

FEATHER PALM FOLIAGE FROM THE MESSINIAN OF ITALY (CAPO DI FIUME, PALENA AND POLLENZO NEAR ALBA) WITHIN THE FRAMEWORK OF NORTHERN MEDITERRANEAN LATE MIOCENE FLORA

VASILIS TEODORIDIS

Department of Biology and Environmental Studies, Faculty of Education, Charles University in Prague, Magdalény Rettigové 4, 116 39 Prague 1, the Czech Republic; e-mail: vasilis.teodoridis@pedf.cuni.cz

ZLATKO KVAČEK

Institute of Geology and Palaeontology, Faculty of Science, Charles University in Prague, Albertov 6, 128 43 Prague 2, the Czech Republic; e-mail: kvacek@natur.cuni.cz

SILVANO AGOSTINI

Soprintendenza Archeologia dell'Abruzzo, Via degli Agostiniani 14, I-66100 Chieti, Italy; e-mail: silvano.agostini@beniculturali.it

EDOARDO MARTINETTO

Dipartimento di Scienze della Terra, Università degli Studi di Torino, Via Valperga Caluso 35, I-10123 Torino, Italy; e-mail: edoardo.martinetto@unito.it

MARIA ADELAIDE ROSSI

Soprintendenza Archeologia dell'Abruzzo, Via degli Agostiniani 14, I-66100 Chieti, Italy; e-mail: mariaadelaide.rossi@beniculturali.it

ORESTE CAVALLO

Museo Civico "Federico Eusebio", Via Vittorio Emanuele 19, I-12051, Alba (CN), Italy; e-mail: museo@comune.alba.cn.it



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Abstract. New records of plant macrofossils of palms and other groups are evaluated within the framework of the Messinian environment at the newly studied site of Capo di Fiume, Palena, central Italy. Similar palm foliage has been also recovered from the Messinian deposits of Pollenzo near Alba, northern Italy. The palm leaves were assigned to *Phoenicites* sp. based only on the leaf morphology. The floristic composition of the Palena plant assemblage shows a relatively high abundance of woody elements typical of a subhumid environment (*Tetraclinis*, *Cupressus*, Leguminosae), but also includes common mesic elements (*Pinus*, *Magnolia*, *Ilex*, *Berberis*, cf. *Trigonobalanopsis*, *Paliurus*, *Myrica*, *Engelhardia*), which are known from other Messinian floras of Italy, France and Greece. The affinities of several angiosperm macrofossils including enigmatic inflorescences resembling palms and *Butomus*, foliage of *Dicotylophyllum* sp. div. and disseminules of *Carpolites* sp. div. remain unresolved. The reconstructed vegetation type is interpreted as coastal non-swampy, wet soil (riparian) vegetation with a high abundance of woody elements growing under warm and semi-arid/sub-humid climatic conditions.

■ feather palms, conifers, angiosperms, vegetation, Messinian, Italy.

