the glacioeustatic oscillations of the sea level caused the terracing of the alluvial fan body. Fluvial erosion spared only two large flaps separated from the present course of the Stura di Lanzo river: the high terraces of La Mandria (right) and Vauda (left) (Martinetto and Farina, 2005). Pliocene continental sediments crop out in the deep incisions of watercourses, and the fine-grained ones frequently yield plant fossils. Already in the 19th century Sismonda (1859), Sacco (1888) and Peola (1896b) reported plant fossil remains along the Ceronda and Stura di Lanzo rivers.

Table 1. Continued

Site Nr.	Year and status during last visit	Scientific potential	Further sampling requirements	Sampling effort	Piana et al., 2017 formation
∑57	2003, no more exposed	Single leaf sample	New sampling not necessary	Just-a-glance	San Martino unit, "Villafranchiano B"
∑58	2005, almost covered wall close to a farm; 2022, totally covered	Leaf physiognomic analysis / assessment of palaeofloral diversity	Leaf-bearing stratum possibly no more accessible	Moderate	Ferrere unit, "Villafranchiano B"
∑59	2000, leaf-bearing deposit covered by discharge earth	Cuticular analysis / CO_2 values reconstruction/ assessment of local plant palaeocommunity features. The assemblage is scarcely suitable for leaf physiognomic analysis	New sampling would require a specific budget for excavation with caterpillar, and it would not add much information	Moderate	San Martino unit, "Villafranchiano B"
∑59	2000, leaf-bearing deposit covered by discharge earth	Assessment of local plant palaeocommunity features	New sampling not necessary	Scarce	San Martino unit, "Villafranchiano B"
∑59	2000, leaf-bearing deposit covered by discharge earth	Assessment of local plant palaeocommunity features	New sampling not necessary	Scarce	San Martino unit, "Villafranchiano B"
∑60	1995, leaf-bearing deposit still well-exposed; 2024, covered	Cuticular analysis / CO_2 values reconstruction / assessment of local plant palaeocommunity features. The assemblage is scarcely suitable for leaf physiognomic analysis	The original outcrop, visited in 2024, was covered by colluvium and vegetation; a bed with compressed leaves was scarcely cropping out in the bed of the brook	Just-a-glance	San Martino unit, "Villafranchiano B"

∑01. Fiano – The area is covered by the geological study by Forno et al. (2009) and is included in the "La Mandria" – Natural Park. The outcrops are located along the Ceronda stream, near Fiano, about 30 km NNW from Turin. The action of the stream has produced an erosional slope in the right bank, where a sedimentary succession of about 3 metres in thickness of the fluvial-swampy "Villafranchiano" unit is exposed. At the base, a sandy layer occurs, that can be interpreted as a river channel deposit, overlaid by a laminated set of grey silts, rich in well-preserved leaf impressions. About 20 m further upstream the silty layer shows a high degree of load deformation with intercalations of other sandy deposits. Above the silty layer, there are sandy deposits truncated at the top by an erosional surface. Some fallen-down blocks of the leaf-bearing layer, indicated by the label "FI1", were recovered only in the 1990s (MGPT), even if the layer was again very well exposed in the year 2017. The ~30 leaf impressions already gathered in the MGPT collection can be used to establish the characteristics of the local plant palaeocommunity. The quality of the leaf impressions is not very high, but most of them show fairly well the margin and the venation pattern, as to permit their identification. The assemblage is dominated by *Acer tricuspidatum* ssp. *lusaticum* (Fig. 6.1), with subordinated *Carpinus betulus*, *Fagus haidingeri* and *Sequoia abietina*. The outcrop should be monitored together with the management of the Natural Park in order to save from destruction eventual leaf-bearing samples removed from the fossiliferous layer due to natural erosion. Being one of the two sites within the territory of "La Mandria"–Natural Park (the other is La Cassa), Fiano has a high potential for the public display.

∑02. Stura di Lanzo Fossil Forest – The outcrop is located in the riverbed of the Stura di Lanzo River, between the municipalities of Nole Canavese and Ciriè, 20 km N from Turin, at the elevation of about 345 m a.s.l., where the erosion operated by the river exposed fluvial-swampy deposits of the "Villafranchiano" lithostratigraphic unit. Studies on this site started in the 1980s (Cerchio et al., 1990) and since the year 1988 an increasing quantity of palaeobotanical samples was recovered by the Department of Earth Sciences of the Turin University (Martinetto, 1994; Martinetto and Farina, 2005; Martinetto et al., 2007; Vassio et al., 2008). The sediments range from clayey silt to sandy silt and provided abundant carpological remains (CCN). The leaf samples (MGPT) are also abundant, but highlight an

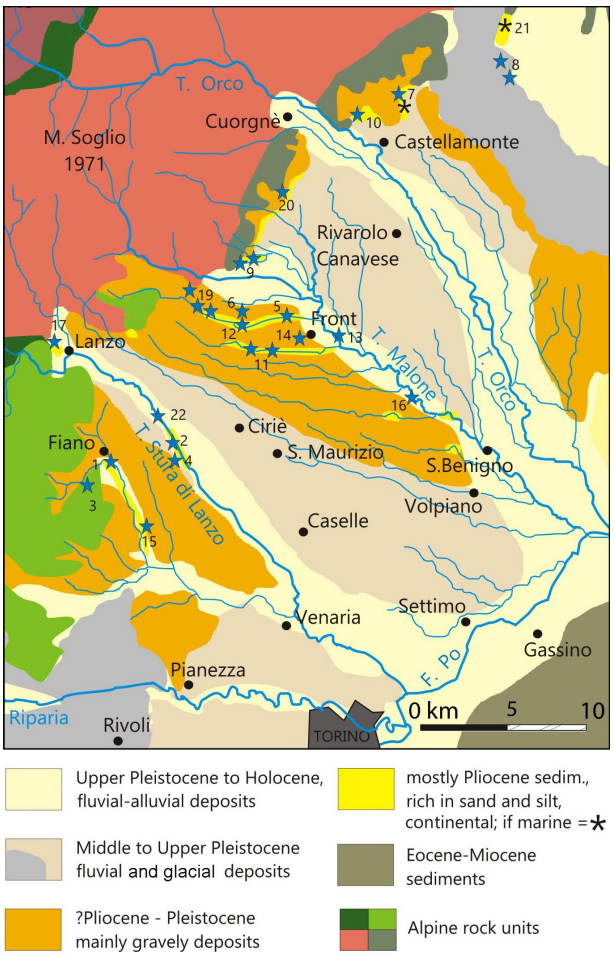

Figure 3. Map of the area with dense site coverage in the NW Sector, whose numbers correspond to those preceded by "∑" above and in Table 1. 1. Fiano, 2. Fossil Forest of the Stura di Lanzo, 3. Varisella, 4. Vastalla, 5. Vauda Inferiore, 6. Barbania, 7. Benasso, 8. Borriana and Pranzalito, 9. Ca' Viettone and Levone, 10. Canton Talentino, 11. Ceretti and Vauda Canavese, 12. Fandaglia, 13. Front, 14. Front-Rio Secco, 15. La Cassa, 16. Lombardore, 17. Momello-Lanzo, 19. Remondato, Rio del Caporale and Boschi di Barbania (NW to SE), 20. Rivara, 21. Sento and Pian Torinetto, 22. Villanova Canavese

oligotypic assemblage, with dominance of *Alnus gaudinii* in a lower leaf bed, and *A. cecropiifolia* in an upper one (Fig. 6.6, 6.7). The leaves are oxidised, show a medium-high detail of venation, whereas the margins are often difficult to distinguish, due to the large overlap of specimens. During the last visit, in the year 2023, the outcrop was still well exposed. However, given the long-lasting sampling, it is not compelling to recover further remains. The resources should instead be directed towards an analysis of the samples already available, which may contribute to unravel still unknown features of the local palaeoflora. Studies carried out on palaeocarpological (Martinetto, 1994, 1995) and palynological samples (Cerchio et al., 1990; Bertoldi and Martinetto, 2001) already enabled the reconstruction of a swamp palaeoenvironment with shallow waters, occasionally invaded by more turbulent flows. In the original forest it is possible to imagine groups of trees, not very dense, belonging to the genera *Glyptostrobus* and *Alnus*.

Moreover, given the abundance of autochthonous plant remains, the site is highly adequate for a reconstruction of plant taxa according to the "Whole-Plant Concept" (Kvaček, 2008). Indeed, in the macrofossil record of this site there is just one common type of conifer "Whole-Plant" (Martinetto and Macaluso, 2018), i.e. *Glyptostrobus europaeus* (Vassio et al., 2008). The reconstruction of other angiosperm "Whole-Plant" taxa is still to be carried out. The palaeoflora is the reference assemblage of the "Stura Floristic Complex" (Martinetto, 1995), and is attributable to a warm-temperate phase of the Piacenzian.

The site is also important for its diverse fruit and seed assemblages (Martinetto, 1994) and for the occurrence of leaves certainly suitable for cuticular analysis, that could possibly also enable the reconstruction of palaeo-CO_2 values. A particularly rare and limited deposit, which preceded the settlement of the *Glyptostrobus* swamp, provided excellently preserved organic remains of mesic plants with dominance of *Fagus* (Fig. 6.3, 6.5). This deposit has been scarcely sampled so far and, pending its re-location, a further study could increase our knowledge on the diversity of the local palaeoflora and could provide information about the Whole-Plant Concept (Kvaček, 2008) of a few species, e.g. *Fagus haidingeri* (Fig. 6.5).

The site can be considered of particular scientific and conservation interest, for the type and rarity of the represented geoevent, for its location and easy accessibility, for the fascinating outcrops showing numerous logs and stumps *in situ*, arranged along the course of the river for a hundred metres. The outcrop does not offer a stable condition, and the possibility to observe plant fossils is linked to the chance of any violent flood of the Stura river.

∑03. Varisella – The outcrop is cited by Forno et al. (2009) and its palaeobotanical interest is linked to a sandy-silty sediment in which an allochthonous plant assemblage is preserved, characterised by a low diversity. The collected samples (MGPT) show oxidised traces of cones (*Pinus* sp.) and leaves, with medium quality of morphological details. These remains could provide some limited

