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REMAINS OF A SUBTROPICAL HUMID FOREST IN A MESSINIAN EVAPORITE-BEARING SUCCESSION AT GOVONE, NORTHWESTERN ITALY – PRELIMINARY RESULTS

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Abstract: The first results of a multidisciplinary study on the Messinian evaporitic interval of the Govone section (northwestern Italy), subdivided into several sedimentary cycles, are reported here. Primary sulphate evaporites and intercalated shaly deposits, which formed during the Messinian Salinity Crisis, contain well-preserved and taxonomically determinable terrestrial plant remains. Palynomorphs are present continuously all along the analysed succession and among them, pollen is especially abundant and diverse. Additionally, a few fragments of silicified wood (which are rare in the studied area) occurred in layers rich in phytodebris, but their analysis showed poor preservation of anatomy. Carpological remains are not abundant and are strongly altered by diagenesis. Compressed conifer shoots and angiosperm leaves are well-preserved in several layers, one of which yielded a particularly diverse assemblage. The various plant records have been integrated to obtain an initial general idea on the floristic composition of the assemblages and the palaeoenvironment. We hypothesize that a subtropical humid forest may have surrounded the basin, not only during the deposition of shale deposits, but also during the formation of gypsum, generally considered a product of arid climate. Despite the low-resolution sampling strategy for macrofossils, the identification of several relevant plant taxa (*Engelhardia orsbergensis*, *Eurya stigmosa*, *Symplocos casparyi*, *Taiwania* sp.), seems to indicate that the Govone section could provide an interesting glimpse into the composition of the palaeoflora of northern Italy during the deposition of the Messinian evaporites.

Key words: palaeobotany, leaves, carpology, palynology, fossil wood, Messinian Salinity Crisis, Miocene

Introduction

The very peculiar palaeogeographic context of the Piedmont Basin (PB; Text-fig. 1), surrounded to the west and to the south by the Alpine chain, determined an abundant input of terrestrial phytodebris before, during, and after the Messinian Salinity Crisis (MSC), one of the major palaeoceanographic events that affected the entire Mediterranean Basin around 6 Ma (5.97–5.33 Ma; Roveri et al. 2014). In the PB, the sedimentary deposits of the MSC are particularly well exposed in the surroundings of the town of Alba (northwestern Italy; Text-fig. 1). Macroremains (leaves, fruits and seeds) from this area have been described in several

papers (Cavallo et al. 1986, Guglielmetto and Iguera 1994, Martinetto et al. 2000, 2007, Cimino et al. 2016, Martinetto and Macaluso 2018), but an overview of the macroflora was only provided at the scale of whole northern Italy, in the form of tables also reporting palynological remains (Bertini and Martinetto 2008, 2011). From a palaeobotanical point of view, several sites in the PB are still not accurately studied, which is not surprising in view of the abundance of outcrops in the area and of plant remains in several layers.

The establishment of a high-resolution chronostratigraphic framework for the thick Messinian succession of the Alba area (Dela Pierre et al. 2011, Violanti et al. 2013) makes the sampling and analysis of fossil plant assemblages more

intriguing, because the results of such studies provide very precise dating of each plant-bearing locality, described either in the past or in this work. Additionally, the recent cyclostratigraphic refinement of one of the thicker and most continuous sections of the Alba area, the Govone section (Text-fig. 2; Gennari et al. 2020), allows constraining the position of its plant assemblages to a specific part of a precession-driven climatic cycle. The aim of this paper is to describe the preservation and preliminary taxonomic assignments of the plant macro- and microfossils so far observed in particularly interesting stratigraphic positions, including those preserved within the primary evaporites, at Govone. Having at hand this valuable record of the plant cover of the northernmost offshoot of the Mediterranean Basin during the deposition of primary gypsum, we will also discuss its perspective relevance in terms of climatic requirements and vegetation type. The present paper provides a first glimpse into the characteristics of the Govone plant fossils, which we intend to further study in the future by means of more extensive sampling and more detailed analyses (e.g., cuticles).

Geological and stratigraphical context

The Piedmont Basin (PB) is a wedge top basin located at the western termination of the Po Plain Basin, and filled with upper Eocene – Messinian sediments (Text-fig. 1; Mosca et al. 2010). The Messinian deposits are presently exposed on the southern (Alba sector) and northern (Monferrato sector) margins, whereas in the depocentral zones they are buried below Pliocene and Quaternary sediments of the Savigliano and Alessandria Basins (Irace et al. 2009, Dela Pierre et al. 2011). The Messinian sequence starts with a cyclical succession of outer shelf to slope muddy sediments (Marne di Sant'Agata Fossili Formation, MSF, Tortonian-lower Messinian) which, in the upper part, records progressively more restricted conditions, heralding the onset of the MSC (Sturani and Sampò 1973, Lozar et al. 2010, Violanti et al. 2013). The cyclicity of these deposits is given by the rhythmic repetition of shale/marl couplets, which according to Lozar et al. (2010), Natalicchio et al. (2019), Gennari et al. (2020), Sabino et al. (2020), records a precession-driven fluctuation between more humid (shale) and more arid (marl) climate with a periodicity of about 20 kyr. The MSF

are conformably overlain by a thick succession of primary sulphates (Primary Lower Gypsum unit, PLG), comprising a cyclical alternation of gypsum and shale intervals, which record stage 1 of the MSC (5.97–5.60 Ma; Manzi et al. 2013, Roveri et al. 2014). Up to 13 PLG cycles have been observed in the marginal sector of the southern PB (Dela Pierre et al. 2011); towards the distal sectors (i.e., the studied Govone section), the gypsum beds laterally pass into organic-rich shales indicative of poorly oxygenated environment (Sabino et al. 2021). The cyclical stacking pattern of the PLG unit was also assumed by previous authors to be related to the alternation of precession-driven arid (gypsum) and humid (shale) climate changes. Independent data from gypsum fluid inclusions (Natalicchio et al. 2014), inorganic and organic geochemical analyses (Natalicchio et al. 2019, 2022) and from the gypsum palaeobiological content (Dela Pierre et al. 2015, Pellegrino et al. 2021) suggest that the deposition of the PLG unit or its time equivalent deep-water deposits in the PB was influenced by important pulses of fresh water from continental runoff. Such pulses promoted the input of nutrients into the basin, in turn stimulating primary productivity in the water column.

The PLG is overlain by clastic gypsum facies corresponding to the Resedimented Lower Gypsum unit (RLG) deposited during stage 2 of the MSC (MSC acme, 5.60–5.55 Ma; Dela Pierre et al. 2011, Roveri et al. 2014). This unit is floored by an erosional unconformity corresponding to the Messinian erosional surface (Dela Pierre et al. 2011). The RLG unit is overlain by the Conglomerati di Cassano Spinola Formation (CCS), consisting of fluvio-deltaic and lacustrine sediments with Lago Mare molluscs and ostracods in the upper part (Dela Pierre et al. 2011). These terrigenous facies record stage 3 of the MSC (5.55–5.33 Ma; Roveri et al. 2014) and are in turn overlain by Zanclean marine clays and marls (Argille Azzurre Formation), which mark the end of the salinity crisis at 5.33 Ma (Violanti et al. 2011).

Messinian evaporitic deposits in the Govone section

The Govone section (44° 48′ 08″ N, 8° 07′ 03″ E; Text-fig. 1) has a total thickness of 137 m and includes the Messinian pre-evaporitic and the MSC deposits (Dela Pierre et al. 2011, Gennari et al. 2020, Sabino et al. 2020). Messinian deposits start with 35 lithological cycles (Gm1–Gm35) of marl and shale alternations belonging to the MSF from the lithostratigraphic
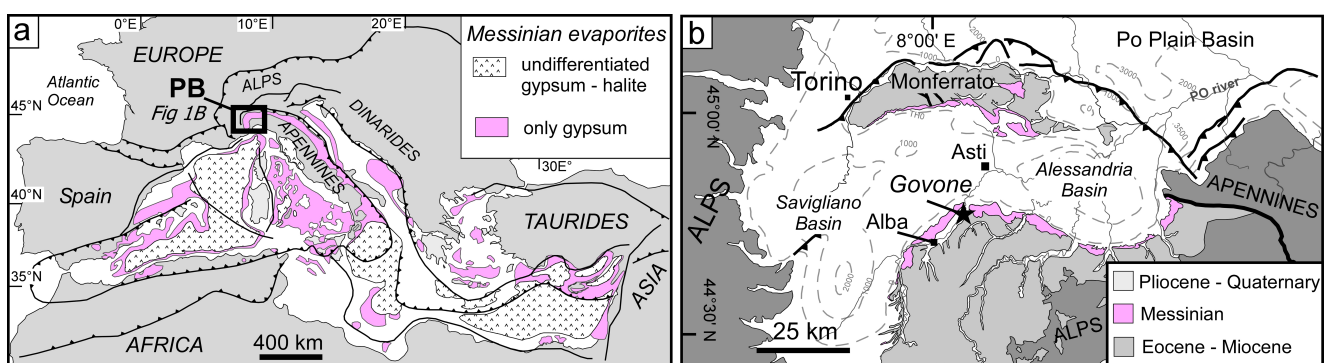
Text-fig. 1. Context and location of the Govone outcrop. a: Location of the Piedmont Basin at the northern margin of the Mediterranean Basin and distribution of Messinian evaporites. b: Simplified geological map of the Piedmont Basin showing the location of the Govone outcrop close to the town of Alba.
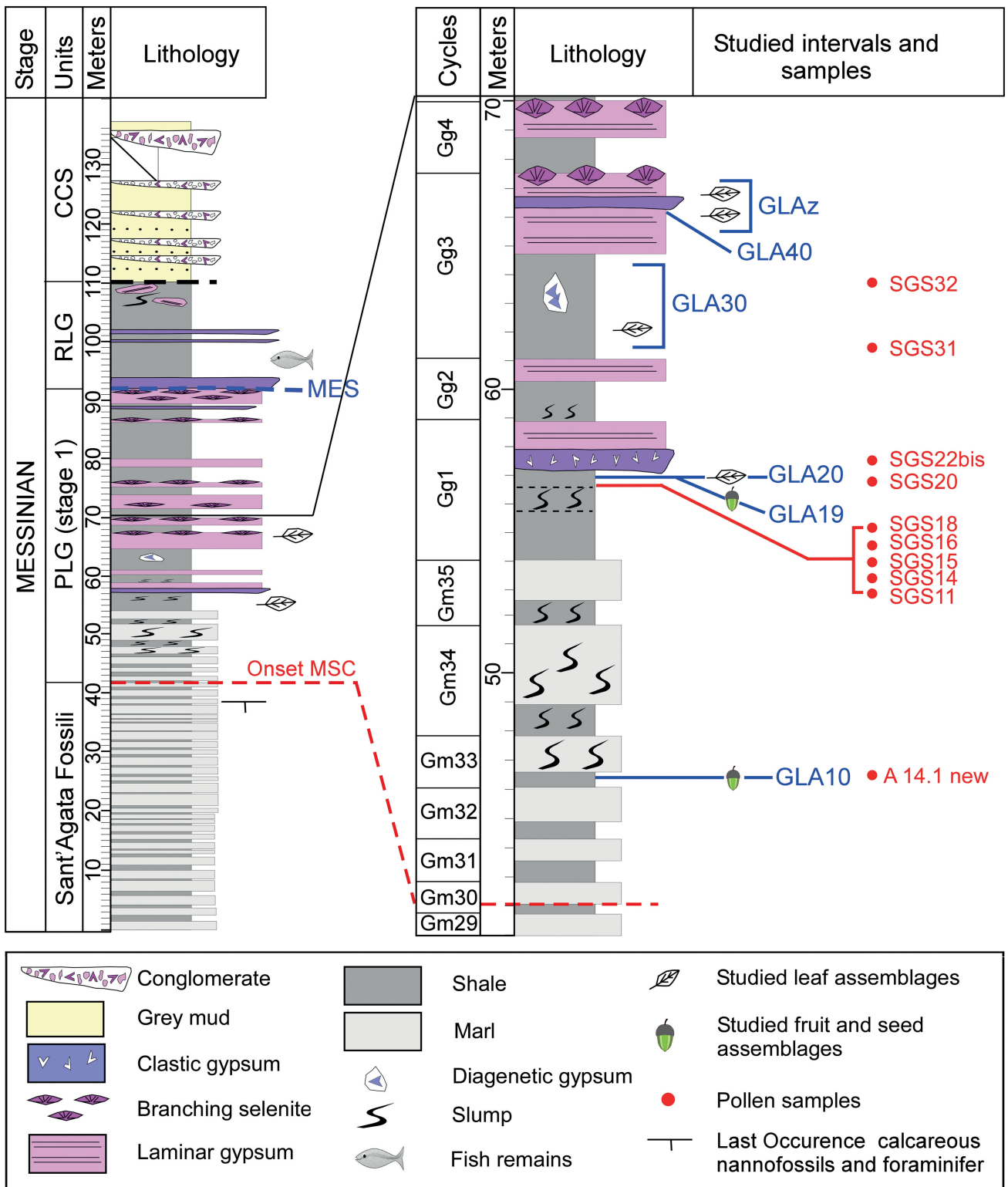
Text-fig. 2. Stratigraphic column of the Govone section with a detail of the sampled intervals on the right. CCS – Cassano Spinola Conglomerates; Gm and Gg – sedimentary cycles, respectively marl-dominated or gypsum-dominated; MES – Messinian Erosional Surface; MSC – Messinian Salinity Crisis; PLG – Primary Lower Gypsum; RLG – Resedimented Lower Gypsum.

point of view (Gennari et al. 2020). Following the age model of Gennari et al. (2020), the onset of the MSC is placed at the base of the marls of cycle Gm30, which corresponds to the onset of gypsum precipitation in other Mediterranean sections (i.e., the base of PLG1 in the Sorbas Basin, Spain; Manzi et al. 2013). The syn-evaporitic portion of the MSF (cycles Gm30–Gm35) represents the deep-water equivalent of gypsum beds deposited at the basin margins. They were deposited in a stratified water column with oxygen-depleted bottom waters (Sabino et al. 2021). In the Govone section, the first gypsum bed (cycle Gg1; Text-fig. 2), corresponding to the PLG7 appears only six lithological cycles above the MSC onset. In total 9 PLG cycles (Gg1–Gg9, only four of them shown in Text-fig. 2) up to 7 m thick have been observed,

and they are characterized by the alternation of organic-rich shales and gypsum layers. The gypsum lithofacies consists of laminar gypsum, which produced by the settling of fine-grained crystals nucleated in the water column, and centimetre- to decimetre-sized cones belonging to the bottom-grown branching selenite facies (Natalicchio et al. 2021). Most of the studied macrofossils and pollen samples derive from parts of cycles Gg1 and Gg3 (Text-fig. 2).