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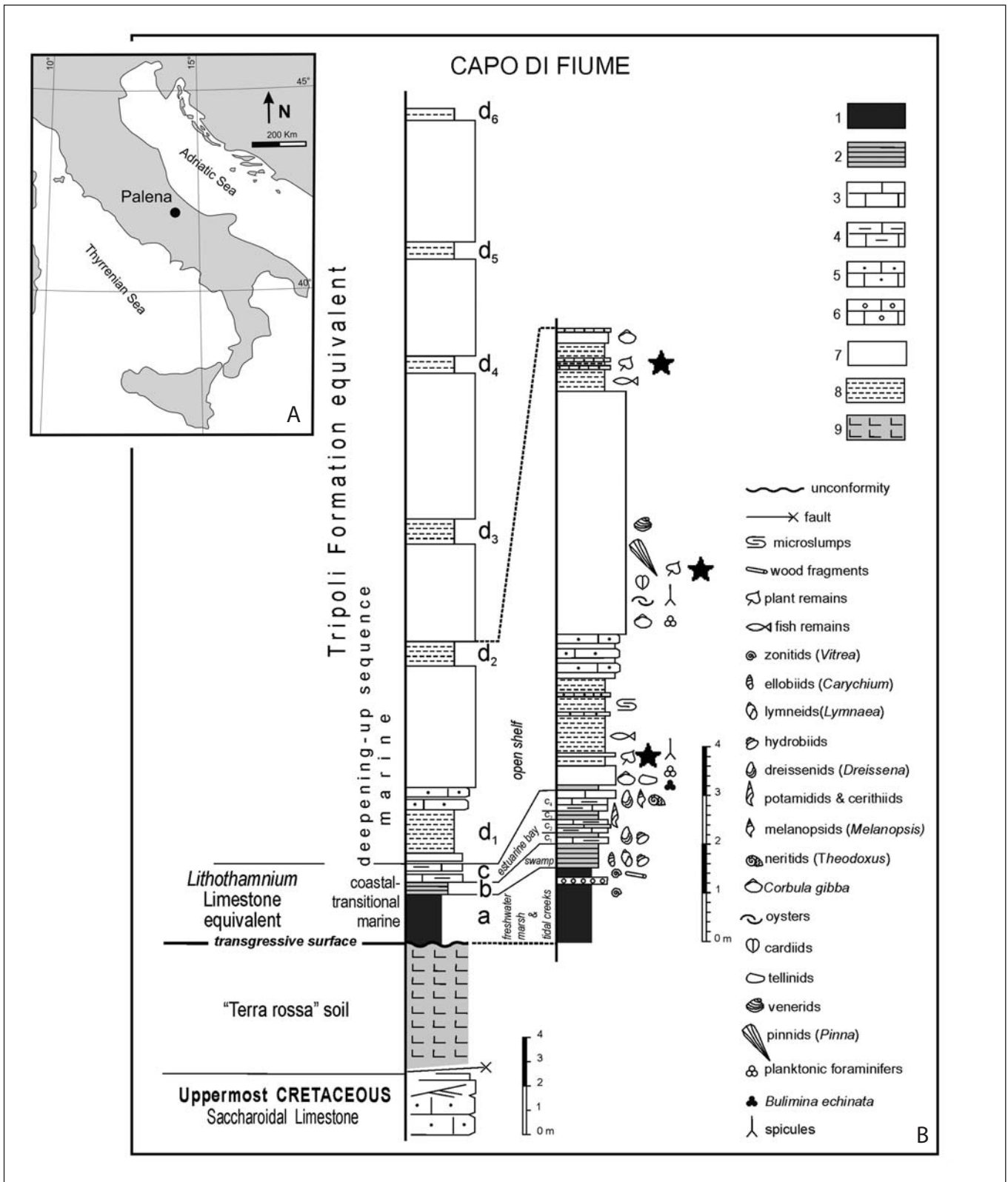
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Introduction

Fossil palm foliage is relatively common in the Italian Eocene and Oligocene sites (e.g., Bonci et al. 2011, Giuseberti et al. 2014), but quite rare in the late Neogene, as it is also elsewhere in Europe. Only a few records of foliage were described by Massalongo and Scarabelli (1859) /it is proved by accurate research e. g., G.B. Vai/ and Gaudin and Strozzi (1859) and Sordelli (1896) commented on its lack in some areas of the Italian Neogene. Recently two specimens of feather ("pinnate") palm foliage were collected in NW and central Italy, namely at Pollenzo near Alba (Cavallo et al.

2008, Dela Pierre et al. 2011) and Capo di Fiume, Palena (Bertini and Martinetto 2008) respectively – see Text-fig. 1A. At the Pollenzo site, in addition to the palm leaf, only a single leaflet impression of *Engelhardia* LESCHENAULT ex BLUME was recovered. In contrast several other plant remains were collected at the Capo di Fiume site and require a short treatment in terms of floristic and vegetation reconstruction within the framework of the geological and palaeoecological information so far available for this site.