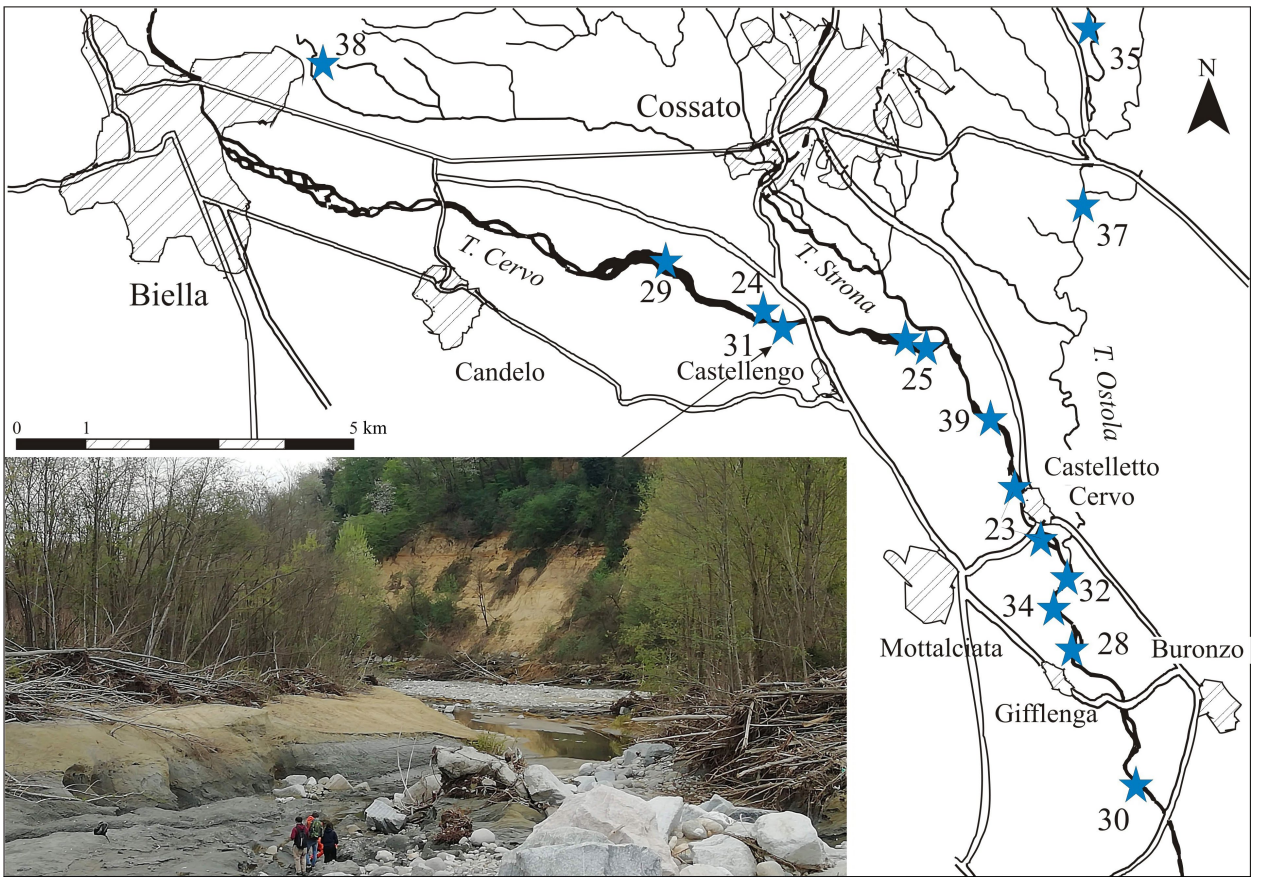

Figure 4. Map of the area with denser site coverage in the NE Sector (Biellese district), whose numbers correspond to those preceded by "∑" above and in Table 1. 23. Canton Iuli, 24. Castellengo (TC1), 25. Cossato, 28. Buronzo, 29. Candelo-Bocca del Lupo, 30. Buronzo-Cascina Colombera, 31. Castellengo (TC20), 32. Castelletto Cervo I and II, 34. Garella di Fondo, 35. Masserano, 37. Rolino, 38. Ronco Biellese, 39. Terzoglio. An example of the large outcrops along the Cervo River is shown in the photograph at the bottom (Castellengo site, TC1 on the left and TC20 in the background)

contribution to assess the local palaeoflora features. Further sampling is not needed.

∑**04**. **Vastalla** – Detailed information about this site is still unpublished. The samples were recovered from an outcrop consisting of a steep wall in a dense woodland. The muddy sediments are likely referable to an ancient alluvial plain, originally crossed by a channel filled in by silty sandy sediment. The assemblage retrieved is oligotypic, with dominance of *Salix* sp. and *Ulmus* sp. (MGPT). Details of the oxidised impressions are scarcely visible due to the overlap between specimens, for this reason the samples are mostly suited to the reconstruction of characteristics of the local plant palaeocommunity. The fossiliferous layer is currently difficult to locate and a hypothetical excavation would present serious issues due to the covering vegetation and the above-cited difficulty in obtaining the permission.

∑**05** and ∑**12**. **Vauda Inferiore** and **Fandaglia** – In the vicinity of the Villages of Barbania and Vauda Inferiore, the Fandaglia stream produces a series of ephemeral outcrops (FN1 to FN5) of the fluvial-swampy deposits of the "Villafranchiano" lithostratigraphic unit. The prevailing sediments are sandy silts, part of an ancient waterlogged alluvial plain. A few dozen taxa were identified through carpological analysis (CCN) in the outcrops FN3 and FN5, close to a hamlet also named Fandaglia (Martinetto, 1995). These are interesting, but less diverse than those of the very similar, previously mentioned site of the Stura di Lanzo Fossil Forest. Leaf assemblages (FN2, FN3, FN4) allowed to recognize less than ten taxa (MGPT). Site FN3 is particularly interesting for the occurrence of compressed leaves, mainly of *Acer tricuspidatum* ssp. *lusatictum* (Fig. 6.2).

We also evaluate another locality with similar sediments along the Fandaglia stream, labelled "FN1", which is close to the village of Vauda Inferiore. In this case, the fossil assemblage is oligotypic, with dominance of Cyperaceae (Fig. 6.4), but Martinetto and Gregor (1989), who described the outcrop for the first time, also reported an impression of an endocarp

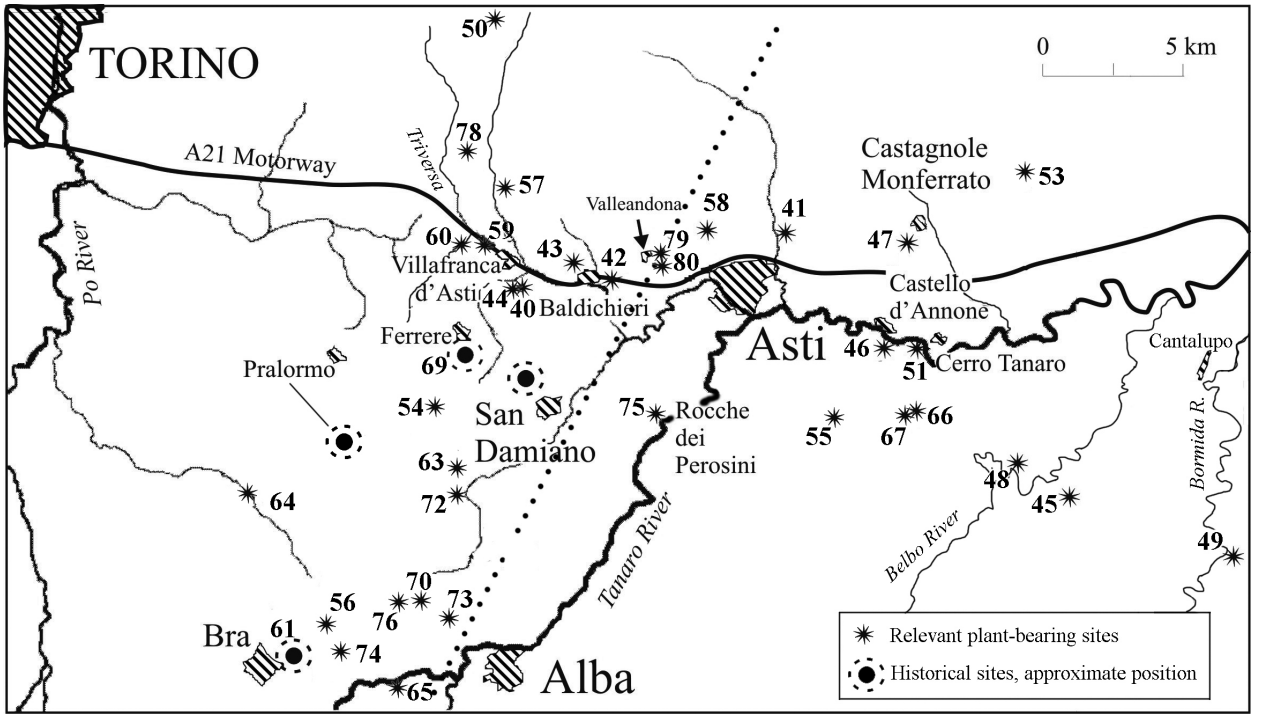

Figure 5. Map of the area with denser site coverage in the Southern Sector, whose numbers correspond to those preceded by "∑" above and in Table 1. 40. Arboschio, 41. Asti-Cascina Risso, 42. Baldichieri-Fornace, 43. Baldichieri-North, 44. Cantarana, 45. Casa Barbarino of Bruno, 46. Cascina Rapetto-Rocchetta Tanaro, 47. Castagnole Monferrato, 48. Castelnuovo Belbo-Graveyard, 49. Castelnuovo Bormida, 50. Castelnuovo Don Bosco-Layer CDB1, 51. Cerro Tanaro, 53. Fubine, 54. Gherba, 55. Mombercelli, 56. Rocca dell'Eremita of Pocapaglia, 57. Roatto-Cascina Melona, 58. Valmanera, 59. Villafranca d'Asti-RDB Quarry, 60. Villafranca d'Asti-Rio Stanavasso, 61. Bra, 63. Canale d'Alba, 64. Ceresole d'Alba, 65. Cherasco-Stura, 66. Cortiglione d'Asti, 67. Cortiglione-Serralunga, 69. Ferrere, 70. Monteu Roero, 72. Madonna di Mombirone, 73. Monticello-Graveyard, 74. Pocapaglia, 75. Rocche dei Perosini, 76. San Giacomo di Montaldo Roero, 78. Valdelserro-Cascina Caretto, 79. Valle Botto, 80. Valleandona

of *Sinomenium cantalense*. The oxidised leaf impressions (MGPT) can only be employed to assess the local palaeofloral features, and further sampling is not required, considering that the deposit, in the year 2017, was already deeply buried by a thick cover of debris.

Other sites of the NW Sector – ∑06. Barbania (very scarce oxidised leaf impressions: MGPT), ∑07. Benasso (Martinetto, 1995, carpological material: CCN), ∑08. Pranzalito and Borriana (carpological material: CCN, unpublished), ∑09. Ca' Viettone (carpological material: see Martinetto et al., 2018b, CCN; scarce compressed leaves: MGPT) and Levone (oxidised leaf impressions: MGPT, unpublished), ∑10. Canton Talentino (Martinetto, 1995, carpological material: CCN), ∑11. Ceretti and Vauda Canavese (oxidised leaf impressions: MGPT, unpublished), ∑13. Front (Martinetto et al., 2007, carpological material: CCN), ∑14. Front-Rio Secco (oxidised leaf impressions: MGPT, unpublished), ∑15. La Cassa (Martinetto, 1995, carpological material: CCN; oxidised leaf impressions and compressed leaves: MGPT, unpublished), ∑16. Lombardore (carpological material: CCN, unpublished except for a mention in Martinetto, 2015), ∑17. Momello-Lanzo (Martinetto, 1995, carpological material: CCN; oxidised leaf impressions and compressed leaves: MGPT, unpublished), ∑19. (From NW to SE) Remondato (oxidised leaf impressions: MGPT, unpublished), Rio del Caporale (oxidised leaf impressions: MGPT, unpublished) and Boschi di Barbania (Martinetto, 1995, carpological material: CCN), ∑20. Rivara (Martinetto, 1995, carpological material: CCN), ∑21. Sento and Pian Torinetto (Basilici et al., 1997, carpological material: CCN, MGPT), ∑22. Villanova Canavese (oxidised leaf impressions: MGPT, unpublished). The sediments of Lombardore are probably of Pleistocene age (Martinetto, 2015).