The PLG is overlain by clastic gypsum facies (gypsrudites and gypsarenites) interbedded with fine-grained slumped deposits and organic-rich laminated mudstones. These deposits are equivalent to the RLG deposits of stage 2 of the MSC (Roveri et al. 2014). The uppermost part of the Govone section is made up of fine-grained deposits interbedded with meter-thick beds of clastic evaporites (CCS), deposited in a fluvio-deltaic environment during stage 3 of the MSC (Roveri et al. 2014; Text-fig. 2).

Material and methods

Studied plant macrofossil-bearing intervals

Plant macrofossils were observed in abundance at the Govone outcrop after flooding events of the Tanaro river, yet only a minor part was sampled (73 macroremains from 5 layers). Field surveys were carried out for several years,

starting from 2001, during days in which the water level was low, but the exposed bedding planes were still wet. These conditions were only detected during four years in the last two decades, so that the data reported in the present work were collected during no more than ten days total. Fossils at risk of damage from drying out were removed first, to preserve them from desiccation cracking. Afterwards we removed those fossils that we worried might soon be re-flooded (Martinetto et al. 2018a). The exposed fossil plant remnants, often retaining most of their original organic material, appear to be very well preserved as long as they are saturated with water, but sunlight can destroy them in a few hours in summer (Cimino et al. 2016), whereas in other seasons they last for several days. Freezing in winter is even more destructive than sun in summer. Well-preserved plant remains can be extracted from waterlogged sediments for a long time after floodings, but partially dry sediments provide only damaged and altered fossils, both fragmented and/or covered by gypsum encrustations.

Plant fossils were observed in several layers throughout the outcropping succession (Text-fig. 2). The 20 m of succession (Text-fig. 3a) deposited at the beginning of the MSC contain the highest concentration of terrestrial plant remains, which are more scattered in the pre- and post-evaporitic (Niccolini et al. 2022) deposits, not treated here.

Five stratigraphic intervals of different thickness (Text-fig. 2: the acronym GLA originates from the locality name

Text-fig. 3. a: Panoramic reconstruction of the portion of the Govone outcrop from intervals GLA10 to GLA20 in condition of low river level. b: Transported leaf assemblage in the bottom part of bed GLA20. c: Detail of the outcrop of the leaf-bearing bed GLA20 and the underlying wood-rich layer GLA19.

Text-fig. 4. Laminated silts with almost complete leaves at the top of bed GLA20: *Dicotylophyllum* sp. 3 (left: MGPT-PU141032) and *Laurophyllum* sp. 2 (right: MGPT-PU141082). Scale bar 10 mm.

“Govone Lago Ario” = Ario Lake), have been sampled for their plant macrofossil content (Tab. 1):

• GLA10 is a layer about 80 cm thick, belonging to cycle Gm33, and consists of silty sand with cm-sized lithoclasts and concentration of compressed wood remains, with only the largest ones permineralized in the innermost part; this layer contains, among abundant woody fragments, a few strongly compressed seeds and fruits; the most resistant ones were sieved out of the sediment (sample C3X, sediment volume about 3 dm^3);

• GLA19 belongs to cycle Gg1 and consists of a lenticular layer about 2–10 cm thick, whose lithic part is mainly made up of sands and scattered cm-sized lithoclasts; the abundant organic portion consists of a concentration of compressed, variously-sized wood remains, reaching up to several centimetres. From this layer, we processed a sediment sample to sieve out compressed seeds and fruits (sample D2A, sediment volume about 1 dm^3);

• GLA20 may be considered a composite, about 20 cm thick bed, following directly above GLA19 (cycle Gg1) and consisting of fine-grained bluish-grey sediments. The bottom part (about 3–8 cm) is made up of silt with some sand, rich in chaotically disposed angiosperm leaves (mostly in small to large fragments) and conifer shoots (GLA20bot; Text-fig. 3b); the top part (about 10 cm; Text-fig. 3c) consists of laminated silty marls with mostly almost-complete angiosperm leaves (GLA20top; Text-fig. 4);

• GLA30 is a portion of the organic-rich shales of cycle Gg3 (equivalent to the PLG9), about 4 m thick, framed between the gypsum layers of cycles Gg2 and Gg3;

• GLAz is a laminar gypsum layer of cycle Gg3, about 3 m thick, consisting of mm-sized acicular gypsum crystals dispersed in a muddy matrix (see Pl. 3, Fig. 8); plant remains are scattered, and include angiosperm leaf fragments and a few complete angiosperm leaves and conifer shoots. Samples collected within GLAz, but in the about 1 m thick layer below a white layer of gypsum-arenite, have been labelled GLA40.

Table 1. Abundance of plant macroremains recovered from five layers of the Govone section indicated in Text-fig. 2. The bottom part summarizes the number of specimens and taxa of conifer leaves, shoots and woods, angiosperm leaves and fruit/seeds.

Taxon	part	GLA10	GLA19	GLA20	GLA30	GLAz
Abies	leaf					2
cf. *Acer tricuspidatum*	leaf			1		
Alnus sp. indet.	infructescence					1
Cryptomeria sp.	shoot			1	1	1
Cupressinoxylon	wood	1	1			
Daphnogene polymorpha	leaf				1	
Dicotylophyllum sp. 1	leaf			1		
Dicotylophyllum sp. 2	leaf			1		
Dicotylophyllum sp. 3	leaf			2		
Engelhardia orsbergensis	leaf			6		
Eurya stigmosa	seed	2				
Fagus cf. *gussonii*	leaf			2		2
Glyptostrobus europaeus	shoot			1	1	1
Laurophyllum sp. 1	leaf			2		
Laurophyllum sp. 2	leaf			3		
Liquidambar cf. *europaea*	infructescence		1			
Morella sp.	leaf			1		
cf. *Ocotea heeri*	leaf			3		
Pinaceae	wood		1			
Pinus	cone/brachyblast (b)		1c	1b		2b
Platanus leucophylla	leaf			2		
Pterocarya paradisiaca	leaf			3		
Quercus sp.	leaf			1		
Quercus pseudocastanea/roburoides	leaf			1		
Sequoia abietina	shoot			1		1
Symplocos casparyi	fruit	1				
Taiwania sp.	shoot			1		
Taxodium dubium	shoot			2		
Tetraclinis salicornioides	shoot	2				
"*Thuja*" *saviana*	shoot			1	1	1
Toddalia latisiliquata	seed	1				
Toddalia rhenana	seed	2	1			
Tsuga vel *Pseudotsuga* sp.	leaf			1	2	1
Visnea germanica	fruit	1				
Total fruits/seeds		7	3	0	0	1
Fruit/seed taxa		5	3	0	0	1
Total woods		1	2	0	0	0
Total angiosperm leaves		0	0	29	1	2
Angiosperm leaf taxa		0	0	14	1	1
Total conifer leaves		0	0	1	2	3
Conifer leaf taxa		0	0	1	1	2
Total conifer shoots		2	0	10	3	6
Conifer shoot taxa		1	0	7	3	5
TOTAL specimens		**10**	**5**	**40**	**6**	**12**
TOTAL taxa		**6**	**5**	**22**	**5**	**9**

Macrofossil preparation and analysis

A part of the specimens we studied were only photographed in the field, but not collected. Several leaves were photographed in the field and designated by a code, reported on a small resealable plastic bag, into which we put a portion of the compressed leaf lamina, kept in a solution of Polyethylene glycol 4000. The macroscopic leaf specimens were immediately prepared in the field by spraying a consolidating product on it, either vinyl glue or cyanoacrylate. The best results were obtained by spraying the wet sediment sample with the compressed leaf on it 5–10 times, during about 30 minutes, in hot and sunny conditions. Slower drying was found to favor a detrimental encrustation by gypsum. Most of the recovered samples are stored at the Museum of Geology and Palaeontology of Turin University (acronym MGPT-PU). A few others, figured by Cimino et al. (2016) are presently hosted at the Territorial Palaeontological Museum of Asti (acronym MPTA).

A macromorphological and, when necessary, stereo-microscope analysis (×40) was carried out for all carpological remains from bulk samples (GLA10 and GLA19) and most leaf remains, in order to verify the state of preservation (see below), and to detect characters useful for their taxonomic assignment. The identification of relevant plant remains detected on sediment slabs or in the residue of the bulk samples was carried out by consulting the extensive literature on similar fossils (e.g., for Italy: Martinetto 1998, 2003, 2015, Fisher and Butzmann 2000, Teodoridis et al. 2015a, b, 2017; for the whole Europe: Mai and Walther 1988, 1991, Barrón and Diéguez 2001, Kvaček et al. 2002, 2020, Denk 2004, Kunzmann and Mai 2005, Güner et al. 2017, Zidianakis et al. 2020), and by direct comparison with reference fossil and extant specimens. Fruits and seeds were compared to fossils stored in the CENOFITA collection (Martinetto and Vassio 2010) and extant reference material of the Modern Carpological Collection of the Turin University (Martinetto et al. 2014). The descriptions of taxa based on leaves are restricted to the specimens figured on the plates. Currently, taxonomical assignment of the leaves is based on gross morphology only, but cuticular studies are in preparation. Descriptive terminology is based on the Manual of leaf architecture (Ellis et al. 2009). Length × width (l × w) and l/w ratio are provided. In the cases of incomplete leaves, measurements refer to full size estimation. Angles of secondary veins are provided as narrow (prevailingly <45°), moderate (prevailingly 30–60°) or wide (prevailingly >50°).

The permineralized wood samples were prepared according to a standard technique for the study of the palaeo-xylotomical features with thin-slide preparation (transverse, radial and tangential sections). IAWA terminology for softwood (IAWA Committee 2004) together with Esteban et al. (2004) have been used for the anatomical study of the fossil wood samples. Microscopic observations were made with a Leica© DM 5500 light microscope, equipped with a Leica© digital camera (DFC 480).