The fossil content from this Messinian succession consists of abundant leaves, branches, pine cones, fruits and seeds as well as animal remains, such as a nearly complete



Text-fig. 1. A. Location of the sites of Capo di Fiume, Palena and Pollenzo near Alba. B. Capo di Fiume stratigraphic section. Facies of coastal-transitional marine associations – a. Freshwater marsh and tidal creeks interval, b. Swamp interval, c₁–c₄. Facies of eustrarine bay associations, d₁–d₆. Facies of open shelf marine associations. Symbols: “black star” – fossiliferous horizon with plant material studied here, 1. mottled grey to dark-brown marls and clayey marls, 2. fissile dark-grey marls and shaly marls, 3. limestones, 4. marly limestones and limey marls, 5. bio-lithoclastic calcarenites, 6. lime conglomerate, 7. massive muddy deposit produced by mass-flow mechanism, 8. diatomitic marls, 9. “terra rossa” soil (modified after Carnevale et al. 2011).

articulated skeleton of the ochotonid *Prolagus cf. apricenicus* MAZZA, 1987 (see Mazza et al. 1995), bird feathers, rare echinoids, decapod crustaceans, bivalves and numerous

fishes. The well preserved fish fossil assemblage includes 22 different taxa from 14 families, of which the clupeid *Spratelloides gracilis* TEMMINCK et SCHLEGEL, 1846 is the

most abundant (e.g., Carnevale and Landini 2000, 2001, Carnevale 2011). The Italian Ministry of Cultural Heritage issued a special decree in 1998 aimed at preserving the Capo di Fiume site due to the extraordinary scientific interest.

Geological setting

The Capo di Fiume stratigraphic section is composed of paralic to open marine Messinian deposits that unconformably overlie a “terra rossa” soil formed during prolonged exposure to karst and illuvial processes (see Carboni et al. 1992, Miccadei and Parotto 1998, Carnevale et al. 2011). The “terra rossa” consists of Fe and Mn hydroxide rich clay, with eolian quartz grains and layers of limestones and cherty pebbles. The “terra rossa” soil overlies uppermost Cretaceous carbonates characterized by medium-grained bioclastic limestones with a pseudo-crystalline texture deposited in an open shelf environment. The lithofacies exposed in the Capo di Fiume stratigraphic section can be described as containing 3 different parts as follows (see Text-fig. 1, Carnevale et al. 2011): (1) Mottled marls, clayey marls and lenticular beds of pebbly conglomerates (indicated as “a” in Text-fig. 1B), that represent a paralic deposit with hydromorphic features in a strongly reducing environment of fresh water marsh and tidal creeks. The fossil content consists of terrestrial pulmonate gastropods (zonitids) and plant remains including wood fragments and cavities created by root activity. (2) Fissile marls, shaly marls (indicated as “b–c” in Text-fig. 1B) characterized by thin lumachella layers of *Dreissena* BENEDEN, 1835; these are swamp deposits with salinity fluctuating from hypohaline to oligohaline conditions, containing hygrophilous land gastropods, ellobiids, lymneids, hydrobiids, vertiginids and brackish fossil assemblages of ostracods, potamidids and cerithioids belonging to the families Cerithiidae, Diastomidae and Litiopidae. The gastropods are indicative of stagnant freshwater ponds and of a humid densely vegetated land with a progressive increase in salinity. All the facies are referred to as estuarine bay (indicated as “b–c” in Text-fig. 1B). The above mentioned first three parts of the deposits (see Text-fig. 1B/a–c) correspond to coastal transitional marine facies which are related to the Lithotamnium Limestone Fm. The *Lithotamnium* Limestone Formation is always conformably overlain by hemipelagic deposits with *Turborotalia multiloba* ROMEO, 1965 whose first occurrence has been astronomically dated at 6.415 Ma (Hilgen and Krijgsman 1999, Sierro et al. 2001). (3) The sequence evolves upwards into open-marine shelf diatom-rich deposits, equivalent to the Messinian Tripoli Formation. They consist of diatomitic marls, bio-lithoclastic calcarenites, marly limestones and calcareous marls, and a massive muddy deposit produced by a mass-flow mechanism. The thickness of this interval is approximately 30 metres divided into six cycles (indicated as “d_{1–6}” in Text-fig. 1B). Each cycle is constituted of dark-grey calcareous marls and finely laminated diatomitic marls. The marls show a decrease in thickness throughout the interval, ranging from about 180 cm in the first cycle to 50 cm in the sixth. The fossil content consists in rare dreissenids, abundant bivalves (primarily *Corbula gibba* OLIVI, 1792, oysters, cardiids, semelids, tellinids) and planktonic foraminifers. The diatomitic marls are constituted by clastic-biogenic couplets made up of siliceous laminar mats, felted