NE SECTOR (BIELLESE AND VALSESIA)

The fossil leaves recovered from the majority of Pliocene sites of this sector sum up to a few specimens, therefore we focused on the four sites (∑23–26) with more abundant material. In this sector, Pliocene sediments, both marine and continental, crop out in fluvial incisions, particularly in the basin of the Cervo

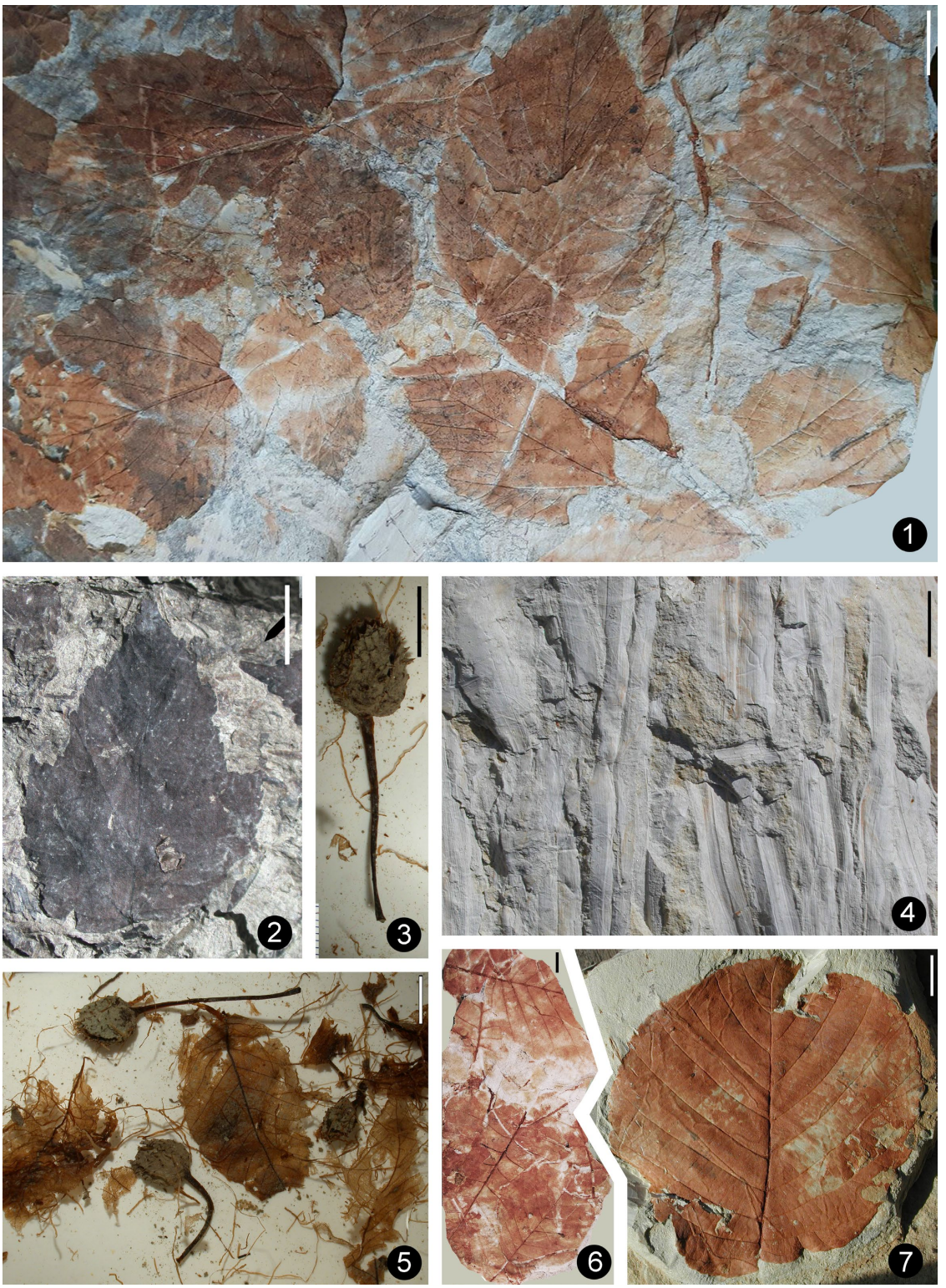

Figure 6. Plant fossils from the NW Sector of Piemonte; **1**. *Acer tricuspidatum* ssp. *lusaticum*, leaf assemblage, Fiano, MGPT-PU141482; **2**. *Acer tricuspidatum* ssp. *lusaticum*, compressed leaf, Fandaglia, MGPT-PU141483; **3**. *Fagus deucalionis*, mummified cupule, Stura di Lanzo Fossil Forest, CCN; **4**. Cyperaceae indet., leaf impressions with preferential alignment, Vauda inferiore-Locality FN1, MGPT-PU141484; **5**. *Fagus deucalionis* and *Fagus haidingeri*, mummified cupules and leaves, Stura di Lanzo Fossil Forest, CCN; **6**, **7**. *Alnus cecropiifolia*, leaf impressions, **6**. densely packed leaves, Stura di Lanzo Fossil Forest, MGPT-PU141485, **7**. isolated leaf, MGPT-PU141486. Scale bar = 1 cm

River. Fine-grained deposits with plant fossils are less abundant than in the NW Sector and the location of the known localities is shown in Fig. 4, which does not include only the sites of Boca, Cerrione-Cascina Galanta and Valduggia, whose location is shown in Fig. 2.

The thick Plio-Pleistocene sedimentary succession of the Biella area was formed in the

frame of a few Pliocene cycles of transgression-regression (Martinetto, 2001; Martinetto and Festa, 2013), which affected the entire fringe of the Alps, with deposition of siliciclastic sediments of shallow marine, transitional and continental environments. The Pliocene succession crops out throughout the hilly area to the east of Biella and, in some cases, further south, along the courses of the main rivers. The Pliocene succession is covered by Quaternary, mainly gravelly deposits, part of the infilling of the Padane Basin (Carraro, in Bortolami et al., 1967). About 1 km south of Castelletto Cervo, the erosion produced by the Cervo river exposed sediments of specific palaeobotanical interest, due to the rich content of plant fossils (Cavallo and Martinetto, 2001; Martinetto and Festa, 2013; Martinetto, 2015). These are siliciclastic deposits of coastal and continental palaeoenvironments that, due to their facies and position (above the Pliocene marine deposits: Aimone and Ferrero Mortara, 1983; Martinetto, 2001), are assigned to the informal lithostratigraphic unit named "Villafranchiano" (sensu Caramiello et al., 1996).

∑**23**. **Canton Iuli** near **Castelletto Cervo** – Group of sites included in the area geographically known as Biellese (Fig. 4), part of the north-eastern sector of Piemonte (Cavallo and Martinetto, 2001; Martinetto, 2001; Martinetto and Festa, 2013). Data concerning the outcrop of Canton Iuli can be found in Martinetto (2001). In this work, samples from two different layers ("CC8" and "CC30") of silty sands were analysed (MGPT). Both sites provided leaf assemblages referable to a swamp environment (Basilici, 2001), which are rare in the whole Biella area. The CC30 layer shows a mixed assemblage of woody and aquatic plants, with compressed leaves that could be suitable for cuticular analyses and reconstructions of CO_2 values. The CC8 layer, on the other hand, yielded an oligotypic assemblage of oxidised leaf impressions (Fig. 7.3a) dominated by *Acer tricuspidatum* ssp. *lusaticum*, which is very useful for establishing the characteristics of the plant palaeocommunity of this specific area. Some small leaves show good detail of the venation and margin (Fig. 7.3b, 7.3c). Moreover, from the CC30 layer, several interesting specimens of fruits and infructescences have been extracted (CCN: Martinetto, 2001). Further sampling in the area is not necessary or, in the case of the CC30 layer, impractical.

∑**24**. and ∑**31**. **Castellengo** – This site was studied by Ferrero et al. (2003). In spring 2000 the climatic conditions, together with some human interventions carried out inside the riverbed of the Cervo River, brought to the light a sandy deposit rich in remains of marine molluscs. After a temporary disappearance in the years 2001 and 2003 (Ferrero et al., 2005), the outcrop was again visible, with an extended area, in the years 2020–2023 (Fig. 4). This deposit (labelled TC1) provided numerous mummified cones, fruits and seeds (CCN), that could offer a chance for the correlation between marine and continental palaeoenvironments. The data on molluscs and the comparison with other Pliocene localities around Biella allow only the attribution to the large MPMU1 mollusc biozone (Raffi and Monegatti, 1993; Monegatti and Raffi, 2007), preceding the temperature deterioration starting around 3.2 million years ago.

The new material we analyse here (MGPT) originated from a silty-sandy layer (TC20) lying about 15–20 m above the TC1 deposit. It consists of a single sediment sample bearing a few leaves, among which only two specimens of *Fagus haidingeri* can be determined. However, this sample was recovered by one of us (E.M.), at the beginning of the 21st century, from a group of fallen-down blocks rich in leaf impressions, which were not preserved due to intense freezing (field notes: *Laurophyllum*, *Liquidambar*, *Salix*, cf. *Trigonobalanopsis*). A preliminary sedimentological analysis (Basilici, 2001) suggested a palaeoenvironment corresponding to an ancient tidal plain, which received an allochthonous assemblage of leaves, possibly with high diversity. The little information available suggests a potential interest of further leaf samples, eventually retrieved from this site, for physiognomic analysis and for an attempt to reconstruct the diversity of the local palaeoflora. The outcrop, visited again in 2023, was still in a similar condition as nearly 20 years before: a well exposed, steep wall with consistent danger for falling blocks and pebbles.

∑**25**. **Cossato-Layer CO2** – The site is mentioned in Martinetto (2001) and its relevance is linked to a diverse leaf assemblage. This was yielded by a layer of very fine silty sands, labelled "CO2", originally located in a channel that crossed an ancient tidal plain. The allochthonous assemblage of fossil leaf impressions often shows a high degree of fragmentation

Figure 7. Plant fossils from the NE Sector of Piemonte; **1**. Plant remains (impressions) from the Cossato site-Layer CO2, MGPT-PU141487, **1a**. bedding plane rich in leaf fragments, **1b**. cf. *Populus*, **1c**. *Ocotea heeri*; **2**. *Ocotea heeri*, from the Southern Sector (for comparison), leaf impression with possible domatia or glands (Bůžek et al., 1996) at the axil of the most prominent secondary veins, Baldichieri-Fornace, MGPT-PU141488; **3**. Canton Iuli site, near Castelletto Cervo-Layer CC8, MGPT-PU141489, **3a**. leaf assemblage with a large incomplete leaf of *Acer tricuspidatum* ssp. *lusaticum*, a nearly complete leaf of *Alnus* cf. *ducalis* with emarginate apex (arrow) and a small leaf of *Rosa* sp., **3b**. *Rosa* sp., detail of leaf margin, **3c**. *Rosa* sp., overview of the same, nearly complete leaf; **4**. Compressed leaf of cf. *Trigonobalanopsis rhamnoides* with cracks occurred after partial drying; Valduggia, Crabbia site, MGPT-PU141490. Scale bar = 1 cm

(Fig. 7.1a). However, several hundreds of oxidised leaves were fairly complete, with a medium-low quality of vein preservation and margin details (Fig. 7.1b). This entails a good opportunity for a physiognomic analysis of the leaves and assessment of local palaeofloral diversity. Supplementary File contains a small portion of samples (MGPT), the remaining ones

were studied in an unpublished thesis (Valeria Venezia). The main occurring taxa are shared with similar assemblages of the Southern Sector (see below), e.g. *Alnus* spp., *Fagus*, *Laurophyllum*, *Platanus*, *Populus*, *Ocotea* (Fig. 7.1c), *Quercus* and *Salix*.

The outcrop is currently well exposed, but further sampling is not necessary given the abundant material recovered in emergency during the past thirty years, when the floods caused the removal of large blocks from the CO2 layer. From the year 2022 onwards, more caution should be paid in recovering drifted blocks in order to avoid mixing of different assemblages. In fact, a previously covered lens of fine-grained sediments, bearing a few leaf impressions, cropped out 3–4 m below CO2.