Preservation of plant macrofossils

Stereomicroscope analysis (×40) of conifer shoot remains allowed to see cell patterns and differences in color and luster (Text-fig. 5a), which suggest the presence of the cuticle, at least in several specimens. Several angiosperm leaf fragments, collected from bed GLA20 prior to chemical treatment and drying, showed well-preserved cuticles in transmitted light (×40), e.g., MGPT-PU141017, often still accompanied by compressed remains of the mesophyll (Text-fig. 5b). Observations in strong reflected light (×40) allowed observation of cuticle remains in several other angiosperm leaf samples, including those which seem having lost the
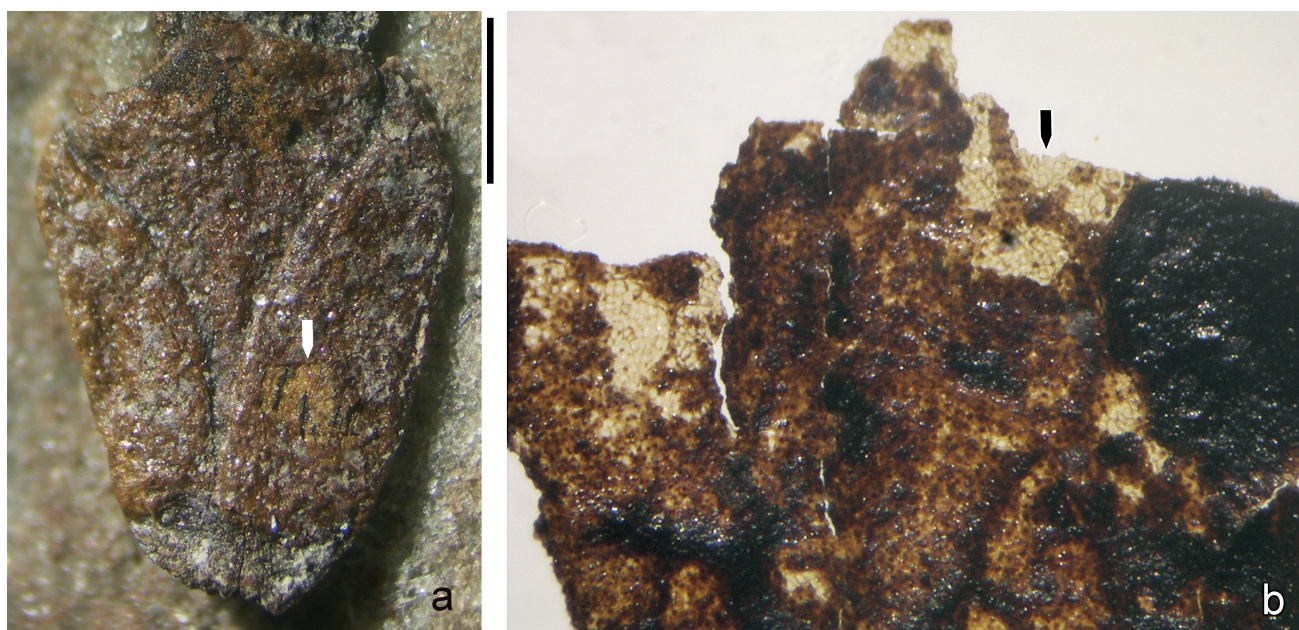
Text-fig. 5. Plant fragments from Govone with evidence of preserved cuticle. a: Decussate pair of leaves of "*Thuja*" *saviana* (C.T.GAUDIN) C.T.GAUDIN with a window (arrow) opened in the brownish cuticle, showing the yellowish mesophyll cells and some possible resin canals (dark), MGPT-PU141094. b: Angiosperm leaf fragment (from sample MGPT-PU141017) under the stereo-microscope, showing the blackish compressed mesophyll on the right and patches of cleaned, yellowish cuticle at the top (arrow). Scale bar 1 mm.
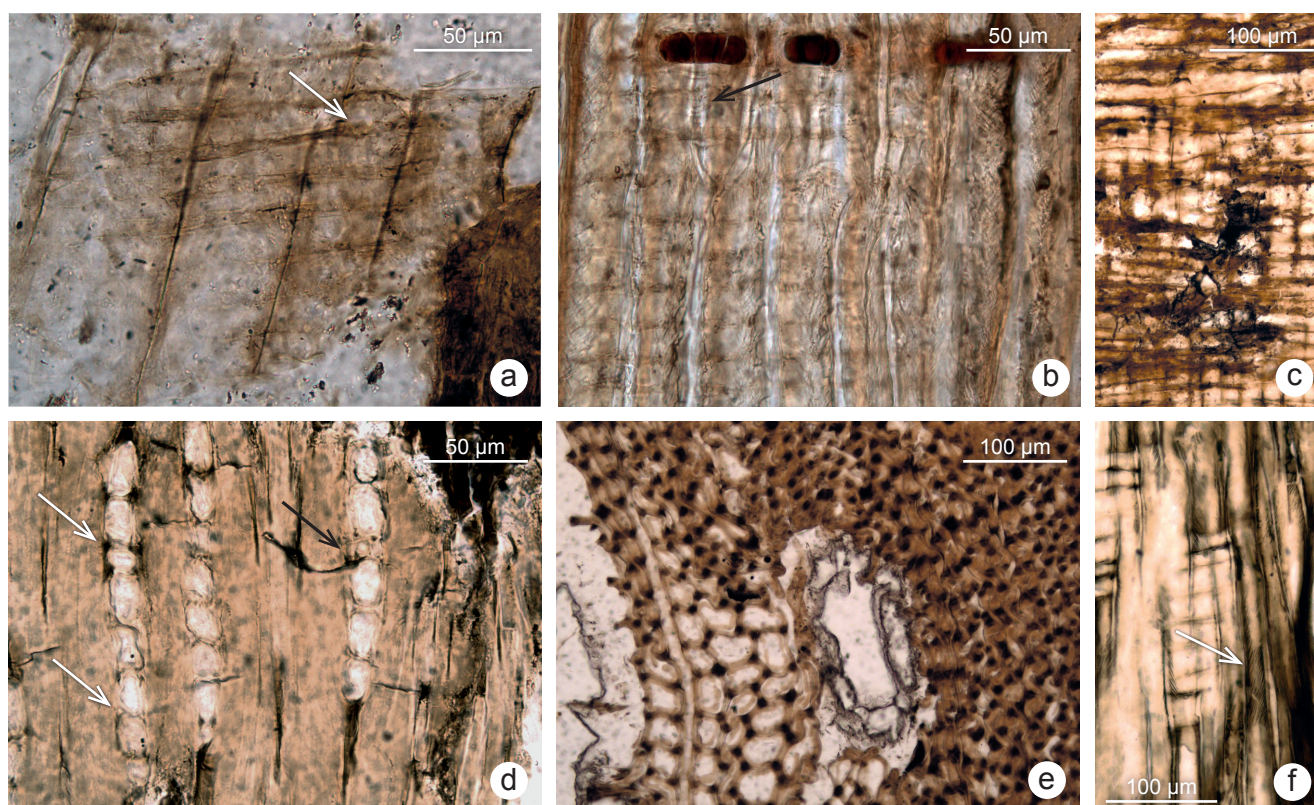
Text-fig. 6. Transmitted light microphotographs of permineralized wood from Govone. a, b: cf. *Cupressinoxylon* sp., radial section, MGPT-PU141105, a – nodular end of ray parenchyma (arrow), b – thick and pitted horizontal walls of ray parenchyma (arrow). c–f: Pinaceae gen. et sp. indet., MGPT-PU141107, c – abnormal discoloration due to ecological disruptions (radial section), d – rays up to 10 cells high, uniseriate, partly biseriate (black arrow), intercellular spaces observed (white arrows) (tangential section), e – large, thick-walled axial resin canal with more than 9 epithelial cells observed, axial resin canal diameter >60 μm (transverse section), f – spiral thickenings due to compression (white arrow) (radial section).

mesophyll during a sort of natural maceration (MGPT-PU141031, MGPT-PU141032).

The first analyses of three permineralized wood samples showed that the preservation of anatomical structures was limited (Text-fig. 6), and the diagnostic characters for a detailed taxonomic assignment have been altered or erased.

The analysis of sediment bulk samples from layers GLA10 (C3X) and GLA19 (D2A), prepared for carpological analyses, showed that the strongly compressed fruits and seeds cannot be concentrated through flotation. An infructescence found in GLA19 (Pl. 3, Fig. 3) was so brittle that any attempt to isolate it from the sediment would have resulted in complete destruction. A few more robust seeds (e.g., Text-fig. 7) survived the sieving operations, even though compressed and fragmented. Nevertheless, the recovered fruit and seed assemblages are biased by a very selective preservation of the specimens.

Studied pollen samples

Palynological investigations have already been performed throughout the 137 m thick Govone section shown in Text-fig. 2, in the frame of a PRIN program and Florence University Grants. Publications are in progress for the older part of the succession, whereas the youngest part is treated by Niccolini et al. (2022). Here, only ten samples from the middle part of the section were selected (Tab. 2) to cover the same stratigraphical interval which yielded plant macrofossils, except for GLAz.

The palynological samples were submitted to a standard chemical-physical procedure at the Palynological Laboratory of the Department of Earth Sciences, University of Florence. Dry samples were first weighed, and *Lycopodium* tablets were added to each sample to provide palynomorph concentrations. The procedure included treatments with HCl (20%), HF (40%), sodium hexametaphosphate, KOH (10%) and $ZnCl_2$ separation (solution density ca. 2.0). Residues were sieved at 10 μm and mounted using glycerol. Mobile slides ensure a more accurate morphological identification than the fixed ones. Palynological analyses were performed using an optical microscope at 750× and 1,250× magnifications. The pollen floral list (Tab. 2) is based on a total of 6,212 pollen grains.

Preliminary identifications of the fossil plant remains

The arrangement of conifer taxa follows Christenhusz et al. (2011), whereas that of angiosperms follows the system introduced by the Angiosperm Phylogeny Group IV (APG IV 2016). Only those pollen taxa are treated here (complete list in Table 2) that may have been produced by plants also documented by macroscopic remains, with the intention to approximate the whole-plant concept (Kvaček 2008,

Table 2. List of pollen taxa detected in the stratigraphic interval of the Govone section in which plant macrofossils have been studied.

Taxa	Palynological samples									
	A 14,1 new	SGS11	SGS14	SGS15	SGS16	SGS18	SGS20	SGS 22bis	SGS31	SGS32
Ephedra fragilis-type				X					X	
Cupressoideae		X	X					X	X	X
Juniperus-type				X					X	X
?Cunninghamioideae	X	X	X	X	X	X	X	X	X	X
Sequoia-type	X	X	X	X	X	X	X	X		X
Taxodioideae/Sequoioideae	X	X	X	X	X	X	X	X	X	X
Taxodium/Glyptostrobus-type	X	X	X	X	X	X	X	X	X	X
Sciadopitys	X	X	X	X					X	X
cf. *Taxus*		X	X							
Pinus haploxylon-type	X	X	X	X	X	X	X	X	X	X
Pinus diploxylon-type	X	X	X	X	X	X	X	X	X	X
Picea	X	X	X	X	X	X	X	X	X	X
Abies	X	X	X	X	X	X	X	X	X	X
Cedrus	X	X	X	X	X	X	X	X	X	X
Tsuga canadensis-type	X	X	X	X	X	X	X	X	X	X
Tsuga diversifolia-type	X	X	X	X	X	X	X	X	X	X
Pinaceae indet. (saccate)									X	
cf. *Cathaya*	X			X	X	X	X	X	X	
Betula	X	X	X	X	X	X	X	X	X	X
Corylus									X	
Carpinus betulus-type	X				X					
Carpinus orientalis-type	X	X	X	X	X	X	X	X	X	
Ostrya							X			
Alnus	X	X	X	X	X	X	X	X	X	X
Fagaceae							X			
Quercus	X	X	X	X	X	X	X	X	X	X
Quercus ilex/coccifera-type		X	X				X			X
Fagus	X	X	X	X	X	X	X	X	X	X
Castanea		X	X		X		X			
Ulmus	X			X			X	X	X	X
Zelkova	X			X	X	X	X	X		X
Acer	X	X	X			X	X			
Carya	X	X	X	X	X	X	X	X	X	X
Pterocarya		X	X	X			X	X	X	
Engelhardia	X	X	X	X	X	X	X	X	X	X
Juglans		X	X	X		X	X	X	X	X
Parrotia										X
Liquidambar	X						X		X	X
Tilia		X	X	X					X	
cf. *Craigia*	X									
Rhus								X		
Ilex				X			X		X	
Buxus		X	X		X		X			
Arecaceae									X	
Magnoliaceae									X	
Moraceae									X	
Morella/Myrica		X	X	X			X	X		
Nyssa	X	X	X	X	X		X	X		
Rutaceae				X						
cf. Sapotaceae							X			
Saxifragaceae						X				

Table 2. continued

Taxa	A 14,1 new	SGS11	SGS14	SGS15	SGS16	SGS18	SGS20	SGS 22bis	SGS31	SGS32
							Palynological samples			
Hedera							X			
Caryophyllaceae				X			X			
Amaranthaceae				X		X	X			X
Artemisia				X			X			X
Asteraceae Asteroideae				X	X	X	X		X	
Asteraceae Cichorioideae		X	X						X	
Brassicaceae						X				
Knautia						X				
Ericaceae					X		X		X	
Geranium									X	
Poaceae	X	X	X	X				X	X	
Lygeum				X						
Plantago									X	
Rumex						X				
Ranunculaceae		X	X							
Neurada									X	
Rosaceae		X	X							
Galium									X	
Apiaceae				X						
Typha latifolia-type						X			X	
	GLA10	1–50 cm below GLA 19					GLA 20		GLA 30	
	Corresponding plant macrofossil bearing layers									

Martinetto and Macaluso 2018, Niccolini et al. 2022). Open nomenclature (cf., sp.) is used according to Bengtson (1988) ("indet." is only used for taxa above the rank of genus).

Clade Coniferales

Coniferales gen. et sp. indet.
Pl. 2, Fig. 6

M a t e r i a l . A single specimen from GLAz (MGPT-PU141015).

D e s c r i p t i o n . Apical fragment of a thick needle-leaf with acute apex.

R e m a r k s . The acute apex differs from those of *Abies* MILL., *Tsuga* (ENDL.) CARRIÈRE, *Nothotsuga* HU ex C.N.PAGE and *Pseudotsuga* CARRIÈRE, and the width is larger than in *Pinus* L. needles. The longitudinal ridge on the adaxial side of the leaf could be compatible with *Sequoia* ENDL. or with some Pinaceae, e.g., *Picea* LINK or Taxaceae. More accurate analyses are needed, e.g., cuticle.

Order Pinales GOROZH., 1895
Family Cupressaceae GRAY, 1822 nom. cons., sensu Farjon 2005
Subfamily Taiwanioideae QUINN, 2000

Genus *Taiwania* HAYATA, 1906

Taiwania sp.
Pl. 1, Fig. 1

M a t e r i a l . A single shoot from GLA20 (MGPT-PU141001).

D e s c r i p t i o n . A leafy shoot, leaves helically arranged, falcate, slightly hook-shaped, with broad basis attached to the axis, apex acute.

R e m a r k s . The leaves are particularly short, similar to those of *Taiwania* described by Fischer and Butzmann (2000) from the Pliocene of central Italy. The occurrence of other specimens in the Messinian of Italy was already reported by Teodoridis et al. (2015b).

Subfamily Cunninghamioideae QUINN, 2000

?Cunninghamioideae gen. et. sp. indet.
Pl. 5, Fig. 21

M a t e r i a l . Pollen grains of ?Cunninghamioideae occur in all the analysed samples, usually in high quantity.

R e m a r k s . Formerly, Cunninghamioideae were included in Taxodiaceae, e.g., Page (1990). After a taxonomic reassessment (Gadek et al. 2000, Farjon 2005), Cunninghamioideae and Taxodioideae are considered subfamilies of Cupressaceae. Pollen of *Cunninghamia* SCHREB. has been reported, e.g., from the Middle Miocene deposits of Lavanttal (Austria; Grímsson and Zetter 2011), from Neogene deposits of Georgia (Transcaucasia) (Shatilova et al. 2018). Macroremains have been described from the late Oligocene to Pliocene of Central Europe (Kovar 1982, Walther 1989, 1999, Mai and Walther 1991), as well as from the Middle and Late Miocene of Romania (Givulescu 1975). Light microscope studies of *Cunninghamia* pollen morphology were carried out by Jimbo (1933), Wodehouse (1935), Erdtman (1943,

1957), Ueno (1951), Van Campo-Duplan (1951); recently, Bouchal and Denk (2020) extensively described the pollen morphology of *C. lanceolata* (Lamb.) Hook. under both the optical microscope and SEM. The abundant pollen grains from Govone do not show diagnostic features under the light microscope, despite having a morphology quite comparable to Cunninghamioideae. For an unquestionable attribution to this taxon, a SEM morphological study would be necessary, as recommended by Bouchal and Denk (2020).