∑**26**. **Valduggia** – A few samples of fossil leaves stored at the MGPT were only labelled "Valduggia", a Pliocene leaf-bearing locality already cited by Sordelli (1896). During a field survey at Valduggia in the year 2003, a few leaf impressions have been recovered from an ephemeral outcrop ("Molino Rastelli site") close to a factory, and added to the MGPT collection. These were enclosed in fine sandy sediments attributed to a marine palaeoenvironment (Fantoni et al., 2005) in which leaves drifted from a terrestrial environment were buried. The little information collected in the field suggested a possible, limited relevance of the palaeobotanical material yielded by a more extensive sampling at the unpublished Valduggia-Molino Rastelli site (Supplementary File). However, in the year 2022, we verified that such a site vanished, whereas we got information about abundant fossil plant material exposed by the erosion of a brook not far from it. The new "Crabbia site" proved to be much richer in plant fossils, and the abundant leaves are not only impressions, but also compressions (Fig. 7.4), which could be useful for cuticular studies. The preliminary examination of the assemblage indicated a possibility for leaf physiognomic analysis and for the assessment of the local palaeofloral diversity. Even the few dozen samples saved so far from destruction (MGPT) suggest a diversity of leaf morphotypes which is not reflected by the small historical collection of leaf impressions, possibly deriving from a neighbouring outcrop, which is stored at the Calderini Museum of Varallo Sesia (Sordelli, 1896; Fantoni et al., 2005).

Other sites of the NE Sector – ∑27. Boca (Martinetto, 1995, carpological material: CCN), ∑28. Buronzo (Martinetto, 2001, carpological material: CCN), ∑29. Candelo-Bocca del Lupo (Martinetto, 1995, carpological material: CCN), ∑30. Buronzo-Cascina Colombera (carpological material: CCN, unpublished), ∑32. Castelletto Cervo I and II (Cavallo and Martinetto, 2001, carpological material: CCN), ∑33. Cerrione-Cascina Galanta (oxidised leaf impressions: MGPT, unpublished), ∑34 Garella di Fondo (Martinetto, 2001, carpological material: CCN), ∑35. Masserano (compressed leaves: MGPT, unpublished), ∑36. Plello near Valduggia (carpological material: CCN, unpublished), ∑37. Rolino (carpological material: CCN, unpublished), ∑38. Ronco Biellese (Martinetto, 1995, carpological material: CCN), ∑39. Terzoglio (carpological material: CCN, Martinetto and Festa, 2013). The sediments of Buronzo, Cascina Colombera, Castelletto Cervo II and Garella di Fondo are most probably of Pleistocene age (Martinetto, 2015).

SOUTHERN SECTOR (CUNEESE-ASTIGIANO-ALESSANDRINO)

This sector is extremely rich in outcrops of Pliocene sediments, with a prevalence of marine ones, which nevertheless often contain drifted remains of terrestrial plants. Indeed, the presently known marine plant-bearing sites only represent a small part of those which could be discovered in this area. Conversely, fine-grained continental deposits with plant fossils occur in more restricted areas. Some sites of this sector provided the richest sets of fossil leaves of the whole Piemonte region, and we were able to treat all of them in this paper (∑40, 51, 52, 58, 59), together with sites that yielded no more than a few dozen leaf specimens (∑41–50, 53–57, 60). The location of the majority of the plant-bearing localities of this sector is shown in Fig. 5, which does not include the sites of Benevagienna, Breolungi, Carrù-Mondovì, Crava di Morozzo, Fossano and Madonna di Galizia of Benevagienna, whose location is shown in Fig. 2. The location of the historical sites of San Damiano d'Asti and Pralormo (Peola, 1896a) is also approximately indicated in Fig. 5.

∑**40**. **Arboschio** – GCTM157 – Details about the Pliocene succession of Arboschio can be found in Pavia (1970), in the monographic revision of the "Villafranchiano" unit in the

type-area of Villafranca d'Asti, edited by Carraro (1996), and in Martinetto (2003). The large outcrop that was visible in the second half of the 20th century, due to a quarry, obviously had a relevant palaeobotanical interest for the occurrence of plant fossils (Fig. 1B) over a long stratigraphic interval and for the excellent preservation of some leaf impressions (lithozone 4 of Pavia, 1970). These represent, possibly, the morphologically best preserved Pliocene specimens of the whole Piemonte region. Several hundreds of fossil leaf samples (Pavia, 1970; Martinetto, 2003) from two superposed sedimentary bodies of this succession (Arboschio-L1 and Arboschio-L4, lithozones 1 and 4 of Pavia, 1970) are stored both at the MGPT (Pavia et al., 2017) and MPTA (unpublished material). In this paper we newly analysed 8 sediment samples bearing impressions of leaves of *Acer tricuspidatum lusaticum*, *Alnus gaudinii* and shoots of *Taxodium dubium*.

In 2018 the whole Arboschio outcrop was covered by vegetation, but a few small uncovered patches, exposing the uppermost layer, A5 of lithozone 7 (Martinetto and Mai, 1996; Martinetto, 2003), were still available at Bricco Barrano. We aimed to evaluate the relevance of such residual exposure, indicated as Arboschio-L7. The layers of clayey silts assigned to an original swamp environment (Carraro, 1996) constitute the uppermost portion of the rather thick section (Pavia, 1970). We only catalogued 4 new sediment samples from layer A5 (Supplementary File), but we could also use the information available on about one hundred other samples described by two unpublished student reports (Argentero, Spallone). Thus, we can assess that layer A5 provided a diverse, transported leaf assemblage with both sclerophyllous and papery leaves (dominance of *Quercus pseudocastanea* and *Daphnogene polymorpha*, occurrence of *Cornus* cf. *studeri*, *Fagus haidingeri*, *Quercus mediterranea* and cf. *Myrtus*, Fig. 8.5). Additionally, several three-dimensional impressions of carpological parts (*Quercus* cupules, *Symplocos* endocarps, *Toddalia* seeds) have been recovered (cited in Martinetto and Mai, 1996). This layer is visible in a high, steep-walled outcrop, and only blocks fallen-down at its base could be sampled. However, a properly organised hand excavation would still be possible, and probably it would provide a rich leaf and carpological assemblage, potentially useful for the reconstruction of the regional palaeoflora. Conversely, further sampling of the underlying layer A4 would be logistically complicated (and/or very expensive), and probably would not add much information. In the year 2023 an active quarry exposed leaf-bearing layers of lithozone 1, 500 m to the SE of the former Arboschio outcrop, and the analysis of the material is in progress.

∑**41**. **Asti-Cascina Risso** – The previous treatment in Martinetto (2003) provides a complete palaeontological analysis of this site. The location of the outcrop, close to the Risso farmhouse, is also locally known as "Vallescura". From a palaeoenvironmental point of view, the plant-bearing layer, constituted by very fine silty sand (Martinetto, 2003), is located at the marine-continental transition. Despite the scarce sampling and the status of the outcrop, which does not encourage further research activities, the allochthonous leaf assemblage seemed to show rather high diversity (6 taxa over 9 samples: Supplementary File). Among the presently available specimens (MGPT), the impression of a leaf attributed to cf. *Posidonia* sp. (Fig. 9.3a) is remarkable, where a bryozoan colony is clearly visible on the leaf lamina (Fig. 9.3b, c). Signs of plant-animal interaction were detected on some fossil leaves (e.g. *Ulmus affinis*, Fig. 8.2a, 8.2b, with probable feeding marks by animals on the margins).

∑**42**. **Baldichieri-Fornace** (GCTM148a in Pavia et al., 2004) – Gregor (1990) named this site "Baldichieri (Fornace di) c/o Torino". It is located 1100 m from the centre of Baldichieri, in an ESE direction, where a quarry was active until 1990. The stratigraphic section has not been described in detail in the previous literature; it was about 10 m thick and consisted of marine sand with a concentration of shells in the highest part (Martinetto, 2003). The bottom of the succession probably reached the base of the Asti Sands, since it showed blue-grey silty sands with mummified remains of plants and small mussels (not yet studied in detail), that indicate a transition between an offshore and shoreface palaeoenvironment (Martinetto, 2003). Poor sampling provided very limited documentation of the original palaeoflora. An outstanding feature of the assemblage (MGPT) is the occurrence of large, entire leaf impressions of *Ocotea heeri*, associated to a few other taxa, such as *Trigonobalanopsis rhamnoides*, rare in the Asti area (Supplementary File).

Figure 8. Plant fossils from the Southern Sector of Piemonte; **1**. *Ulmus affinis*, Gherba, MGPT-PU141491; **2a**, **b**. *Ulmus affinis*, Asti-Cascina Risso, leaf impression with possible animal damage and its counterpart, MGPT-PU141492; **3a**, **b**. *Alnus gaudinii*, leaf adpression with traces of organic matter and a detail of the teeth in the apical part, Ceresole d'Alba, MGPT-PU141493; **4**. *Alnus gaudinii*, from an oligotypic assemblage of Roatto-Cascina Melona-Layer A, MGPT-PU141494; **5**. cf. *Myrtus*, Arboschio-L7, layer A5, MGPT-PU141495; **6**. Oligotypic assemblage of Roatto-Cascina Melona-Layer A, with leaves of *Alnus gaudinii* associated with fruit-bearing amenta of *Alnus* sp. (arrows), MGPT-PU141496; **7**. *Fagus haidingeri*, two leaves from an assemblage of Valmanera dominated by this species (Cascina Ignota), MGPT-PU141497; **8a**, **b**. *Alnus ducalis*, Gherba, MGPT-PU141498; **9**. *Alnus ducalis*, leaf impression from Valmanera-Villa Paolina, detail of the entire leaf impression figured in Martinetto (2003: pl. 3, fig. 1) and Martinetto et al. (2023, fig. 21c), showing a margin similar to the leaf specimen from Gherba, MGPT-PU105018. Scale bar = 1 cm

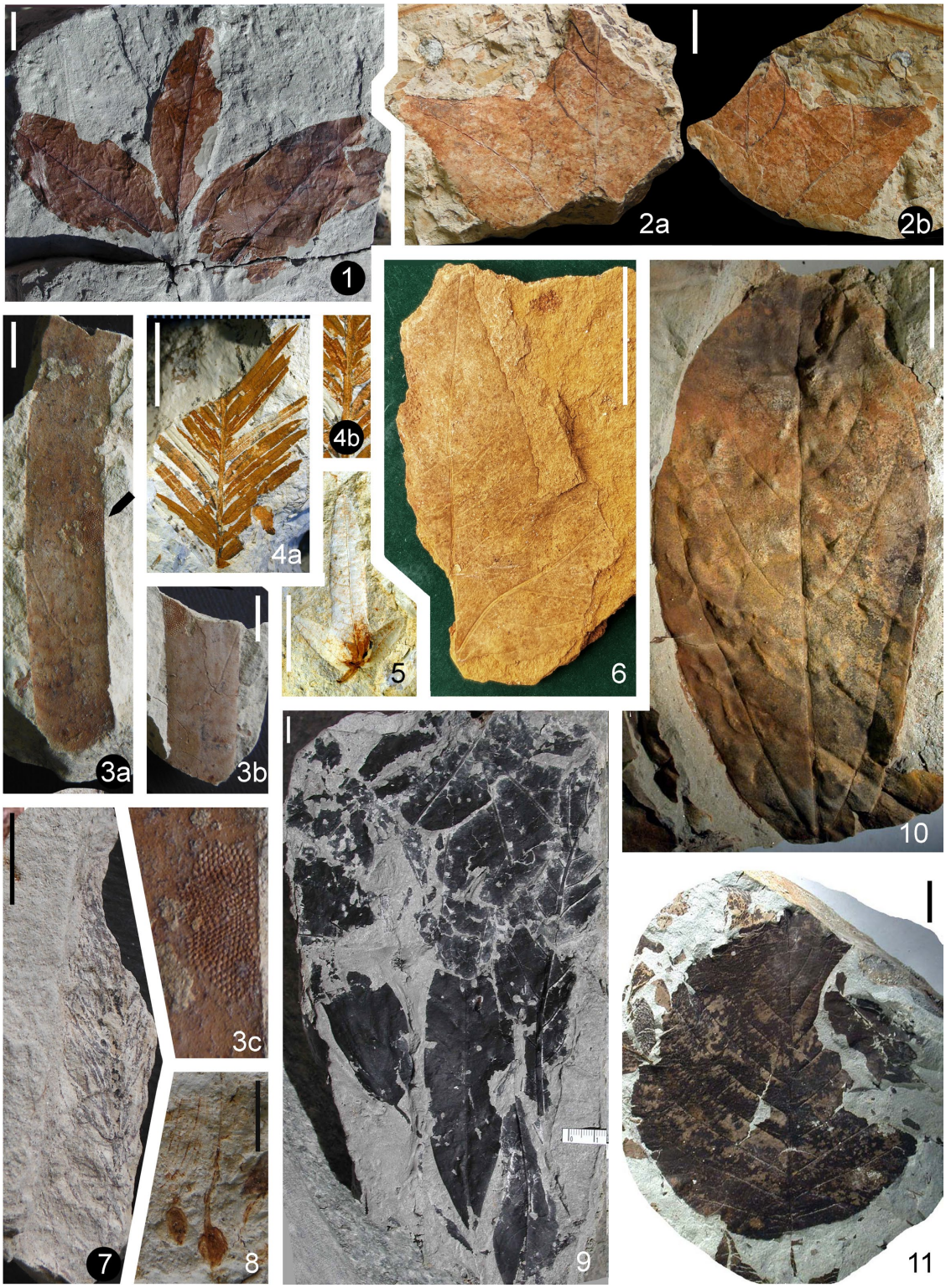

Figure 9. Further plant fossils from the Southern Sector of Piemonte; **1**. *Laurophyllum pseudoprinceps*, four compressed leaves still attached to a branch, Fossano-Section A-Layer FO4, MGPT-PU105168; **2a**, **b**. *Liquidambar europaea*, incomplete leaf impression and its counterpart, Castelnuovo Belbo-Graveyard, MGPT-PU141499; **3a–c**. cf. *Posidonia*, impression of a leaf and its counterpart, both bearing the impression of a colony of bryozoans, shown in detail in 3c; Asti-Cascina Risso, MGPT-PU141500; **4a**, **b**. *Taxodium dubium*, portion of a leafy shoot with a detail of leaf attachment, Gherba, MGPT-PU141501; **5**. *Carpinus betulus*, impression of a fruit-bearing bract, probably associated with a three-dimensional mould of the fruit (not visible), Gherba, MGPT-PU141502; **6**. *Liquidambar europaea*, incomplete leaf impression, Rocca dell'Eremita of Pocapaglia, Craveri Museum of Bra; **7**, **8**. *Ceratophyllum* sp., portion of a branch (adpression) and impressions of two fruits, one with long style, Castelnuovo Bormida-Lens 7 (Irace et al., 2017), MGPT-PU141504; **9**. Assemblage of compressed leaves, when recovered from the field. Presently, after 20 years of preservation under vacuum, the compressed leaf specimens show abundant cracks, even if vacuum conditions were maintained; Fossano-Section A-Layer FO4, MGPT-PU141505; **10**. *Ocotea heeri*, oxidised leaf impression of a specimen that was previously permineralised, notice the possible domatia or glands at the axil of the lateral most prominent secondary veins, Cerro Tanaro, MGPT-PU141507; **11**. *Alnus cecropiifolia*, permineralised leaf, Cerro Tanaro, MGPT-PU141506. Scale bar = 1 cm

Unfortunately, further sampling is no longer possible due to the abandonment of the quarry and the construction of buildings.

∑**43**. **Baldichieri-North** – In this outcrop, cited in Martinetto (2003), a sandy succession was exposed between 1994 and 2002, with a thickness of 14 m, in a small quarry located 1 km NW from the village of Baldichieri, 30 m east from the way leading to Castellero. The lower and upper parts of the succession contained intensely bioturbated sediments, rich in marine bivalve shells, such as *Glycymeris* and *Spondylus*. The middle part included well-preserved sedimentary structures with different surfaces characterised by reddish impressions of wood fragments. A 10 cm thick sandy layer preserved various leaf impressions in a poor state of preservation (Martinetto, 2003). Yet, the fossils mostly showed enough characters for a taxonomic identification of several types (e.g. *Ulmus affinis*, Fig. 8.1), pointing to a potentially diverse assemblage. Therefore, the assemblage would have been suitable for physiognomic analysis and to provide a contribution to the assessment of the local palaeofloral features. Unfortunately, the leaf impressions recovered in emergency conditions in the past (MGPT) are scarce and difficult to employ in palaeobotanical studies. Further sampling is impossible due to the dense vegetation cover occurring at present and for the difficulty to obtain permission and financial support for an eventual excavation.

∑**44**. **Cantarana** – The site is mentioned in Carraro (1996), but with scarce information. In this work we examined fossil plant specimens from two different outcrops. The first, named "Cantarana – Graveyard", was located in a marine-continental transition zone, where an allochthonous leaf assemblage with high diversity was collected (samples at MGPT and MRSNT). The available samples (Fig. 10.1) suggest that the fossil assemblage would have been suitable for leaf physiognomic analyses and assessment of local palaeoflora diversity. Several impressions of small leaves of *Ulmus* (Fig. 10.1) were recovered.

The second outcrop, named "Cantarana – Locality Martinetto", yielded a clayey silt deposit, where a monotypic assemblage of oxidised fossil leaf impressions with dominance of *Salix* sp. was sampled (MGPT). In both sites, further sampling is discouraged for the same reasons mentioned for the Baldichieri-North site.

∑**45**. **Casa Barbarino of Bruno** – The locality is included in the area mapped by d'Atri et al. (2016) and consists of a wall behind a house, where fine-middle-grained sand of marine-continental transition still cropped out during the last visit in 2017. The site provided a few samples (MGPT) of an allochthonous leaf assemblage of possibly high diversity, with dominant sclerophyllous leaf types (*Daphnogene*, *Laurophyllum*, *Trigonobalanopsis*). The so-far recovered samples show oxidised leaf impressions with very poor detail of venation, whereas the margin is better preserved. With further sampling the assemblage could become suitable for leaf physiognomic analysis and assessment of local palaeofloral diversity.

∑**47**. **Castagnole Monferrato** – GCTM176 – Site located 1.15 km south-east from the centre of Castagnole Monferrato, where a large quarry extracted Pliocene sediments, which were exposed for a thickness of about 50 m. The whole section is of marine facies, with mussel assemblages indicating an offshore bottom (Martinetto, 2003). The impressions of oxidised leaves were collected in the year 2000 in the topmost layer, formed by rather homogeneous silty sands with apparent flat stratification (MGPT). Individual leaves are mostly isolated within the sediment, but a single block often shows more than one leaf type, thus suggesting a simultaneous pre-burial transport of different leaves (Martinetto, 2003). The material listed in Supplementary File only represents a portion of that listed in Martinetto (2003), that also includes leaves of *Alnus cecropiifolia*, *Carpinus* cf. *betulus*, *Platanus leucophylla*, *Thuja saviana* (a shoot) and cf. *Trigonobalanopsis rhamnoides*. Currently, the quarry is not active and the outcrop is densely covered by vegetation, so that the plant-bearing layer could be no longer accessible.

∑**48**. **Castelnuovo Belbo-Graveyard** – Information collected during a single visit (year 2003) indicates that the sediment is composed of fine sands deposited in an original shallow marine environment. The diversity of the plant assemblage is unknown due to the small number of samples available. However, the few leaf fragments recovered (MGPT) possess a good detail of veins and margins (Fig. 10.2a, 10.2b), thus suggesting the possibility of physiognomic analysis and reconstruction of local palaeoflora.

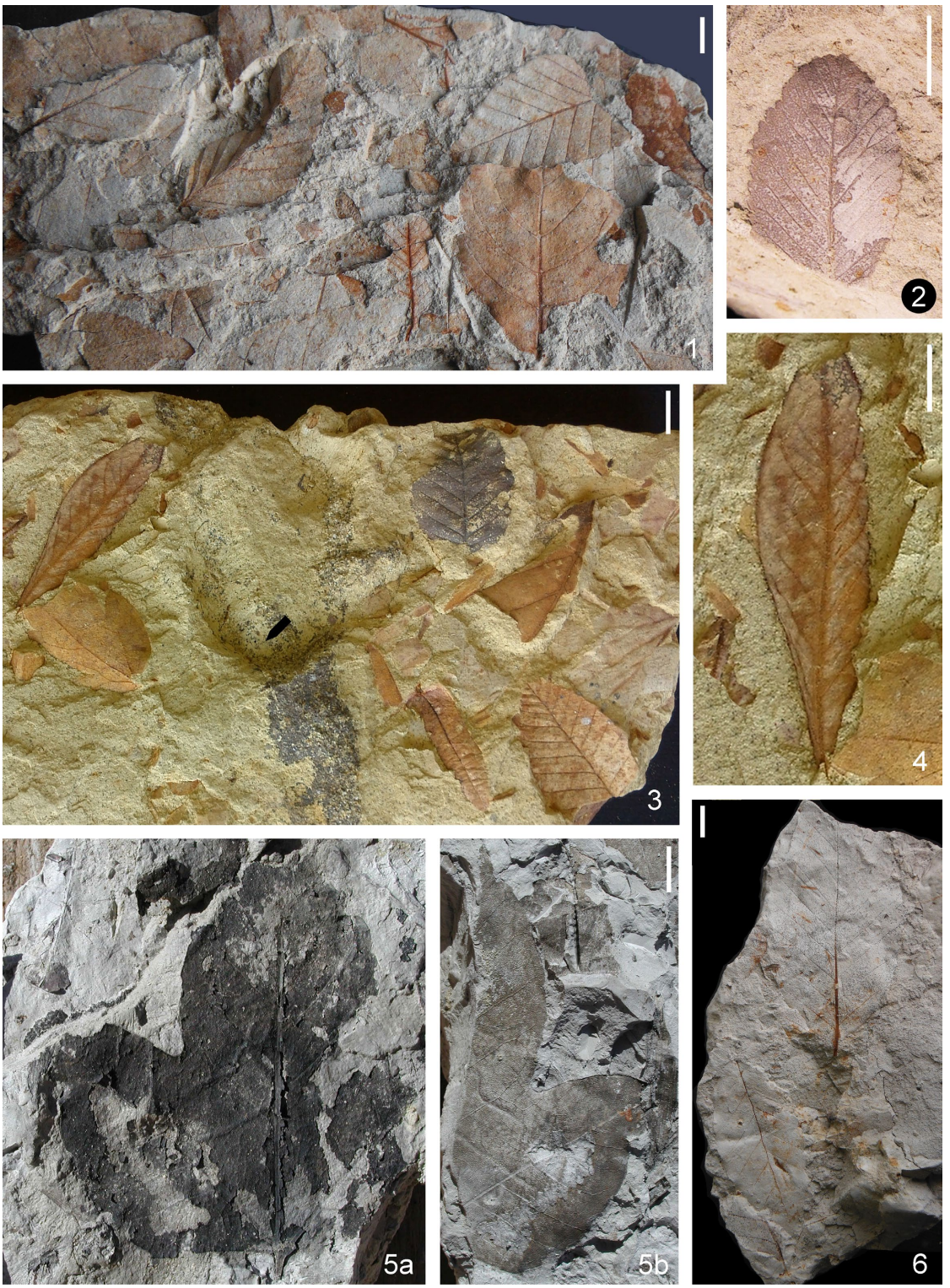

Figure 10. Further plant fossils from the Southern Sector of Piemonte; **1**. Diversified leaf assemblage from Cantarana-Graveyard, with *Fagus haidingeri* and *Alnus ducalis* (bottom, right), MGPT-PU141508; **2**. *Ulmus* sp., leaf impression, Cantarana-Graveyard, MGPT-PU141509; **3**. Diversified leaf assemblage from Fubine, with cf. *Clematis* (left, central), *Carpinus betulus* (two leaf fragments and a fruit-bract) and cf. *Prunus* sp., MGPT-PU141510; **4**. cf. *Prunus* sp., detail of the leaf impression, Fubine, MGPT-PU141510; **5**. cf. *Acer integerrimum*, Villafranca d'Asti-Rio Stanavasso-SV1, **5a**. leaf compression, **5b**. part of the impression of the same leaf, MGPT-PU141511; **6**. *Fagus haidingeri*, leaves from an Early Pleistocene assemblage of Castelnuovo Bormida-Lens 7, dominated by this species, MGPT-PU141512. Scale bar = 1 cm