Subfamily Taxodioideae Endl. ex K.Koch, 1873 and Sequoioideae Quinn, 2000

Taxodioideae/Sequoioideae undifferentiated
Pl. 5, Fig. 13

M a t e r i a l . Pollen grains of Taxodioideae/Sequoioideae undiff. are abundant and present in all samples.

R e m a r k s . These pollen grains are well preserved, but under light microscope their morphology does not allow an unequivocal discrimination among taxa belonging to Taxodioioideae or Sequoioideae (Bouchal and Denk 2020).

Subfamily Sequoioideae Quinn, 2000

?Genus *Sequoia* Endl., 1847

Sequoia-type
Pl. 5, Fig. 8

M a t e r i a l . *Sequoia*-type pollen grains are frequent.

R e m a r k s . The pollen grains are well preserved. They are much more abundant here than in the post-evaporitic sediments (Niccolini et al. 2022). The description of Bouchal and Denk (2020) was followed for determination. The presence of *Sequoia abietina* (Brongn.) Erw.Knobloch supports this assignment (see below).

Genus *Sequoia* Endl., 1847

Sequoia abietina (Brongn.) Erw.Knobloch, 1964
Pl. 1, Fig. 2

M a t e r i a l . A leafy shoot from GLAz, a fragment of which is preserved in MGPT-PU (MGPT-PU141002). Another very fragmentary shoot from GLA20 (MGPT-PU141090).

R e m a r k s . The best specimen with typical characters was photographed in the field, and soon after was damaged by water from the Tanaro river. It differs from *Taxodium* by the curved instead of straight outline of the leafy shoot, and leaves closely adhering to the axis or just slightly protruding. The occurrence of *Quasisequoia couttsiae* (Heer) L.Kunzmann is unlikely because it has never been reported from the Italian Neogene, otherwise it would be difficult to assign fragmentary leafy shoots to either species.

Subfamily Taxodioideae Endl. ex K.Koch, 1873

Genus *Cryptomeria* D.Don, 1838

Cryptomeria sp.
Pl. 1, Figs 3a, b, 5

M a t e r i a l . Two leafy shoots from GLAz (MGPT-PU141003, MGPT-PU141004) and two others from GLA20 (MGPT-PU141091, MGPT-PU141092).

R e m a r k s . The leaves are narrower than those of *Taiwania* and the shoot does not bear the delicate and short scaly leaves of *Glyptostrobus europaeus* (Brongn.) Unger. The same kind of foliage is associated in a few Pliocene sites, e.g., Ca' Viettone (Bertoldi and Martinetto 1995) and Momello-Lanzo (Martinetto 1998), with globose cones very similar to those of the extant *Cryptomeria japonica* D.Don.

Genus *Glyptostrobus* Endl., 1847

Glyptostrobus europaeus (Brongn.) Unger, 1850
Pl. 1, Figs 4, 6a

M a t e r i a l . A leafy shoot with one cone from GLAz (photograph) and a small shoot from GLA20 (MGPT-PU141005a).

R e m a r k s . The pyriform cone is diagnostic of *Glyptostrobus*. The sterile leafy shoots have more delicate and short scaly leaves compared to *Cryptomeria* and *Taiwania*.

Genus *Taxodium* Rich., 1810 vel *Glyptostrobus* Endl., 1847

Taxodium/*Glyptostrobus*-type
Pl. 5, Fig. 12

M a t e r i a l . *Taxodium*/*Glyptostrobus*-type pollen grains are very abundant.

R e m a r k s . Although the pollen morphology of both *Taxodium* and *Glyptostrobus* has been accurately described (e.g., Bouchal and Denk 2020) it is still very difficult to distinguish *Taxodium* from *Glyptostrobus* under the optical microscope. Both taxa (and their abundances) are, however, indicative of swamp environment. Among the macroremains, the former is represented by *T. dubium* (Sternb.) Heer and the latter by *G. europaeus* (Brongn.) Unger (see below).

Genus *Taxodium* Rich., 1810

Taxodium dubium (Sternb.) Heer, 1853
Pl. 1, Figs 6c, 7

M a t e r i a l . Two leafy shoots from GLA20 (MGPT-PU141005c, MGPT-PU141006).

D e s c r i p t i o n . In the longer shoot, the helically arranged leaves are slightly curved along their longitudinal axes. They have only slightly narrowing but decurrent bases, typical for fragments of leading shoots. By contrast, the shorter shoot fragment (Pl. 1, Fig. 7) shows leaves in two ranks at the shoot, which are more contracted, twisted and petiolate.

Subfamily Cupressoideae Sweet, 1826

Cupressoideae gen. et sp. indet. and *Juniperus* L.-type
Pl. 5, Fig. 16

M a t e r i a l . Few Cupressoideae pollen grains were found in five samples (Tab. 2).

R e m a r k s . Cupressoideae are very uncommon unlike the post-evaporitic phase (Niccolini et al. 2022). The presence of the *Juniperus*-type is also observed. However, it is very difficult to identify to the species or even genus level (Van Campo-Duplan 1953, Kurmann 1994).

Fossil-genus ?*Cupressinoxylon* Göpp., 1850 emend. Dolezych 2005

cf. *Cupressinoxylon* sp.
Text-fig. 6a, b

M a t e r i a l . Fossil wood specimen MGPT-PU141105 (Repository: MGPT-PU), small part of MGPT-PU141105 specimen and 3 slides. Specimen MGPT-PU141106 collected by P. Damarco (Repository: MGPT-PU), small part of MGPT-PU141106 specimen and 3 slides.

M a c r o s c o p i c d e s c r i p t i o n . The slides MGPT-PU141105 come from a permineralized woody axis of variable color, mostly from very dark (blackish) to light grey; approximate dimensions in cm: 150 × 60 × 30. The longer axis was in a horizontal position, still in situ within the plant-rich bed GLA10. The slides MGPT-PU141106 come from a permineralized wood sample, mostly of brownish-grey to light grey color; approximate dimensions in cm: 30 × 10 × 5. The sampling place was indicated in the area where the plant-rich bed GLA19 crops out.

M i c r o s c o p i c d e s c r i p t i o n . Transverse section: Distinct growth ring boundaries, axial tracheids of polygonal to roundish section. Axial parenchyma observed.

Tangential section: not observed due to poor preservation.

Radial section: Absence of ray tracheids, bordered pits (tracheid pitting in radial walls) not observed, cross field pits not observed, nodular end and thick (and possibly pitted) horizontal walls of ray parenchyma.

R e m a r k s . Although the anatomical characters are not sufficient for a detailed identification, the absence of resin canals excludes Pinaceae, while the presence of nodular end and thick (and possibly pitted) horizontal walls of ray parenchyma cannot be found in the former Taxodiaceae; rather, they can be found in the Cupressoideae. For the observed – relatively small – roundish tracheids and the absence of radial (and axial – even traumatic) resin canals this wood can possibly be assigned to *Cupressinoxylon* as emended by Dolezych (2005), on the basis of the description by Göppert (1850). The absence of callitroid thickenings excludes *Callitrixylon* Privé, the presence of circular tracheids observed is not related to taxonomy, but to ecology, therefore *Tetraclinoxylon* Grambast is also excluded. The co-occurrence of nodular end and thick (and possibly pitted) horizontal walls of ray parenchyma is not found in *Widdringtonioxylon* Greguss, *Libocedroxylon* Chudajb., *Thujoxylon* (Unger) Hartig and *Chamaecyparioxylon* Chudajb. *Palaeocallitroxylon* Greguss is regarded as a junior synonym of *Juniperoxylon* Houlbert. The latter genus could represent our fossil, judging from the co-occurrence of nodular end and thick (and possibly pitted) horizontal walls, but its nomenclatural priority is a matter of discussion (Philippe and Bamford 2009). In our case unfortunately, the tangential section does not provide a view on the pitting of the cross walls of ray cells, which is crucial, and should be scalariform in case of this genus (Gothan 1905).

Botanical affinities. Specific genera in Cupressaceae s. l. (Román-Jordán et al. 2017) have nodular end, and thick and pitted horizontal walls of ray parenchyma: *Diselma*

Text-fig. 7. Stereomicroscope microphotographs of plant remains sieved out of a sediment bulk sample (C3X) from bed GLA10 of Govone. a: *Tetraclinis salicornioides* (Unger) Kvaček, shoot fragment, MGPT-PU141083). b: *Toddalia latisiliquata* (R.Ludw.) H.-J. Gregor, seed, MGPT-PU141084. c: *Toddalia rhenana* H.-J.Gregor, seed, MGPT-PU141085. d: *Eurya stigmosa* (R.Ludw.) Mai, small seed with piths filled by organic remains and sediment, MGPT-PU141086. e: *Eurya stigmosa* (R.Ludw.) Mai, fragmentary seed, MGPT-PU141087. f: *Visnea germanica* Menzel, fruit from two opposite sides, MGPT-PU141088. g: *Symplocos casparyi* R.Ludw., endocarp in lateral view from two opposite sides, MGPT-PU141089. Scale bar 1 mm.

HOOK.F., *Fitzroya* HOOK.F. ex LINDL., *Calocedrus* KURZ, *Chamaecyparis* SPACH, *Hesperocyparis* BARTEL et R.A.PRICE, *Cunninghamia*. The poor preservation of the here-described wood does not allow us to suggest a relationship to an extant genus.

Genus *Tetraclinis* MAST., 1893

Tetraclinis salicornioides (UNGER) KVAČEK, 1989
Text-fig. 7a

M a t e r i a l . Two shoot fragments from layer GLA10 (MGPT-PU141083).

D e s c r i p t i o n . Fragments of plagiotropic leafy shoots with dimorphic scale leaves in whorls of four, with shallow longitudinal furrows on the broad facial leaves. Lateral leaves narrow and indistinct at the base.

R e m a r k s . Comparable and more abundant shoot fragments in association with cones are reported from the post-evaporitic Messinian of a neighbouring locality (Niccolini et al. 2022).

Genus ?*Thuja* L., 1753

"*Thuja*" *saviana* (C.T.GAUDIN) C.T.GAUDIN, 1859
Text-fig. 5a, Pl. 1, Figs 8, 9

M a t e r i a l . Two leafy shoots from GLAz (MGPT-PU141007, MGPT-PU141008), one from GLA20 (MGPT-PU141093) and another from GLA30 (MGPT-PU141094).

D e s c r i p t i o n . Plagiotropic leafy shoots with dimorphic decussate scale leaves, with broad facial leaves and lateral ones usually not touching each other at the base.

R e m a r k s . The shoots seem to be identical to the Miocene shoots from central Italy on which Gaudin and Strozzi (1859) based their fossil-species *Thuja saviana*. However, the general picture is complicated by the association of such shoots in the type locality (Gaudin and Strozzi 1859: pl. 1), and in a Spanish site (Barron and Diéguez 2001) with cones that may belong to *Calocedrus*. Therefore, it is suspected but not proved, that the type of *T. saviana* may belong to *Calocedrus* (see also Kvaček et al. 2020 for the fossil record in Europe), a hypothesis further supported by the fact that cones with diagnostic characters for *Thuja* have never been reported for the Neogene of Italy. Their rather typical morphology suggests applying a name which is precise and in the meantime indicates the ambiguous generic placement (i.e., not Cupressaceae gen. et sp. indet., but cf. *Thuja saviana* or "*Thuja*" *saviana*).

The shoots of "*Thuja*" *saviana* are similar to another common type of shoot found in the Italian Messinian, which has lateral leaves touching each other at the base (Guglielmetto and Iguera 1994), and has been assigned to *Chamaecyparis* sp. (Teodoridis et al. 2015a, b). This identification receives support from the occurrence of *Chamaecyparis* cones and seeds in the Italian Neogene (but only in Pliocene sites; e.g., Martinetto et al. 2018b), even if they have not yet been described in detail. We hope that future cuticular studies will permit a more definite generic assignment of both types of shoots.

Family Pinaceae SPRENG. ex F.RUDOLPHI, 1830 nom. cons.

Pinaceae gen. et sp. indet.
Text-fig. 6c–f

M a t e r i a l . Fossil wood specimen MGPT-PU141107, in part permineralized, collected by P. Damarco (Repository: MGPT-PU), small part of MGPT-PU141107 specimen and 3 slides. The sampling place was indicated in the area where the plant-rich bed GLA19 crops out. The presence of permineralized wood within this bed was recently verified by the first author.

M a c r o s c o p i c d e s c r i p t i o n . The slides come from a permineralized wood fragment of very variable greyish color; approximate dimensions in cm: 15 × 10 × 5.

M i c r o s c o p i c d e s c r i p t i o n . Transverse section: Distinct growth ring boundaries, axial tracheids of polygonal section. Axial parenchyma observed. Large, thick-walled axial resin canal (normal or traumatic?) with more than 9 epithelial cells observed.

Axial resin canal diameter >60 μm. Intercellular spaces observed. Tangential section: Rays 1–10 cells high, uniseriate, partly bi-seriate. Intercellular spaces observed.

Radial section: Absence of ray tracheids, bordered pits (tracheid pitting in radial walls) not observed, cross field pits not observed, smooth (and possibly pitted) horizontal walls of ray parenchyma. Spiral thickenings observed.