In the year 2003, the Graveyard outcrop was already poorly exposed, but similar leaf-bearing sediments were available at a large outcrop 1 km to the south, along the Belbo river. A survey in the year 2023 proved that the outcrop is still extended and well exposed, nevertheless the interest of the site is limited by the danger deriving from the fall of blocks

from the top and the difficulties implicit in recovering fossil samples from a steep wall.

∑**49**. **Castelnuovo Bormida** – A detailed description of the outcrop can be found in Irace et al. (2017). A few plant fossils provided by a lens of silty sediment called "Lens 7", assigned to the Early Pleistocene, are evaluated in this paper. These are oxidised leaf impressions from a mixed assemblage (MGPT), whose most peculiar aspect is the possibility to combine some fruits and leafy axes of aquatic plants (e.g. *Ceratophyllum*, Fig. 9.7, 9.8) for a "Whole-Plant" hypothesis (Martinetto and Macaluso, 2018). The leaves of non-aquatic plants did not seem to be rare during field work (focused on carpological analyses), but the few samples recovered only show *Fagus haidingeri* (Fig. 10.6). The current status of the quarry was not verified, but the works were proceeding very fast during the last visit in the year 2015 and it is highly probable that the plant-bearing layer is no longer accessible.

∑**50**. **Castelnuovo Don Bosco-Layer CDB1** – This outcrop is described by Forno et al. (2015) and Festa et al. (2009). The lithological characteristics of the outcropping sediments are very similar to those of the San Martino unit, "Villafranchiano B" of Villafranca d'Asti (Carraro et al., 1996). The compressed fossil plant samples analysed conserve the remains of oligotypic assemblages with dominance of *Taxodium dubium* (MGPT). These are compressed leafy shoots, which are suitable for cuticular analysis. A few valuable reddish impressions of *Taxodium dubium* shoots have also been recovered (Forno et al., 2015: fig. 21) together with a single specimen of *Alnus gaudinii*. Already during the last visit to the site, dating back to the year 2000, it seemed clear that the deposit would no longer be accessible due to the construction of large buildings. Moreover, an additional sampling would not add much information and would entail problems concerning permission and budget, as the use of a digger would be required.

∑**51**. **Cerro Tanaro** – The Pliocene succession of Cerro Tanaro constitutes a rare example in the Asti area of marine fossil deposits influenced by palaeobiological contributions of brackish environments. The succession documents a phase of marine ingression which correlates with other situations already known in the Asti area. The Cerro Tanaro site consists of two outcrops separated by the Tanaro river. The one on the left bank, an erosional wall, mainly yielded marine mollusc remains, a mammal bone and carpological remains, while the one on the right bank is characterised by sandstone beds with rich leaf assemblages. This second outcrop was just briefly mentioned in Martinetto (2003), and shows an 8 metres thick succession mainly composed of cemented sediments, which, stratigraphically, should lay under the succession of Outcrop 1, given that there is no sign of tectonic disturbance. An interesting aspect of this Outcrop 2 is the high degree of cementation of the sediments, both pelitic and arenitic, that determines a permineralization of the plant remains (Fig. 9.11). This contrasts with the Asti Sands norm (Ferrero and Pavia, 1996), which is typically represented by non-lithified sediments. The peculiar lithology and the features of the leaf assemblage lead to the hypothesis (Martinetto, 2003) that the deposit could have provided the "Annone d'Asti" (Castello d'Annone, a larger village, close to Cerro Tanaro) palaeoflora described by Peola (1896a), whose original material has unfortunately gone lost. The leaf assemblage shows definite clues for a rapid burial, indicated by leaf sheets often wrapped, and not parallel to the horizontal bedding planes. The taxonomic composition (Martinetto, 2003) indicates the origin from plant communities composed mainly of deciduous angiosperms, with contributions both from the riparian environment (*Alnus cecropiifolia*, *A. ducalis*) and from mesophytic forests (*Fagus haidingeri*, *Zelkova zelkovifolia*); the lauraceous *Ocotea heeri* is dominant among the evergreen forms (Fig. 9.10). The palaeofloral context is analogous to that reconstructed for the Arboschio (Pavia, 1970; Martinetto and Mai, 1996) and Valmanera (Martinetto, 2003) sites and is indicative of warm-temperate and humid climate. The outcrop of Cerro Tanaro was probably brought to light by the erosion associated with the floods of the River Tanaro at the end of the 20th century. The normal dynamics of the river bed involves bank erosion over time and, therefore, determines the modification of the outcrop, with possible exposure of new fossil beds in the future.

The uniqueness of the fossil leaf assemblage, the possibility for reconstructions of brackish invertebrate palaeobiocoenoses (Ferrero and Pavia, 1996), and the uncommon record of a late Pliocene phase of marine ingression

advise to reserve particular attention to this outcrop in terms of geoconservation. However, abundant material was stored at MGPT and MPTA for an ex-situ conservation of the geoheritage.

∑**52**. **Fossano**, **Fossil forest area** – The site is characterised by the recent outcrop of a fossil forest near Fossano (Macaluso et al., 2018). Stratigraphic information has been collected for more than a decade from another site where the lower and higher layers of the Pliocene succession cropped out (location indicated as "Section A" in Macaluso et al., 2018). A third section (Layer FO5) provided scarce palaeobotanical data, but it could be significant for future investigation (MGPT). In the site of Section A, Martinetto (2015) and Macaluso et al. (2018) described carpological remains (CCN) and several compressed leaves (MGPT), with dominance of Lauraceae (Fig. 10.1). The samples listed in our Supplementary File represent a very small part of the available material.

This site has many potential interests for palaeobotany. As already demonstrated by Macaluso et al. (2018), the leaves from the FO4 layer are suitable to cuticular analysis and could be used to reconstruct CO_2 values at the time of leaf growth; additionally, they could reveal precious palaeoenvironmental information, if subjected to physiognomic analysis. The density of leaves on the bedding planes is usually high, but the outline of individual specimens can be evidenced through careful removal of the matrix in a still waterlogged state (Fig. 10.9). The samples which were retrieved in the past already contributed to the knowledge of the diversity of the local palaeoflora and could provide information about the Whole-Plant Concept (Kvaček, 2008) of a few species, e.g. of *Tetraclinis salicornioides*, which occurs with whole shoots and abundant cones in the same layer, even if never found in connection so far (Macaluso et al., 2018). The sites of both the fossil forest and the FO4 layer were still well exposed during the last field visit, dating back to the year 2017, and are suitable for further sampling.

∑**53**. **Fubine** – This outcrop of Pliocene sands and silts is unpublished. A fallen block recovered by Mr. Giuntelli in the year 2001 provided an allochthonous assemblage of about 20 oxidised leaf impressions (MGPT), that allowed us to infer a rather high diversity (Fig. 10.3). This site yielded two leaf morphotypes which were not yet found in any other site of the Piemonte region (cf. *Clematis* sp., cf. *Prunus*, Fig. 10.4). For this reason, the assemblage could provide some contribution to assess the diversity of the local palaeoflora. A survey in the year 2022, in the place indicated by Mr. Giuntelli, showed that the outcrop, surely laying on private ground, has been reduced and closed by a fence. An eventual interest for further sampling should afford the problem of obtaining the permission and locating a leaf-bearing deposit.

∑**54**. **Gherba** – The site, mentioned in the study concerning the succession of Villafranca d'Asti by Forno et al. (2015), has not been the main subject of any publication. The outcrop is a huge quarry, but the sediments are mainly sterile sand and sandy gravel, deposited in an area that originally was at the transition between the marine and continental environment. Plant fossils were located at the eastern border of the quarry, in a lens of very fine silty sands. The assemblage is of the allochthonous type, the diversity cannot be assessed due to the few samples available, but the site appears to be of potential interest. In fact, it provided valuable impressions of oxidised leaves (MGPT), with good detail of margin and veins preservation in angiosperm leaves (*Ulmus affinis*, Fig. 8.1; *Alnus ducalis*, Fig. 8.8), in leafy shoots of *Taxodium* (Fig. 9.4) and in a fruit-bract of *Carpinus betulus* (Fig. 9.5). Further recoveries would be difficult due to the covering vegetation, which makes the outcrop difficult to locate.

∑**55**. **Mombercelli** – Outcrop of silty sediments pertaining to a marine palaeoenvironment (Argille Azzurre Fm.), far from the coast, where oxidised impressions of rare and scattered leaves have been noticed, but just 2 plant specimens were saved from destruction (MGPT, Supplementary File). The site was a large quarry, recently filled up, so that sampling would be impossible at present. The single angiosperm leaf which was recovered shows lesions attributable to feeding activity by plant-eating animals.

∑**56**. **Rocca dell'Eremita of Pocapaglia** – This site is a natural beauty attracting local people for its steep walls and gullies of Pliocene yellow sands. A limited lens with oxidised, reddish leaf impressions was observed in the year 2021 during several days of field campaigns for the Natural Sciences students

of the Turin University. A few blocks, fallen down from the towering leaf-bearing deposits (Martinetto et al., 2023: fig. 19), contained fragmentary specimens of *Daphnogene polymorpha*, cf. *Alnus gaudinii* (base), *Liquidambar europaea* (Fig. 9.6), *Platanus* sp., cf. *Pterocarya paradisiaca* (apical half) and *Ulmus* sp. The leaf assemblage (a few leaves stored at the Craveri Civic Museum of Bra) is apparently allochthonous and high diversity might be foreseen, but the oxidised impressions preserve scarce details, even if some permineralization (probably cell walls) can be detected using a stereomicroscope. Additional sampling would be possible by recovering other blocks which will certainly fall down in the future. By collecting further material, the assemblage could become useful for physiognomic analysis and assessment of the local palaeoflora. The leaf bearing deposit belongs, according to the interpretation of Ghielmi et al. (2019), to a late Zanclean deltaic system. The stratigraphic position has a special relevance because it is, first of all, several tens of metres above the rich carpoflora of Pocapaglia (Cavallo and Martinetto, 1996) and, in addition, it is stratigraphically interposed between the leaf flora of Bra (Peola, 1895; Martinetto et al., 2023, in need of revision) and the flora of Ceresole d'Alba (Ciangherotti et al., 2007).

∑**57**. **Roatto-Cascina Melona** – GCTM152 – This site was mentioned in Martinetto and Mai (1996), but a detailed description of the remains is still not available. Plant-bearing deposits were sampled in three layers indicated as A, B and RT1. The lowermost layer RT1 provided a fruit and seeds assemblage described by Martinetto and Mai (1996) and a compressed leaf of *Acer tricuspidatum lusaticum*. Layer A is a clayey silt sediment from an original swamp environment. It provided a monotypic assemblage composed of oxidised impressions of fossil leaves with dominance of *Alnus gaudinii* (Fig. 8.4, 8.6). Despite the recovery of several dozen leaves (MGPT), the morphological details are not well documented, due to the superposition of many specimens. However, the visible characters are in total agreement with those of isolated leaves recovered from neighbouring sites (Fig. 8.3a, 8.3b). The samples from the silty layer B are more isolated and the assemblage is more diverse (Supplementary File). Given the concomitant occurrence of leaves and fructifications of *Alnus* (Fig. 8.6), the outcrop is important for the "Whole Plant Concept" (Kvaček, 2008) of such taxon. Additional sampling is not required and the outcrop has probably now disappeared.

∑**58**. **Valmanera** – GCTM163 – Martinetto (2003) reported that, in the year 1997, some layers containing fossil leaves were found during the restoration work of the "Villa Paolina" residential complex, which now houses the WWF centre for environmental education. Another large outcrop was later created by an excavation behind a farmhouse, indicated by Martinetto et al. (2023) as "Cascina Ignota". At both outcrops, the whitish, reddish and/or blackish impressions of leaves were very abundant in many blocks deriving from some layers of very fine silty sands, included in the succession of the Asti Sands (Martinetto, 2003). The samples saved from destruction and stored at MPTA and MGPT contain several dozens of fossil leaves, with a prevalence of *Fagus haidingeri* (Fig. 8.7). The leaf impressions show a good detail of veins and leaf margins (Fig. 8.9). The analyses of Martinetto (2003) only concerned the samples from "Villa Paolina", whereas those from "Cascina Ignota" (Supplementary File) are only in small part figured and treated by Martinetto et al. (2023: figs 22, 23) and still await accurate analysis. All the remains of these two outcrops, representing allochthonous assemblages of high diversity, are suitable for physiognomic analysis of the leaves and can prove very useful for assessing the diversity within the local palaeoflora. A survey in the year 2022 showed that both of the outcrops have been covered by buildings and are today totally inaccessible for further sampling.

∑**59**. **Villafranca d'Asti-RDB Quarry** – GCTM156 – This site has been extensively investigated in various publications, especially within the monograph by Carraro (1996). We directly examined material from layers named "R1", "R4", R5low, R7 of the RDB Quarry at Villafranca d'Asti (Martinetto and Mai, 1996), from which oligotypic assemblages of fossil leaves have been sampled (Supplementary File). The sediment is clay and silt referable to a swamp palaeoenvironment (Basilici, 1996). What predominantly differentiates these layers are the dominant plant species: *Taxodium dubium* for the R1 layer and *Alnus gaudinii* for the R4 and R7 layers.

While the R7 layer samples are useful only to establish the characteristics of the local

palaeoflora, those from R1 and R4 layers could be useful for different types of palaeobotanical studies, such as cuticular analysis, reconstruction of CO_2 values and, in this case too, assessment of the local plant community features. Many samples from Villafranca d'Asti – RDB Quarry are stored at MGPT and not yet studied; only a small portion is listed in Supplementary File. Further sampling would require a very high budget and, probably, would not add much information.

∑**60**. **Villafranca d'Asti-Rio Stanavasso** – This site is a natural outcrop along a brook that was not examined in detail in previous publications (Carraro, 1996). The samples represent silty clay deposited in an original swamp environment, in which an oligotypic assemblage of leaves was buried and preserved as compressed fossils (Fig. 10.5a, 10.5b). The current situation of the site is unknown, however, the few samples of compressed leaves already in the collection (MGPT, Supplementary File), coming from the layer called "SV1", suggest that this site has the potentiality to yield interesting material, allowing cuticular analyses, reconstructions of CO_2 values, assessments of local palaeocommunity features.

Other sites of the Southern Sector – ∑61. Bra (Peola, 1895; Martinetto et al., 2023, hundreds of oxidized leaf impressions: Craveri Civic Museum of Bra), ∑62. Carrù-Mondovì (Peola, 1896b, lost material), ∑63. Canale d'Alba (carpological material: CCN), 46. Cascina Rapetto-Rocchetta Tanaro (permineralised leaves and oxidized leaf impressions, unpublished: MPTA), ∑64. Ceresole d'Alba (Ciangherotti et al., 2007, carpological material and a few leaves: CCN, MGPT), ∑65. Cherasco-Stura (Cavallo and Martinetto, 1996, carpological material: MCEA), ∑66. Cortiglione d'Asti (Martinetto, 2015, carpological material: CCN), ∑67. Cortiglione-Serralunga (abundant oxidized leaf impressions, MGPT, MPTA), ∑68. Breolungi and Crava di Morozzo (Martinetto, 2015, carpological material: CCN), ∑69. Ferrere (Allioni collection, Museo Geologico Sperimentale del C.A.I., Giaveno, oxidized leaf impressions), ∑70. Monteu Roero (cited by Günther and Gregor, 1993, scarce carpological material), ∑71. Madonna di Galizia of Benevagienna (Peola, 1896b, lost material), ∑72. Madonna di Mombirone (Martinetto et al., 2023, oxidized leaf impressions: MCEA), ∑73. Monticello-Graveyard (unpublished, carpological material: CCN), ∑74. Pocapaglia (carpological material: see Cavallo and Martinetto, 1996: MCEA); ∑75. Rocche dei Perosini (pine cones, photo G, Accornero: Martinetto et al., 2023), ∑76. San Giacomo di Montaldo Roero (oxidized leaf impressions: MCEA), ∑77. Sezzadio-Rio della Lupa (Martinetto, 2015, carpological material: CCN), ∑78. Valdelserro-Cascina Caretto (oxidized leaf impressions, MGPT unpublished), ∑79. Valle Botto (Martinetto et al., 2023: field notes only, oxidized leaf impressions), ∑80. Valleandona (Martinetto, 2015, carpological material: CCN).

DISCUSSION

Our work contains the first general survey of all the Pliocene plant-bearing localities of the Piemonte region, even if much material still lays, unstudied, in the collections and much more goes destroyed each year due to natural and human causes, without any retrieval of scientific information. Our partial analysis already showed how the simultaneous observation of plant fossils from several sites enabled a better interpretation of those plant remains which were fragmentary or rare at one site, whereas occurred abundantly in another (e.g. *Ocotea heeri*, Figs 7.1c, 7.2, 9.10). It was also shown how some plant parts, usually occurring isolated, were found in association with others, potentially produced by the same mother plant (e.g. *Fagus*, Fig. 6.3, 6.5; *Alnus*, Fig. 8.4, 8.6). Indeed, co-occurrence of leaves, fruits and/or seeds can throw light on the correct taxonomy of less diagnostic parts, thus confirming uncertain determinations. We suggest that extending the analysis to all the available fossil plant samples from the Pliocene of Piemonte would provide even more significant results.

Starting from the analysis of a part of such samples, which were occasionally recovered from several Pliocene sites of the Piemonte region, we tried to achieve a first step in the evaluation of palaeoenvironmental and geoconservation interest of plant macrofossil localities. The location of the sites is roughly reported on maps of three focus-areas ("Sectors") within the Piemonte region. More detailed information, such as coordinates, accessibility, suitability to certain studies, can be found, in relation to each specific site, in Table 1. Examples

of representative fossil assemblages and taxa of each sector are reported in the five Figures (Figs 6–10).

SYSTEMATIC OVERVIEW

This work also contains a first overview of the regional distribution of Pliocene plant taxa represented by fossil leaves in the Piemonte region (Table 2). Even if Martinetto et al. (2023) recently listed the most common taxa documented by leaves in the whole Neogene of the region, a complete systematic list is still not available, and indeed it could be only assembled after the pending revision of the taxa-rich floras of Arboschio-L4 (Pavia, 1970) and Bra (Peola, 1896). The samples analysed in this work allowed us to enumerate 52 taxa, mostly assigned to precise fossil-species (Supplementary File), the most common ones being: *Acer tricuspidatum lusaticum*, *Alnus cecropiifolia*, *Alnus ducalis*, *Alnus gaudinii*, *Daphnogene polymorpha*, *Fagus haidingeri*, *Laurophyllum* sp./spp., *Ocotea heeri*, *Populus latior* and *Taxodium dubium.* Those leaf taxa which were reported in previous papers on Pliocene floras of Piemonte, and are not represented in our samples, do not seem to be numerous (e.g. *Carya minor*, *Hedera* cf. *helix*, *Smilax* sp. and possibly a few others). In addition, only three taxa, uncertainly identified, are reported here for the first time: cf. *Clematis*, cf. *Myrtus* and cf. *Prunus.*

CHARACTERISTICS OF FOSSIL ASSEMBLAGES AND SITES

Thanks to this rather complete overview of the materials recovered from Pliocene sites of Piemonte (even those not listed in Supplementary File) we are able to summarise the analogies and differences of fossil samples from different sites. This information may be useful for a comparison to the fossil assemblages of other basins and for two additional, distinct reasons. On one hand, palaeontologists are often required by the offices of the Ministry of Culture to interpret some illegally collected or possessed samples of fossils, whose site of origin is mostly unreported. On the other hand, palaeontologist can be interested to check the provenance of plant-bearing samples, occasionally recovered by non-specialist people, in order to guarantee their scientific value. Colour, grain, bedding type and cementation of sediments can provide useful clues to differentiate the material. Other indications can be provided by the preservation type (e.g. compression, permineralization, impression), fragmentation, enrolment and density of plant parts. Further characteristics are those that only palaeobotanists can evaluate, i.e. specific taxonomic features of the plant assemblage.

Still, even a careful consideration of all of the specimen characteristics can lead us to conclude that assignment of a dubious sample to a specific Pliocene site of Piemonte is often not an easy task. However, it is feasible in several cases, as detailed below.

The oxidised leaf impressions on fine sandy sediments from Arboschio-L1 can be very similar to indistinguishable from those of Baldichieri-Fornace and Cantarana-Graveyard. The similar fossils from Baldichieri-North can be distinguished on the basis of the mostly fragmentary leaves with poor preservation of venation, approaching the aspect of samples from Castellengo's layer TC20, Madonna di Mombirone (Martinetto et al., 2023: fig. 16) and Valle Botto. Those from Casa Barbarino show similar bad preservation of the leaf impressions, but with peculiar red and black mineral encrustations, that they share with the fossils of Cortiglione-Serralunga. The yellowish silty sediments of Arboschio-L4, Asti-Casina Risso, Castelnuovo Belbo, Gherba, Fubine and Roatto-Cascina Melona-Layer A are very similar, however. Arboschio-L4 is characterised by an outstandingly good preservation of entire, highly diverse leaves, and Fubine by the occurrence of peculiar types (cf. *Clematis*, cf. *Prunus*, Fig. 10.3).