B o t a n i c a l a f f i n i t i e s . The observation of resin canals in transverse section is of taxonomic importance. According to Esteban et al. (2004), this type of axial thick-walled resin canal with a diameter >60 μm and more than 9 epithelial cells can be found in *Pinus caribaea* MORELET, *Picea orientalis* (L.) PETERM., *Picea likiangensis* (FRANCH.) E.PRITZ., *Larix occidentalis* NUTT. (also in *Keteleeria* CARRIÈRE, although the size of the resin canals does not match with the ones referred to this genus, but this difference in size could be also assigned to ecological/environmental conditions). If the occurrence of the resin canals were of traumatic origin, the taxonomic selection would be wider, including also *Abies* MILL., *Tsuga* (ENDL.) CARRIÈRE and *Sequoia sempervirens* ENDL. (IAWA Committee 2004).

R e m a r k s . In coniferous woods, three types of axial parenchyma are found (a) marginal, (b) fusiform (Noshiro and Fujii 1994) and (c) the one related to the epithelial cells surrounding the resin canals (Hacke et al. 2015), as discussed also in Dolezych et al. (2021). Kuroda (1986) refers to the epithelial cells as "septated cells", while the term used for the same character in Mesozoic fossil woods is "septate tracheids" (e.g., Philippe 1993, Iamandei et al. 2005). Lin et al. (2002) described the structure of resin canals, stating that the epithelium surrounding the canals consists of parenchyma cells, and that the outer parenchyma cells surrounding the epithelium can be partly parenchymatous and partly tracheary or completely tracheary with septa and small pits. The marginal parenchyma (sensu Noshiro and Fujii 1994) associated with the (traumatic and normal) axial resin canals is named "subsidiary parenchyma cells" by Wiedenhoeft and Miller (2002), which is followed by Esteban et al. (2005). Unfortunately, the descriptions of the

fossil record regarding the axial parenchyma are limited to its existence and not on the detailed identification of the axial parenchyma type (or types). The identification of the type of the axial parenchyma can help to distinguish genera within Pinaceae (Noshiro and Fujii 1994).

The occurrence of spiral thickenings, roundish tracheids and partly biseriate rays may be related either to specific genera or to compression wood sensu Timell (1986). The occurrence of relatively large resin canals is also observed in compression wood as in our MGPT-PU141107 sample but could be also of taxonomic importance. Ecological disruptions by biotic, e.g., aphid infection and/or fungi, and abiotic factors can cause the above-discussed abnormalities (Timell 1986), as well as the occurrence of intercellular spaces (or interstitial spaces sensu Bolton et al. 1975), which were also observed in this sample. The observed abnormal discoloration (white and black) could be related to wood shrinkage caused by several factors discussed in Rößler et al. (2021), among which are the mineralization and the decay caused by bacteria and fungi. The latter case is presented also in Wei et al. (2019) and Morris et al. (2021). The specific reason of the discoloration of our specimen remains open.

?Genus *Pinus* L., 1753

cf. *Pinus* sp.
Pl. 1, Fig. 6b

M a t e r i a l . Part of the wing of a seed (MGPT-PU141005b).

R e m a r k s . The morphology of this specimen matches that of the basal part of the wings of seeds of *Pinus*, but similarity to other genera cannot be ruled out.

Genus *Pinus* L., 1753

Pinus spp.
Pl. 2, Figs 3–5, Pl. 5, Fig. 27

M a t e r i a l . A cone from GLA19 (photograph), and three five-needled fascicles of leaves attached to the brachyblast, two from GLAz (MGPT-PU141011, MGPT-PU141012) and one from GLA20 (MGPT-PU141095). *Pinus* pollen grains are quite abundant.

R e m a r k s . Five-needled fascicles are typical of the subgenus *Pinus* subgen. *Strobus*. The short cone recovered in a natural cross-section with rather thick scales is more similar to fossil-species of subgen. *Pinus*, e.g., *P. hampeana* (Unger) Heer. Pollen grains are common and well preserved. There are two main pollen morphotypes: *Pinus* haploxylon-type and *Pinus* diploxylon-type. The latter appears to be much more frequent in the pollen assemblage than *Pinus* haploxylon-type.

Genus *Tsuga* (Endl.) Carrière, 1855

Tsuga canadensis-type and *Tsuga diversifolia*-type
Pl. 5, Figs 28, 29

M a t e r i a l . *Tsuga canadensis* Carrière-type and *T. diversifolia* (Maxim.) Mast.-type pollen grains are frequent.

R e m a r k s . *Tsuga* pollen morphology has been described repeatedly (Ho and Sziklai 1972, Sivak 1973,

1978, Kurmann 1990, Grímsson and Zetter 2011). Two pollen morphotypes were recognized in this work: *T. canadensis*-type and *T. diversifolia*-type. Both pollen types are monosaccate and inaperturate. *T. diversifolia*-type is also echinate (e.g., Grímsson and Zetter 2011). Both types are very common in the selected samples, but *T. diversifolia*-type is more abundant than *T. canadiensis*-type.

Genus *Tsuga* (Endl.) Carrière, 1855 vel *Pseudotsuga* Carrière, 1855

Tsuga vel *Pseudotsuga* sp.
Pl. 2, Figs 7, 8

M a t e r i a l . A leaf from GLA20 (MGPT-PU141013) and another from GLAz (MGPT-PU141014).

D e s c r i p t i o n . Flat and thin needle-leaves with slender petiole, bent in relation to the leaf axis.

R e m a r k s . The above characters are diagnostic for leaves of *Tsuga* or *Pseudotsuga*, but also *Nothotsuga* Hu ex C.N.Page should be considered for possible affinity (Kunzmann and Mai 2005).

Genus *Abies* Mill., 1754

Abies sp.
Pl. 2, Figs 1, 2, Pl. 5, Fig. 31

M a t e r i a l . *Abies* pollen grains were detected in every sample (Tab. 2). Two leaves have been recovered from interval GLAz (MGPT-PU141009, MGPT-PU141010).

R e m a r k s . The pollen grains of *Abies* are very common and well preserved. Under an optical microscope, determination of the species is not possible. The diagnostic characters of needle-leaves are the enlarged petiole base and the retuse apex (e.g., Kvaček et al. 2020).

Clade Basal Angiosperms
Order Laurales Juss. ex Bercht. et J.Presl, 1820
Family Lauraceae Juss., 1789 nom. cons.

Genus ?*Ocotea* Aubl., 1775

cf. *Ocotea heeri* (C.T.Gaudin, 1857) W.R.Müll., 1934
Pl. 2, Figs 11, 12

M a t e r i a l . Two almost complete leaves (MGPT-PU141018, MGPT-PU141096) and a large fragment from the central part of the lamina (MGPT-PU141097), all from GLA20.

D e s c r i p t i o n . MGPT-PU141018 represents the lamina of an almost complete simple leaf, shape elliptic; base shape convex, base angle obtuse, apex not preserved, l × w about 56 × 28 mm, ratio l/w about 2; margin entire; midvein slender, rather straight, secondaries brochidodromous, widely spaced, arising at moderately steep angles, intersecondaries present, tertiaries partly percurrent, partly reticulate, widely spaced, higher order veins reticulate.

R e m a r k s . The coarse secondary and tertiary veins distinguish these leaves among others reported from the Neogene of Italy. The preservation of the two almost entire

specimens does not allow discernment of the diagnostically relevant domatia at the base of the basal secondaries (Martinetto 2003: pl. 5, figs 8–10). However, the original presence of a domatium is suggested by a thickened globular structure of organic material at the base of a secondary vein of the large leaf fragment (Pl. 2, Fig. 12b).

Fossil-genus *Daphnogene* Unger, 1850

***Daphnogene polymorpha* (A.Braun) Ettingsh., 1851**
Pl. 2, Fig. 9

M a t e r i a l . A single leaf impression from layer GLA30 (MGPT-PU141016).

D e s c r i p t i o n . Rather complete simple leaf except missing apex, shape elliptic to slightly obovate, petiole not preserved, base shape slightly convex, base angle obtuse, l × w about 60 × 30 mm, ratio l/w about 2; margin entire, venation suprabasal acrodromous, the basal secondaries running into the apical part of the leaf, next pair of secondaries only in the apical part of the lamina, secondaries brochidodromous; tertiaries hardly visible.

R e m a r k s . The well-preserved basal secondaries that reach into the apical part of the leaf are characteristic. In *Ocotea* the basal secondaries are shorter and less strong.

Fossil-genus *Laurophyllum* Göpp., 1854

***Laurophyllum* sp. 1**
Pl. 2, Fig. 10

M a t e r i a l . Two incomplete leaves from GLA20 (MGPT-PU141017, MGPT-PU141098).

D e s c r i p t i o n . The best preserved specimen (Pl. 2, Fig. 10) consists of the basal part of a probably oblong simple leaf, petiole incomplete, base almost cuneate, l × w about 65 × 14 mm, ratio l/w about 4.6; margin entire, midvein slightly bent, secondaries brochidodromous, very delicate, arising at moderate to steep angles, regularly spaced, tertiaries not discernible.

R e m a r k s . Contrary to cf. *Ocotea heeri*, this leaf is slender, the secondaries are very delicate, regularly spaced, arising at steeper angles, and the tertiaries are not distinct. Assignment of these leaves to Lauraceae is tentative. The frequent occurrence of Lauraceae leaves was proved by cuticular studies in the neighbouring Zanclean locality of Fossano (Macaluso et al. 2018).

***Laurophyllum* sp. 2**
Text-fig. 4 (right)

M a t e r i a l . An incomplete leaf from GLA20 (MGPT-PU141082) and possibly two other nearly complete leaves from the same layer, stored at MPTA (Cimino et al. 2016: pl.1, fig. 2-left and fig. 3).

D e s c r i p t i o n . MGPT-PU141082 is a leaf fragment lacking base and apex; shape broadly elliptical, l × w about 64 × 30 mm, ratio l/w about 2.1; margin entire, midvein slightly bent, secondaries brochidodromous, widely and irregularly spaced, arising at wide to moderate angles, delicate, curved, occasionally forked, looping near margin,

giving rise to exmedial veinlets forming further small loops; intersecondaries occasionally developed; tertiaries widely spaced, (forked) percurrent to reticulate; higher order veins reticulate.

R e m a r k s . The description is based only on specimen MGPT-PU141082, because the other two leaves stored at MPTA were prepared with a method that would hamper a future cuticular analysis (Cimino et al. 2016), and without such analysis it is very difficult to be sure that the three leaves belong to the same species. However, these three specimens display a very similar gross morphology, whereas they differ from *Laurophyllum* sp. 1 by the much broader shape and thinner lamina with well discernible venation.

Clade Eudicots
Order Proteales Juss. ex Bercht. et J.Presl, 1820
Family Platanaceae T.Lestib., 1826 nom. cons.

Genus *Platanus* L., 1753

***Platanus leucophylla* (Unger) Erw.Knobloch, 1971**
Pl. 3, Figs 1, 2

M a t e r i a l . An almost complete leaf (MGPT-PU141019) and a fragmentary one (MGPT-PU141020) have been sampled, both from GLA20.

D e s c r i p t i o n . Lamina palmately lobed, number of lobes 3, petiole straight, length incomplete, 7 mm; base shape almost truncate; lamina about 120 mm long (specimen on Pl. 3, Fig. 1), central lobe longer than the lateral ones, lobe apices acute to attenuate, tip rounded, margin irregularly and coarsely toothed, teeth apices obtuse or acute, sinus rounded, proximal side straight to slightly convex, distal side straight to somewhat concave; venation actinodromous, 3 major veins running into the lobe apices, lateral primaries originating suprabasal; secondaries craspedodromous, tertiaries percurrent.

R e m a r k s . This species was often reported from the Messinian of northern Italy (Kovar-Eder et al. 2006, Teodoridis et al. 2015b, Martinetto et al. 2000).

Order Saxifragales Bercht. et J.Presl, 1820
Family Altingiaceae Horan., 1841 nom. cons.

Genus *Liquidambar* L., 1753

***Liquidambar* sp.**
Pl. 5, Fig. 20

M a t e r i a l . *Liquidambar* pollen grains were observed in four palynological samples of the selected range (Tab. 2), including the layers with plant macrofossils.

R e m a r k s . The conservation of pollen grains is good, but they are not very common in the palynological assemblages.

***Liquidambar* cf. *europaea* A.Braun in Buckland 1836**
Pl. 3, Fig. 3

M a t e r i a l . A very compressed, poorly preserved infructescence in GLA19 (MGPT-PU141021).

Remarks. The radially oriented acuminate remains of individual fruits, in a globular infructescence, are diagnostic because they are larger and less numerous than those in *Platanus*. Although the poor preservation would hamper a species level identification, assignment to *Liquidambar europaea* can be suggested because this is the sole species firmly documented from the Italian Neogene (Teodoridis et al. 2015a, Martinetto et al. 2018b).

Order Fagales ENGL., 1892
Family Fagaceae DUMORT., 1829

Genus *Fagus* L., 1753

Fagus sp.
Pl. 5, Fig. 14

Material. *Fagus* pollen grains were observed in all selected pollen samples.

Remarks. They are common and well preserved, but the morphological characteristics do not allow a clear differentiation to the species level.

Fagus cf. *gussonii* A.MASSAL., 1858
Pl. 3, Figs 8a, b, 9

Material. An almost complete leaf (MGPT-PU141027) and a fragmentary one (MGPT-PU141099) from GLA20, other two almost complete leaves from GLAz (MGPT-PU141026, MGPT-PU141100).

Description. Specimen figured on Pl. 3, Fig. 9. Simple leaf petiolate, petiole fragmentary, lamina elliptic, l × w about 50 × 25 mm, ratio l/w about 2, base shape slightly convex, base angle almost 90°, apex not preserved; margin entire (?), not well preserved; midvein slender, slightly s-shaped; secondaries probably craspedodromous, slender, very regularly spaced, 10 pairs preserved, arising at moderately steep angles, near the base at first slightly converging towards midvein; tertiaries probably percurrent, obtuse to midvein.