Oligotypic assemblages occur in the last group of sites of the Southern Sector, but also in similar deposits of the NW and NE Sectors (Canton Iuli). Some samples of La Cassa and Stura di Lanzo Fossil Forest are peculiar for the dominance of *Alnus cecropiifolia* (Fig. 6.6), whereas dominance of *Alnus gaudinii* (Fig. 8.6) is shared by Arboschio-L4, Fandaglia-FN2-FN3, Ceresole d'Alba, La Cassa, Levone, Pranzalito, Remondato, Roatto-Cascina Melona-Layer A, Stura di Lanzo Fossil Forest and Villafranca-RDB Quarry-R4. Dominance of *Acer tricuspidatum lusaticum* in silty sediments was seen at Canton Iuli-CC8, Ceresole d'Alba, Fandaglia-FN3, Fiano (Fig. 6.1) and Villafranca-RDB Quarry-R4.

Table 2. List of the taxa represented by fossil leaves in the Pliocene of Piemonte, in alphabetical order. The frequency of taxa is expressed by the following symbols: +, taxa which are frequent in various Pliocene sites of Piemonte; *, taxa whose remains have been found in abundance only at a few localities; o, taxa found in more than three fossil sites, but never frequent; -, rare taxa. *Quercus* cf. *roburoides* C.T. Gaudin is only represented by the specimen of Fig. 1A.

Taxa	Notes and systematic references	Extant/ Fossil taxon	Frequency
Acer campestre L.	Martinetto (2003)	e	-
Acer integerrimum Viv. in Keferstein	Martinetto (2003)	f	o
Acer palaeosaccharinum Štúr	Mentioned in Martinetto et al. (2023)	f	-
Acer tricuspidatum A. Braun in Bronn ssp. *lusaticum* H. Walther	Martinetto (2003)	f	+
Alnus cecropiifolia (Ettings.) W. Berger	Martinetto (2003)	f	+
Alnus ducalis (C.T. Gaudin) Erw. Knobloch	Martinetto (2003)	f	+
Alnus gaudinii (Heer) Erw. Knobloch et Z. Kvaček	Martinetto (2003)	f	+
"Bambusa" lugdunensis Saporta	Martinetto (2003)	f	o
Betula sp.	Only at ∑11. Vauda Canavese	e	o
Berchemia multinervis (A. Braun in Buckl.) Heer	Only at ∑52. Fossano-FO4	f	o
Carpinus betulus L.	Martinetto (2003, 2015)	e	+
Carya minor Saporta	Martinetto (2003)	f	o
Celtis trachytica Ettings.	Martinetto (2003)	f	o
cf. *Clematis* sp.	Only at ∑53. Fubine		-
Cornus cf. *studeri* Heer [cited as *Cornus* cf. *graeffii* (Heer) Hantke]	Mentioned in Martinetto et al. (2023)	f	o
Crataegus sp.	Only at ∑11. Vauda Canavese		-
Cryptomeria rhenana Kilpper	Martinetto (2003)	f	+
cf. *Cunnighamia*	Only at ∑40. Arboschio-L7	e	-
Daphnogene polymorpha (Al. Braun) Ettings.	Martinetto (2003)	f	+
Dombeyopsis lobata Unger	Martinetto (2003)	f	o
Fagus haidingeri Kováts	Denk (2004)	f	+
Glyptostrobus europaeus (Brongn.) Unger	Vassio et al. (2008)	f	+
Hedera sp.	Martinetto (2003)	e	o
Ilex sp.	Martinetto (2003)	e	o
Laurophyllum spp.	Macaluso et al. (2017)	f	+
Laurophyllum pseudoprinceps Weyland et Kilpper	Macaluso et al. (2017)	f	*
Laurus abchasica D.K. Ferguson	Only at ∑52. Fossano-FO4	f	-
Liquidambar europaea A. Braun in Buckl.	Martinetto (2003)	f	o
Magnolia sp.	Mentioned in Martinetto et al. (2023)	e	o
cf. *Myrtus*	Only at ∑40. Arboschio-L7	e	-
Ocotea heeri (C.T. Gaudin) W.R. Müll.	Martinetto (2003)	f	+
"Parrotia" pristina (Ettings.) Štúr	Martinetto (2003)	f	o
Pinus palaeostrobus (Ettingsh.) Heer	Not yet described	f	+
Pinus spp.	Not yet described	e	+
Platanus leucophylla (Unger) Erw. Knobloch	Martinetto (2003)	f	+
Populus balsamoides Goepp.	Not yet described	f	o
Populus latior A. Braun	Martinetto (2003)	f	o
Potamogeton sp.	Not yet described	e	o
cf. *Prunus* sp.	Only at ∑53. Fubine		-
Pterocarya paradisiaca (Unger) Il'inskaja	Martinetto (2003)	f	+
Quercus drymeja Unger	Mentioned in Martinetto et al. (2023)	f	o
Quercus cf. *gigas* Goepp.	Mentioned in Martinetto et al. (2023)	f	o
Quercus kubinyi (Kováts) Czeczott	Martinetto (2003)	f	o
Quercus mediterranea Unger	Mentioned in Martinetto et al. (2023)	f	o
Quercus cf. *praecastaneifolia* Erw. Knobloch	Mentioned in Martinetto et al. (2023)	f	+
Q. cf. *pseudocastanea* Goepp. [distinct from *Q.* cf. *praecastaneifolia*?]	Martinetto (2003)	f	?
Rosa sp.	Not yet described	e	-
Rubus sp.	Martinetto (2003)	e	o
Salix varians Goepp.	Martinetto (2003)	f	*
Sequoia abietina (Brongn.) Erw. Knobloch	Martinetto (2003)	f	+
Smilax sp.	Martinetto (2003)	e	o
Taxodium dubium (C. Presl ex Endl.) A. Braun in Walchner	Martinetto (2003)	f	*
Tetraclinis salicornioides (Unger.) Kvaček	Macaluso et al. (2017)	f	+
"Thuja" saviana (C.T. Gaudin) C.T. Gaudin	Martinetto (2003)	f	+
Trigonobalanopsis rhamnoides (Rossm.) Kvaček et H. Walther	Mentioned in Martinetto et al. (2023)	f	+
cf. *Tsuga*/*Pseudotsuga*	Not yet described	e	+
Ulmus affinis A. Massal.	Martinetto (2003)	f	o
Ulmus sp.	Mentioned in Martinetto et al. (2023)	e	o
cf. Vitaceae	Not yet described	f	-
Zelkova zelkovifolia (Unger) Bůžek et Kotlaba	Martinetto (2003)	f	o

Vastalla is distinguished by the almost unseen abundance of *Ulmus*. Assemblages with dominance of *Taxodium dubium* are only known from Arboschio-L4, Villafranca-RDB Quarry-R1 and Castenuovo Don Bosco. Unique types of assemblages, for the features described in Table 1, are those from Arboschio-L7, Castagnole Monferrato, Castelnuovo Bormida-Lens 7, Cerro Tanaro (very similar to the neighbouring Cascina Rapetto-Rocchetta Tanaro), Cossato-Layer CO2, Crabbia, Fossano-Section A-Layer FO4, Rocca dell'Eremita of Pocapaglia, Valduggia and Varisella.

EVALUATION OF PALAEOBOTANICAL INTEREST

Many Pliocene localities within the Piemonte region proved to preserve a rich palaeobotanical heritage, as we synthetically point out below and in Table 1. We also tried to underline the potential interest of poorly known localities, hoping to encourage further research in this area. The fossil material here newly analysed, mainly consisting of leaf samples, provided complementary information to the abundant palaeofloral data obtained through previous carpological analyses (Martinetto, 1994, 2015; Cavallo and Martinetto, 1996, 2001; Basilici et al., 1997; Macaluso et al., 2018; Martinetto et al., 2018b and references therein). The integrated information on plant fossils showed the consistent potentiality of several sites for further palaeobotanical sampling, hoping that the release of permissions for scientific sampling will soon become less complicated than today. In fact, the offices of the Ministry of Culture should more generally consider that the recovery and deposit of fossils in public collections constitutes an action of ex-situ protection of the palaeontological heritage of the Italian State, that should be encouraged by its officials.

There are a number of still accessible sites that are suitable to highlight the outstanding aspects of the Pliocene plant fossil assemblages of Piemonte. The two sites mentioned in old literature, and no longer exposed, which can hardly be replaced by accessible equivalents are those of Arboschio-L4 (Pavia, 1970) and Bra (Peola, 1899). We do not mean that there are no other lost localities among those considered in this paper. Rather, many of the outcrops that existed at the end of the 20th century have now disappeared (Table 1), thus highlighting the need for appropriate geoconservation actions in the interest of maintaining accessibility to particular Pliocene fossil-bearing deposits. What was meant above is that many lost localities yielded plant fossils that, as for type of preservation, diversity and taxonomy, approach materials that we recently observed in available localities.

We believe, having summarised the strengths and weaknesses of each site we considered, that a few sites seemed to present such interesting palaeobotanical records and favourable situations that they would deserve a candidature as potential geosites for conservation and promotion purposes: Arboschio-L7, Cerro Tanaro, Cossato-Layer CO2, Fossano, Stura di Lanzo Fossil Forest and Valduggia. Both in these, and in other minor sites subjected to human or natural hazards, we suggest that it is nonsense just to look at the repeated loss of potentially interesting palaeobotanical material and information. Instead, greater efforts should be devoted to the retrieval of relevant plant remains, before their irreversible deterioration.

Even if our work did not comprehend detailed palaeobotanical studies, it was able to pinpoint several localities where a multidisciplinary approach could be applied, but also those localities that can be suitable for a more specific kind of studies, such as carpological, cuticular or leaf-physiognomic analysis. In addition, our report of no more accessible sites can be useful to pinpoint those areas where it would be better to be ready for recovery of fossils, in case of natural exposures or new excavations for non-palaeontological purposes. Even for this last purpose, we hope for the usefulness of the results of our study summarised in Table 1, reporting the main features and potentialities of each locality.

ACKNOWLEDGEMENTS

Valuable help for the identification of plant macrofossil specimens was provided by the late Zlatko Kvaček (leaves) and Dieter Hans Mai (carpological remains). We thank Piero Damarco and Alessandra Fassio (Territorial Palaeontological Museum of Asti) for the photographs, materials, practical help and information provided about the sites situated in the Asti area; we thank, for the stratigraphic information they provided, Andrea Irace, Luca Martire (Castelnuovo Belbo area) and Bartolomeo Vigna (Southern Sector). For the instructions provided for the determination of the leaf fossils, we thank Thomas Denk, Hans-Joachim Gregor, Lutz Kunzmann and Vasilis Teodoridis. The

following people provided valuable help to us, when consulting collections: Gualtiero Accornero (Museum of Natural History "Don Bosco"), Flavio Bauducco (Federico Sacco Geological Museum of Fossano), Rino Brancato and Marco Terenzi (Craveri Civic Museum of Bra), Oreste Cavallo and Gianni Repetto (Eusebio Civic Museum of Alba), Luca Lacroce, Ennio Lavè, Annalaura Pistarino (Regional Museum of Natural Sciences of Turin). Heartfelt thanks also to the following former students for having contributed, in the context of their curriculum in Natural Sciences or Geology at the University of Turin, to the organisation and systematic study of plant fossils: Tiziano Argentero, Cecilia Binello and Luca Spallone (Asti area); Alfonso Caputo (NW Sector), Antonella Cilia (Fossano), Milva Milano (Cortiglione d'Asti-Cascina Serralunga) and Valeria Venezia (Cossato). Finally, we are very grateful to the reviewers, Cédric Del Rio and Carlos A. Góis-Marques, for their comments and suggestions, that allowed us to substantially improve the manuscript.

ADDITIONAL INFORMATION

CONFLICT OF INTEREST. The authors have declared that no competing interests exist.

ETHICAL STATEMENT. No ethical statement was reported.

FUNDING. No.

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