Remarks. The leaves from Govone fall within the variability of the abundant Messinian leaves from the surroundings of Alba (Martinetto et al. 2000, Denk 2004). Denk (2004) treated this assemblage as *Fagus* cf. *haidingeri* KOVÁTS, but considered it to be in the "hybrid zone between *F. haidingeri*/*F. gussonii*". Later, Teodoridis et al. (2015b, 2017) assigned Messinian specimens from Romagna (northern Italy) to *F. gussonii*. As we do not see definite differences between *Fagus* leaves from the type locality of *F. gussonii* (Senigallia), and those of the Romagna and Alba areas, we propose the use of the name *Fagus* cf. *gussonii* for those from the Alba region. Rich occurrences of *F. gussonii*, e.g., in Turkey (Güner et al. 2017) show wide variability, including leaves identical to those from Govone, and from northern Italy in general. The variation in leaf morphology of *Fagus* of the rich northwestern Italian Pliocene assemblages (Martinetto 2003, Denk 2004) differs from the Messinian ones. Therefore, it appears justified to apply a different name to the Pliocene beech leaves, i.e., *F. haidingeri* (Denk 2004).

Genus *Quercus* L., 1753

Quercus sp. div.
Pl. 5, Fig. 11

Material. *Quercus* pollen grains were observed in all studied pollen samples.

Remarks. Pollen grains are very abundant and well-preserved. The challenge to precisely discriminate the different deciduous, semi-deciduous and evergreen components of the genus *Quercus* under the optical microscope led us to organize the oak pollen into two main types: the first one including deciduous oaks, e.g., *Quercus pubescens* WILLD., and semi-deciduous oaks, e.g., *Quercus cerris* L.-type, the second one *Quercus ilex* L.-*Q. coccifera* L.-type (including all evergreen oaks). However, the *Quercus ilex-coccifera*-type pollen grains are very rare.

Quercus sp.
Pl. 3, Fig. 4a, b

Material. Fragment of a small, compressed leaf in GLA20 (MGPT-PU141022).

Description. Fragment of the middle part of a simple leaf lacking base and apex; lamina oblong (?), l × w about 47 × 21 mm, ratio l/w about 2.2; margin simple toothed, teeth distinct, one above each secondary vein, tooth apex pointed to rounded, sinus rounded, proximal side, convex to flexuous, distal side concave to straight; midvein straight; secondaries regularly spaced, straight, craspedodromous, running into the tooth apices, tertiaries dense, percurrent (?), obtuse to midvein.

Remarks. This specimen resembles *Quercus kubinyi* (KOVÁTS) CZECZOTT.

Quercus roburoides C.T.GAUDIN, 1859 vel
Q. pseudocastanea GÖPP., 1852
Pl. 3, Fig. 7

Material. A fragment representing nearly one third of the compressed leaf lamina in GLA20 (MGPT-PU141025).

Description. Fragment of a simple leaf lacking base and apex; lamina probably obovate, l × w about 80 × 50 mm, ratio l/w about 1.6; margin simple serrate, teeth distinct, big, one above each secondary vein, apex blunt, sinus rounded, proximal and distal sides more or less straight; midvein straight; secondaries craspedodromous, regularly spaced, straight, arising at steeper angles towards apex than near base.

Remarks. This leaf fragment is rather similar to Messinian leaves found at Monte Tondo (some 400 km east of Govone; Teodoridis et al. 2015a), which were assigned to *Q. roburoides* C.T.GAUDIN. Zidianakis et al. (2020: pl. 12, fig. 1) described similar leaves from Pitsidia (Crete, early Tortonian) as *Q. pseudocastanea* GÖPP. Leaves assigned either to *Q. pseudocastanea* or *Q. roburoides* are common in the younger European Neogene, and morphologically are very similar and variable (Kvaček et al. 2020, Zidianakis et al. 2020). Therefore, single findings are difficult to assign to one or the other fossil-species.

Family Myricaceae Rich. ex Kunth, 1817 nom. cons.

Genus *Morella* Lour., 1790 vel *Myrica* L., 1753

***Morella*/*Myrica* sp.**
Pl. 5, Fig. 4

M a t e r i a l . *Morella*/*Myrica* pollen grains were observed in five samples (Tab. 2), including the layers with plant macrofossils.

R e m a r k s . The *Morella*/*Myrica* pollen grains are well-preserved but rare.

Genus *Morella* Lour., 1790

***Morella* sp.**
Pl. 3, Fig. 5, 5b

M a t e r i a l . A compressed leaf fragment from GLA20 (MGPT-PU141023).

D e s c r i p t i o n . Fragment of a simple leaf lacking base and apex; lamina oblong, l × w about 86 × 20 mm, ratio l/w about 4.3; margin simple serrate, teeth small, apex acute, sinus acute, proximal and distal sides rather straight; midvein thick, straight; secondaries delicate, probably semicraspedodromous, arising under wide angles; intersecondaries present.

R e m a r k s . This specimen resembles *Morella lignitum* (Unger) Doweld.

Family Juglandaceae DC. ex Perleb, 1818 nom. cons.

Genus *Engelhardia* Lesch. ex Blume, 1826 nom. cons.

***Engelhardia* sp.**
Pl. 5, Fig. 3

M a t e r i a l . *Engelhardia* pollen grains were observed in all pollen samples.

R e m a r k s . These pollen grains are very abundant and well preserved.

***Engelhardia orsbergensis* (P.Wessel et C.O.Weber) Jähnichen, Mai et H.Walther, 1977**
Pl. 4, Figs 1–3

M a t e r i a l . Two almost complete leaflets (the best preserved one, MPTA 13364, already figured by Cimino et al. 2016; the other is MGPT-PU141028) and four incomplete ones from GLA20 (MGPT-PU141029, MGPT-PU141101, MGPT-PU141102, and one sample stored at MPTA; Cimino et al. 2016: pl. 1, fig. 5-top).

D e s c r i p t i o n . Leaflets, (sub)sessile, lamina oblong, l × w about 40–67 × 10–15 mm, ratio l/w about 4–4.7; base shape asymmetrical, convex, base angle acute, apex probably attenuate; margin simple serrate, only near base entire, teeth tiny, narrow, sharp, widely spaced; midvein straight; secondaries indistinct, probably semicraspedodromous, arising under wide angles; intersecondaries present; further venation not visible.

R e m a r k s . The occurrence of *Engelhardia orsbergensis* at Govone was already reported by Cimino et al. (2016). The characteristic fruit bracts of *Engelhardia* have

been reported from Messinian sites located about 200 km to the East (Teodoridis et al. 2015a, Martinetto and Macaluso 2018).

Genus *Pterocarya* Kunth, 1824

***Pterocarya* sp.**
Pl. 5, Fig. 19

M a t e r i a l . *Pterocarya* pollen grains were observed in six samples (Tab. 2).

R e m a r k s . Pollen grains of *Pterocarya* are rare but well-preserved.

***Pterocarya paradisiaca* (Unger) Iljinsk., 1964**
Pl. 4, Figs 4, 5

M a t e r i a l . Three fragmentary leaflets from GLA20, specimen MPTA 13373 (Cimino et al. 2016: pl. 1, fig. 2), specimen MGPT-PU141108 and another specimen photographed in the field.

D e s c r i p t i o n . Subsessile leaflets lacking the apical part (except MPTA 13373); lamina oblong, l × w about 80 × 23 mm, ratio l/w about 3.5; base distinctly asymmetrical, base shape convex, base angle acute; margin regularly, densely simple serrate, teeth small, directed towards leaf apex, tooth apices blunt; midvein slightly bent; secondaries brochidodromous, arising at medium steep angles, very delicate, slightly curved, looping in some distance from the margin, further details not visible.

Family Betulaceae Gray, 1822 nom. cons.

Genus *Alnus* Mill., 1754

***Alnus* sp.**
Pl. 3, Fig. 6, Pl. 5, Fig. 1

M a t e r i a l . Infructescence from layer GLAz (MGPT-PU141024). *Alnus* pollen grains were observed in all pollen samples.

R e m a r k s . The ovate infructescence with many long bracts is diagnostic of the genus *Alnus*, but determination to the species level is generally not possible, and in any case, the analysis should involve all similar specimens from the surroundings of Alba (Martinetto et al. 2000). *Alnus* pollen grains are well preserved and very common.

Order Sapindales Juss. ex Bercht. et J.Presl, 1820
Family Sapindaceae Juss., 1789

Genus *Acer* L., 1753

***Acer* sp.**

M a t e r i a l . *Acer* pollen grains were observed in five samples (Tab. 2). They were not present in GLA30.

R e m a r k s . The pollen grains are common and well-preserved. There are no morphological characteristics to subdivide them further.

cf. *Acer tricuspidatum* A.Braun in Bronn 1838 emend. Walther 1972
Pl. 4, Fig. 6

Material. A leaf from layer GLA20 (MPTA 13366), assigned to *Acer tricuspidatum* by Cimino et al. (2016).

Description. A probable palmately three-lobed leaf, only the central lobe is almost complete, lateral lobes probably much smaller and shorter than central one; petiole not preserved, l × w about 64 × 47 mm; margin poorly preserved, probably serrate; venation actinodromous with 3 major veins arising at the base of the lamina, running into the lobe apices; exmedially from the lateral main veins 1–2 further delicate and short veins originate at the base running along the leaf margin; secondary veins probably brochidodromous, widely spaced, arising at medium steep angles; intersecondaries occasionally present; exmedial veins originating from lateral main veins looping near margin; tertiaries percurrent, obtuse to midvein.

Remarks. Leaves with comparable outline and venation are common in the local Pliocene sediments and have been assigned to *Acer tricuspidatum* (Martinetto 2003, Ciangherotti et al. 2007), a fossil-species already reported from the Messinian of the Alba area (Martinetto et al. 2000, Kovar-Eder et al. 2006, Cimino et al. 2016). The same name was applied by Zidianakis et al. (2020) to very similar leaves from Crete. The prevalence of rounded forms in these taphocoenoses, rather than forms with narrow and longer lateral lobes, corresponds to forms from Germany treated as *A. tricuspidatum* subsp. *lusaticum* H.Walther by Mai and Walther (1988). Güner et al. (2017) named a leaf with comparable morphology *A. ilnicense* Iljinsk. Also, *Acer pyrenaicum* Rérolle should be kept in mind for future comparisons (Kvaček et al. 2020).

Family Rutaceae Juss., 1789 nom. cons.

Rutaceae gen. et sp. indet.

Material. Rutaceae pollen grains were observed only in one sample below layer GLA19 (Tab. 2).

Remarks. Rutaceae pollen grains are rare. Due to the poor preservation, especially of the exine, a more detailed taxonomic assignment is not possible.

Genus *Toddalia* Juss., 1789

Toddalia latisiliquata (R.Ludw.) H.-J.Gregor, 1979
Text-fig. 7b

Material. A seed from layer GLA10 (MGPT-PU141084).

Remarks. The strongly compressed fossil seed corresponds morphologically to some of the specimens found at Ciabot Cagna and Pollenzo (Niccolini et al. 2022).

Toddalia rhenana H.-J.Gregor, 1979
Text-fig. 7c

Material. 3 seeds from GLA10, one seed from GLA19 (MGPT-PU141085).

Remarks. The seeds are strongly compressed, but they still show the diagnostic characters of this species.

Order Ericales Bercht. et J.Presl, 1820
Family Pentaphylacaceae Engl., 1897 nom. cons.

Genus *Eurya* Thunb., 1783

Eurya stigmosa (R.Ludw.) Mai, 1960
Text-fig. 7d, e

Material. An almost complete seed (MGPT-PU141086) and a fragmented one (MGPT-PU141087) from layer GLA10.

Remarks. These seeds agree in dimensions, shape and sculpture with *Eurya stigmosa*, recently described by Góis-Marques et al. (2019) and Martinetto and Vieira (2020).

Genus *Visnea* Steud. ex Endl., 1837

Visnea germanica Menzel, 1913
Text-fig. 7f

Material. A fruit from layer GLA10 (MGPT-PU141088).

Remarks. In this fruit, the receptacle and some remains of the style are preserved, but no filaments. It corresponds morphologically to some remains found at Ciabot Cagna (Niccolini et al. 2022), even though this fruit was not subjected to the anatomical investigations carried out by Schüßler (2020).

Family Symplocaceae Desf., 1820 nom. cons.

Genus *Symplocos* Jacq., 1760

Symplocos casparyi R.Ludw., 1857
Text-fig. 7g

Material. An endocarp from layer GLA10 (MGPT-PU141089).

Remarks. This fossil is an elongate lignified object with several longitudinal ribs, a small circular pith at the base and three compressed seed locules. These characters and the direct comparison with well-preserved fossils (Mai and Martinetto 2006) permit us to recognize it as a compressed and damaged fruit stone (endocarp) of *Symplocos*. Shape, dimensions and aspect of the longitudinal ribs correspond to those of the common Neogene species *S. casparyi*. This is the first report of this fossil-species for the Miocene of Italy, whereas it was already known from the Pliocene and Pleistocene (Martinetto et al. 2014, 2018b).

Angiosperms incertae sedis

Fossil-genus *Dicotylophyllum* Saporta, 1892

Remarks. Several morphotypes require cuticular studies to improve the taxonomic framing.

Dicotylophyllum sp. 1
Pl. 4, Fig. 7

Material. A leaf compression from GLA20 (MGPT-PU141030).

Description. Simple leaf almost complete, lamina likely coriaceous, distinctly obovate, petiole not preserved; l × w = 56 × 23 mm, ratio l/w = 2.4; base cuneate-decurrent,

apex shape convex, apex angle obtuse; margin entire; midvein straight; secondaries very faint, arising under medium steep angles, dense, straight; further details not visible.

R e m a r k s . This leaf possibly corresponds to *Dicotylophyllum* sp. 1 in Teodoridis et al. (2015a).

In *Sideroxylon* L., similar leaves occur, a genus whose fruit remains have been found in post-evaporitic deposits (Niccolini et al. 2022). For example, the leaves of *S. mascatense* (A.DC.) T.D.Penn. described by Hopkins et al. (2021) resemble in leaf shape and venation to *Dicotylophyllum* sp. 1.

Dicotylophyllum sp. 2
Pl. 4, Fig. 8

M a t e r i a l . A single leaf from GLA20 (MGPT-PU141031).

D e s c r i p t i o n . Basal part of a simple leaf, petiole not preserved, lamina probably elliptic, l × w about 91 × 29 mm, ratio l/w about 3.1; base cuneate to somewhat decurrent, margin entire; midvein straight; secondary veins delicate, dense, arising at wide angles, looping close to the margin forming an intramarginal vein; intersecondaries developed; higher order veins reticulate.

R e m a r k s . This leaf is characterized by a thin intramarginal vein, like in Moraceae, Myrtaceae or Rutaceae.

Dicotylophyllum sp. 3
Text-fig. 4 (left), Pl. 4, Figs 9, 10

M a t e r i a l . The best-preserved leaf (MPTA 13371) was already figured by Cimino et al. (2016), and a similar specimen was recovered in the year 2020 (MGPT-PU141032); both leaves originate from GLA20.

D e s c r i p t i o n . Leaf simple, petiole not preserved, lamina elliptic, l × w = 110 × 40 mm, ratio l/w = 2.5; base shape rather straight, base angle narrow acute; apex shape straight, angle acute, utmost apex blunt; margin entire; midvein straight; secondaries festooned brochidodromous, numerous, arising under narrow angles, ascending steeply, giving rise to exmedial veins; partly composite intersecondaries developed; secondaries, intersecondaries and their branches forming elongated meshes; tertiaries and higher order veins reticulate.

R e m a r k s . The systematic affinity of these leaves remains open.

Synthesis of the macro- and micro-floras

Research carried out on the Govone section resulted in the discovery of 76 taxonomically relevant plant macrofossil specimens, more than half of them (41) concentrated in the GLA20 bed, also known as the "Damarco leaf bed" (Cimino et al. 2016). The last one yielded 22 taxa, 14 based on angiosperm leaves, 7 on conifer shoots and one on a conifer leaf (Tab. 1). A lower number of taxa (9, based on 14 specimens) was identified on the basis of material from the GLAz interval, where most taxa are represented by

conifers. Interval GLA30 yielded 5 taxa, among which only *Daphnogene polymorpha* is not shared with GLA20. Layers GLA10 and GLA19 provided poor assemblages only, whose large taxonomic difference from those of the three above-mentioned intervals (Tab. 1) can be explained by the dominance versus near absence of fruit and seed remains.

Taxa represented both by macroremains and pollen include the conifers *Abies*, *Glyptostrobus*, *Pinus*, *Taxodium* and *Sequoia*. Among angiosperms, there are *Acer*, *Alnus*, *Fagus*, *Engelhardia*, *Liquidambar*, *Morella*, *Pterocarya* and *Quercus*. On the other hand, Lauraceae and *Platanus* are only documented by macrofossils. The quite rich and diversified pollen flora from 10 pollen samples (Tab. 2) consists of 83 taxa (52 trees and 31 shrubs, climbers or herbs). Photos of selected pollen grains are shown in Plate 5.

Conifers include Cupressaceae with *Taxodium*/*Glyptostrobus*-type, Taxodioideae/Sequoioideae undifferentiated, *Sequoia*-type, *Juniperus*-type, Cupressoideae undifferentiated and ?Cunninghamioideae. Pinaceae are also represented by *Abies*, *Picea*, cf. *Cathaya*, *Cedrus*, *Tsuga canadensis*-type, *Tsuga diversifolia*-type, *Pinus* diploxylon-type, *Pinus* haploxylon-type and Pinaceae undifferentiated. *Sciadopitys* is also present.

The woody angiosperms are characterized by Betulaceae (*Alnus*, *Betula* L., *Carpinus orientalis* Mill.-type, *Carpinus betulus* L.-type, *Corylus* L.), Fagaceae (Fagaceae undiff., *Castanea* L., *Quercus*, *Quercus ilex-coccifera*-type, *Fagus*); Ulmaceae (*Ulmus* L., *Zelkova* Spach), Juglandaceae (*Carya* Nutt., *Pterocarya*, *Engelhardia*, *Juglans* L.), *Acer*, *Liquidambar*, *Parrotia* C.A.Mey., *Tilia* L., *Rhus* L., *Ilex* L., *Buxus* L., *Morella*/*Myrica* and *Nyssa* L. are also present. Rare pollen grains of cf. *Taxus* L., Magnoliaceae, cf. *Craigia*, Arecaceae, Sapotaceae were also observed.

The shrub, climbing and herbaceous taxa include *Ephedra* L., Poaceae (including one pollen grain of *Lygeum* L.), Rosaceae (including one pollen grain of *Neurada* B.Juss.), *Galium* L., Rutaceae, Saxifragaceae, *Hedera* L., Caryophyllaceae, Amaranthaceae, Asteraceae-Asteroideae including *Artemisia* L., Asteraceae-Cichorioideae, Brassicaceae, *Knautia* L., Ericaceae, *Geranium* L., *Plantago* L., *Rumex* L., Ranunculaceae, Apiaceae, and *Typha latifolia* L.-type.

Discussion

The syn-evaporitic portion of the Govone section provided several plant organs, fruits and seeds, leaves, pollen and wood, which may serve for a detailed palaeoenvironmental analysis through the integration of the various data sets. However, our first analyses showed that the preservation of anatomical structures in permineralized wood may be limited, and thereby hamper a systematic assignment. The fruit and seed assemblages are biased by selective preservation of specimens that better resisted compression and fragmentation, and therefore offer a restricted view of the palaeoflora. The compressed remains of conifer shoots/leaves and angiosperm leaves document several morphotypes based on gross morphology, and rich pollen data strongly contribute to the definition of the flora composition (Tabs 1, 2).

The plant macrofossil assemblage from layer GLA20 seems to be suitable for the identification of a broad diversity of angiosperm leaf types, because 14 different taxa have already been recognized among 29 specimens (Tab. 1). The results presented here show that GLA20 contains a rich assortment of thermophilic conifers (*Glyptostrobus*, *Taiwania*, *Taxodium*), deciduous angiosperms (e.g., *Platanus*, *Pterocarya*) and evergreen angiosperms (e.g., *Laurophyllum*). The probable preservation of cuticles (Text-fig. 5) enhances the likelihood that precise systematic assignment of several leaf morphotypes will be possible in the future, which is not possible in other assemblages from northwestern Italy of similar age, such as the rich collection of Messinian leaves from Castagnito, Monticello and Piobesi-Scaparoni (also in the Alba area; Martinetto et al. 2000, 2007). The last one provided only a few cuticles (Martinetto, pers. obs.), and only from a few leaf morphotypes.

In the light of the preliminary taxonomic analysis of the GLA20 assemblage, the association of *Cryptomeria*, *Engelhardia*, *Fagus*, Lauraceae and *Taiwania* may point towards a vegetation type similar to subtropical humid forests of southeast Asia. Similar indications are provided by the occurrence of *Eurya*, *Symplocos* and *Toddalia* in the underlying bed GLA10. However, GLA10 and GLA20 are stratigraphically located in shale intervals (Text-fig. 2), thought to be deposited during the more humid part of a precessional cycle (Gennari et al. 2020, Sabino et al. 2020). Therefore, the detection of a humidity-requiring flora may not be surprising, as it was already reported for the PB by Martinetto et al. (2007) and Bertini and Martinetto (2008, 2011), and for the Romagna Basin by Teodoridis et al. (2015b). However, the Govone section also provided plant macroremains from primary gypsum deposits (GLAz, cycle Gg3), which are expected to have formed under more arid conditions. The taxa so far identified from GLAz are just a few (Tab. 1), and most of them also occur in layer GLA20. Our preliminary results are not yet sufficient to state that GLA20 and GLAz represent very similar or almost identical conditions of vegetation. Nevertheless, the association of *Abies*, *Alnus*, *Cryptomeria*, *Fagus* and *Sequoia*, detected in GLAz, is certainly not typical for an arid or subhumid climate (Bouchal et al. 2020, Kovar-Eder et al. 2021). Rather, these taxa (*Abies* excepted) would be compatible with a humid subtropical forest, already reconstructed by Bertini and Martinetto (2011) in the studied area during the evaporitic Messinian, but not yet confirmed by the analysis of plant assemblages from gypsum deposits.

At present, we only know 14 plant macrofossil specimens deriving from the GLAz interval (Tab. 1), and it may be argued that such scarce remains may originate from higher altitudes, not representative of the vegetation and climate from lowlands around the sedimentary basin. However, conifer shoots and leaf fascicles exhibit very little fragmentation, which argues against a long transport distance, according to taphonomic studies (Spicer 1991, Martin-Closas and Gomez 2004). The possible origin of such remains from the lowlands suggests that a humid subtropical forest may have also surrounded the basin during the deposition of gypsum, at least during the sedimentary cycle Gg3.

In agreement with the evidence from plant macrore-mains, the pollen record from Govone indicates that humid conditions dominated the evaporitic Messinian record, despite some fluctuations in humidity. This new evidence, when integrated and compared with the results of previous studies (Suc and Bessais 1990, Bertini 2006, Fauquette et al. 2006), confirms the occurrence of climatic gradients, as well as a complex climate context within the Mediterranean area (see also Bouchal et al. 2020). The scenario proposing a Mediterranean Basin having conditions of total aridity should be regarded as outdated.

Although the information obtained from the Govone section is still limited, and too premature for a detailed palaeoenvironmental analysis, it indicates that the plant assemblages from Govone, in particular from the intervals GLA20 and GLAz, could essentially contribute to a more detailed knowledge of the development of Mediterranean terrestrial ecosystems during the Messinian.

Future perspectives

The robust stratigraphical framework of the plant-bearing section of Govone, the excellent preservation of fossil plant material and the integration of the data from all plant parts all combine to provide a unique opportunity for a more detailed understanding of palaeoenvironmental and climate changes in the northern Mediterranean during the late Neogene. Especially interesting, a thorough sampling of the GLA20 deposit could provide abundant material suitable for cuticular analysis, thus throwing light on several enigmatic leaf taxa described solely on a gross-morphological basis from the Italian Messinian (first by Massalongo and Scarabelli 1859). However, the scattered occurrence of plant macrofossils in the key interval GLAz represents a challenge. The only promising sampling strategy consists in careful observation of the bedding planes to detect plant fossils exposed by flood events of the Tanaro river, as soon as possible after such events. Therefore, the goal to retrieve more abundant material could be only achieved by intensifying field surveys during the next years, which also could permit the detection of presently unknown plant-bearing layers. The assessment of the floristic diversity and abundance of taxa, their variability, as well as of possible differences between the stratigraphic horizons will constitute the basis for a more detailed vegetation analysis and climate reconstruction.

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Explanations of the plates

PLATE 1

Cupressaceae from Govone, Messinian

Taiwania sp., GLA20 bed.
1. Small compressed shoot, MGPT-PU141001.

Sequoia abietina (Brongn.) Erw.Knobloch, GLAz interval.
2. Compressed shoot photographed in situ (a), under the water of the Tanaro river (see Martinetto et al. 2018a: fig. 4d), and its apical part after the extraction (b), MGPT-PU141002.

Cryptomeria sp., GLAz interval.
3. Shoot with almost three-dimensional preservation within small gypsum crystals (a), and detail of the most basal leaf (b), MGPT-PU141003.

Glyptostrobus europaeus (Brongn.) Unger, GLA30 bed.
4. Ramified shoot bearing a pyriform cone (a), shown in detail in (b). Specimen photographed in the field, not recovered.

Cryptomeria sp., GLAz interval.
5. Compressed shoot showing leaves of different length and curvature, more or less densely packed in different portions, MGPT-PU141004.

Taxodium dubium (Sternb.) Heer, GLA20 bed.
6. Long portion of a compressed shoot (c), MGPT-PU141005. The image also shows a small shoot of *Glyptostrobus europaeus* (a, arrow) and part of the wing of a seed of cf. *Pinus* sp. (b, object positioned close to the scale bar).
7. Short portion of a compressed shoot, MGPT-PU141006.

"*Thuja*" *saviana* (C.T.Gaudin) C.T.Gaudin, GLAz interval.
8. Part of a terminal long portion of a compressed shoot, poorly preserved at the apex, MGPT-PU141007.
9. Compressed shoot, MGPT-PU141008.

Thick scale bars 1 mm, thin ones 10 mm.

PLATE 2

Pinaceae and Lauraceae from Govone, Messinian

Abies sp., GLAz interval.
1. Naturally exposed, compressed needle whose upper part was washed out by the river, MGPT-PU141009.
2. Complete compressed needle with retuse apex and enlarged petiole base (a), MGPT-PU141010. Detail of the enlarged petiole base (b) also showing the randomly oriented acicular gypsum crystals of the matrix (arrows).

Pinus sp. ex subgen. *Pinus*, GLA19 bed.
3. Naturally exposed, compressed and abraded cone.

Pinus sp. ex subgen. *Strobus*, GLAz interval.
4. Naturally exposed fascicle of five needle-leaves attached to the brachyblast (see Martinetto et al. 2018a: fig. 4c); the leaves were nearly three-dimensionally preserved within gypsum crystals; one leaf is deeply altered and not visible in the picture, MGPT-PU141011.
5. Naturally exposed fascicle of five needle-leaves attached to the brachyblast; two leaves were substantially damaged when washed out by the river, MGPT-PU141012.

Coniferales gen. et sp. indet., GLAz interval.
6. Apical part of a naturally exposed, compressed needle, MGPT-PU141015.

Tsuga vel *Pseudotsuga* sp., GLAz interval.
7. Naturally exposed, compressed needle, MGPT-PU141013.
8. Basal part of a naturally exposed, compressed needle with complete petiole, MGPT-PU141014; the randomly oriented acicular gypsum crystals of the matrix are also apparent.

Daphnogene polymorpha (A.Braun) Ettingsh., GLA30 interval.
9. Impression of a leaf (apex not preserved), MGPT-PU141016.

Laurophyllum sp. 1, GLA20 bed.
10. Compressed fragment of the basal part of a leaf, MGPT-PU141017.

cf. *Ocotea heeri* (C.T.Gaudin) Takht., GLA20 bed.
11. Compressed remain of a leaf lamina lacking the apex, MGPT-PU141018.
12. Compressed remain of the central part of a leaf lamina (a) with a circular feeding trace and a possible domatium (arrow), MGPT-PU141097. Detail of the possible domatium (arrow) at the axil of a secondary vein (b).

Thick scale bars 1 mm, thin ones 10 mm.

PLATE 3

Angiosperms from Govone, Messinian

Platanus leucophylla (Unger) Erw.Knobloch, GLA20 bed.
1. Possibly complete leaf photographed in the field and its impression on the overlying sediment (right), MGPT-PU141019.
2. Incomplete impression of a leaf with poor organic remains (black), MGPT-PU141020.

Liquidambar cf. *europaea* A.Braun, GLA19 bed.
3. Heavily compressed and brittle fruiting head, MGPT-PU141021.

Quercus sp., GLA20 bed.
4. Portion of a compressed leaf (a) with detail of the margin (b), MGPT-PU141022.

Morella sp., GLA20 bed.
5. Portion of a compressed leaf (a) with detail of the central part and sparsely toothed margin (b), MGPT-PU141023.

Alnus sp., GLAz interval.
6. Infructescence with diagenetic gypsum crystals among the bracts, MGPT-PU141024.

Quercus roburoides Gaudin vel *Q. pseudocastanea* Göpp., GLA20 bed.
7. portion of a compressed leaf, MGPT-PU141025.

Fagus cf. *gussonii* A.Massal.
8. Portion of a compressed leaf (a; GLAz interval) whose central part has been washed away (see Martinetto et al. 2018a: fig. 4a), thus showing the impression on the sediment, made up of small gypsum crystals; the last ones are more visible above the leaf surface. A miniature of the entire specimen is shown in (b), MGPT-PU141026.
9. Remain of an altered leaf adpression (GLA20 bed), with scarce decayed remains of the organic matter, MGPT-PU141027.

Scale bar 10 mm.

PLATE 4

Angiosperms from Govone, Messinian

Engelhardia orsbergensis (P.Wessel et C.O.Weber) Jähnichen, Mai et H.Walther, GLA20 bed.
1. Nearly complete compressed leaflet, MPTA 13364.
2. Compressed leaflet lacking the base, with well-preserved toothed margin, MGPT-PU141028.
3. Basal portion of a compressed leaflet already damaged by the formation of gypsum aggregates, soon after the exposure to the air in the field, MGPT-PU141029.

Pterocarya paradisiaca (Unger) Iljinsk., GLA20 bed.
4. Portion of a compressed leaflet with toothed margin, MPTA 13373.
5. Incomplete compressed leaflet with asymmetrical base, showing better-preserved teeth in comparison to the previous specimen, MGPT-PU141103.

cf. *Acer tricuspidatum* A.Braun in Bronn (1838), GLA20 bed.
6. Impression (with poor organic remains) of a nearly complete leaf with damaged margin, MPTA 13366.

Dicotylophyllum sp. 1, GLA20 bed.
7. Overview of the nearly complete compressed leaf (a) and detail of the rounded apex (b), MGPT-PU141030.

Dicotylophyllum sp. 2, GLA20 bed.
8. Incomplete leaf (a); a thin inframarginal vein is visible in the detail (b), MGPT-PU141031.

Dicotylophyllum sp. 3, GLA20 bed.
9. Detail of the venation of the fragmentary leaf shown in Text-fig. 4 (left), MGPT-PU141032.
10. Nearly complete leaf, MPTA 13371.

Scale bar 10 mm.

PLATE 5

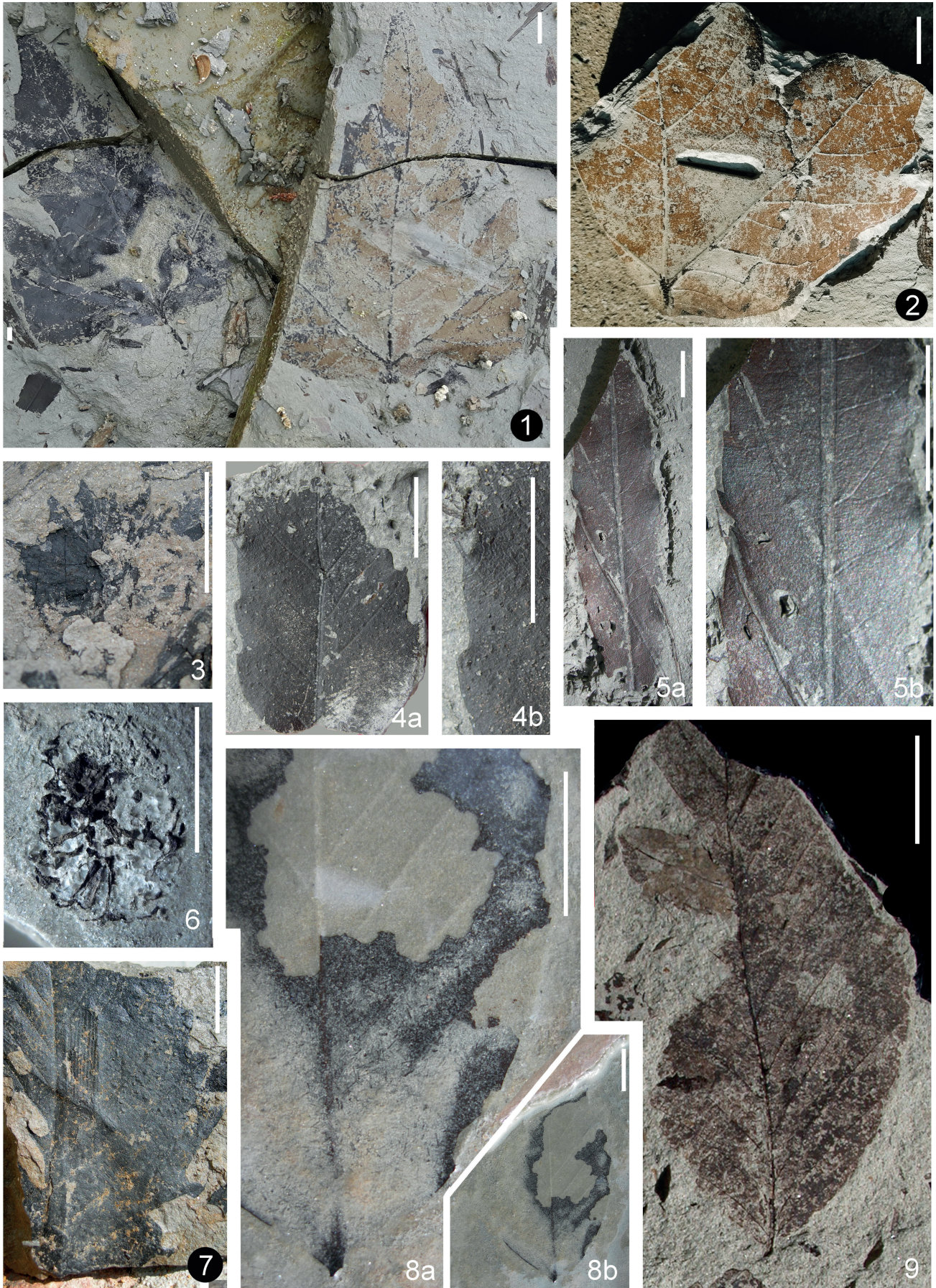Pollen grains from Govone, Messinian, samples indicated in brackets

1. *Alnus* (SGS14).
2. *Betula* (SGS11).
3. *Engelhardia* (SGS15).
4. *Morella*/*Myrica* (SGS15).
5. *Artemisia* (SGS15).
6. cf. Sapotaceae (SGS20).
7. *Neurada* (SGS 25).
8. *Sequoia*-type (SGS15).
9. Ericaceae (SGS16)
10. *Ephedra fragilis*-type (SGS15).
11. *Quercus* (A15.1NEW).
12. *Taxodium*/*Glyptostrobus*-type (SGS15).
13. Taxodioideae/Sequoioideae undiffereniated (SGS15).
14. *Fagus* (A15.1NEW).
15. *Sciadopitys* (SGS15).
16. *Juniperus*-type (SGS15).
17. Amaranthaceae (SGS15).
18. *Tilia* (SGS15).
19. *Pterocarya* (SGS15).
20. *Liquidambar* (SGS20).
21. ?Cunninghamioideae gen. et sp. indet. (SGS15).
22. *Carya* (SGS15).
23. *Lygeum* (SGS15).
24. Poaceae (SGS15).
25. cf. *Cathaya* (SGS15).
26. *Cedrus* (SGS15).
27. *Pinus* diploxylon-type (SGS15).
28. *Tsuga canadensis*-type (SGS15).
29. *Tsuga diversifolia*-type (SGS15).
30. *Picea* (SGS15).
31. *Abies* (SGS15).

PLATE 1

PLATE 2
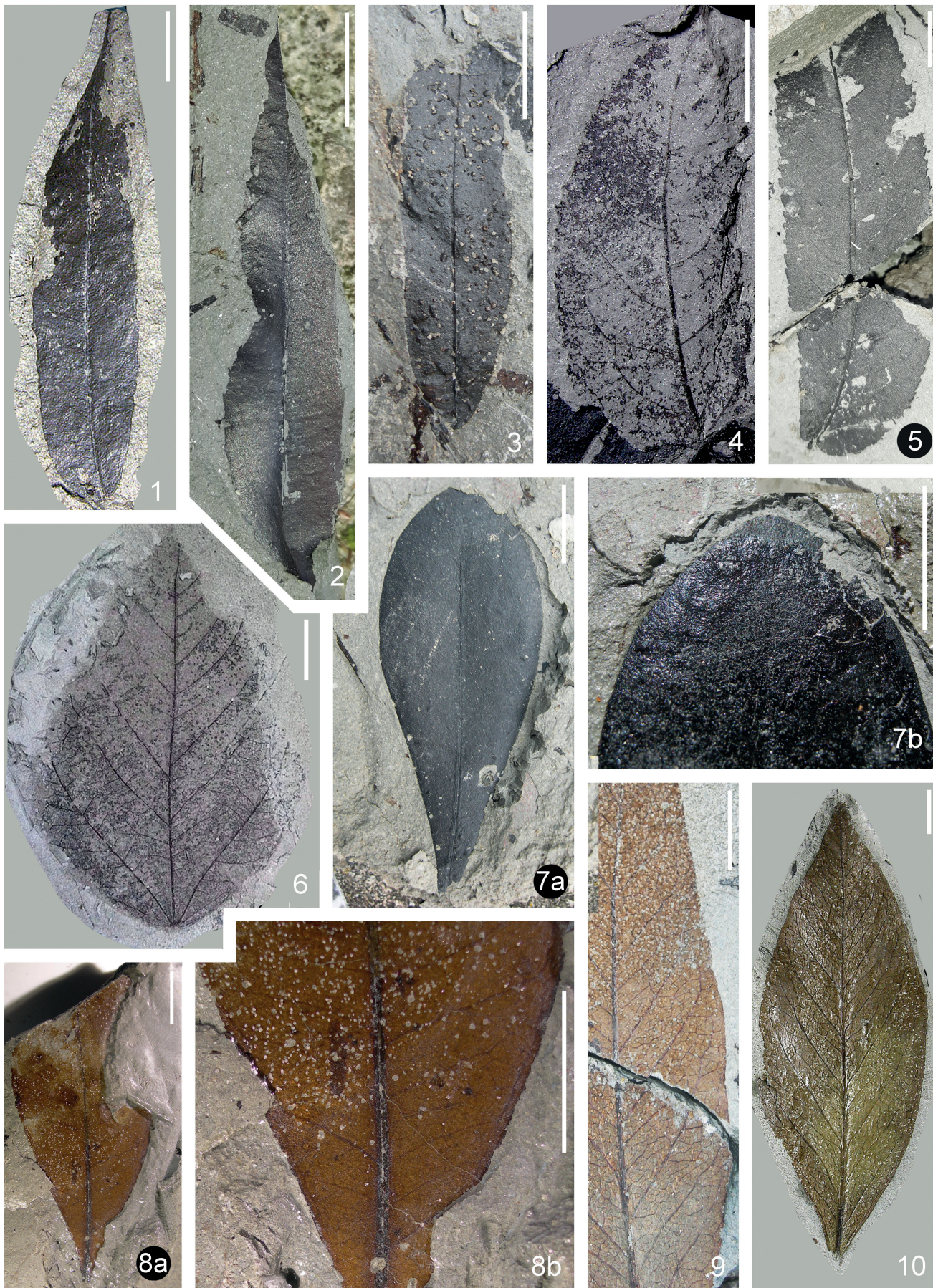
PLATE 3

PLATE 4

PLATE 5

20 µm

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