diatom frustules, calcisiltite laminae, abundant siliceous sponge spicules and fish remains. The skeleton of the ochotonid *Prolagus* cf. *apricenicus* Mazza (see Mazza et al. 1995) occurred at this level, where several plant-bearing horizons have also been found.

Material and methods

The Capo di Fiume site is located in central Italy on the north-eastern slope of the Monte Porrara, along the Aventino River, a few kilometres to the south of the village of Palena (Chieti, Abruzzo, Italy). The Pollenzo site is located near Alba (Cavallo et al. 2008, Dela Pierre et al. 2011), in NW Italy, and its plant fossils were preliminarily introduced in a popular publication (Cavallo et al. 2008). This site yielded, in addition to the palm foliage, only a single leaflet impression assigned to *Engelhardia orsbergensis* (WESSEL et WEBER) JÄHNICHEN, MAI et WALTHER (Bertini and Martinetto 2014).

The studied leaf fossils from the Capo di Fiume and Pollenzo near Alba sites are determined only on the basis of morphological features. Cuticle preparation was attempted on several leaves from the Capo di Fiume site (except the feather palm, which was evidently preserved as an impression), but was always unsuccessful.

The complete palaeontological collection including plants recovered from Capo di Fiume is housed in the “Museo Geopaleontologico Alto Aventino” of Palena (MGPA), where most of the specimens form a part of the “Di Carlo collection”. The figured material from Pollenzo near Alba is housed in the collection of the Museo Civico F. Eusebio (ALB). A binocular magnifying glass was used for observation of details preserved in leaf material. Currently accepted morphological terminology for angiosperm foliage with the exception of palms follows Ellis et al. (2009). The current terminology for palm foliage is in accordance with the published palm monograph (Dransfield et al. 2008).

Systematic palaeontology

The systematic section follows the classification scheme published by the Angiosperm Phylogeny Group (2009) and authors Reveal and Chase (2011).

Subclass **Magnoliidae** NOVÁK ex TAKHTAJAN
(angiosperms)

Superorder **Liliana** TAKHTAJAN (monocots)

Order **Arecales** BROMHEAD

Family **Arecaceae** BERCHTOLD et J. PRESL (palms)

Genus ***Phoenicites*** BRONGNIART emend. READ et HICKEY

Type. *Phoenicites pumila* BRONGNIART, 1828, p. 121, diagnosis generico-specifica.

Comments. The type of the fossil genus *Phoenicites* as emended by Read and Hickey (1972) is a fragmentary palm leaf from the Eocene of France (Chartreuse-de-Brivés, Haute-Loire, France), housed in the Muséum National d’Histoires Naturelles, Paris, No. F. 1934, collection Bertrand-Roux).

Phoenicites sp.

Pl. 1, Fig. 1–4; Pl. 2, Fig. 1–2

2008 cf. *Calamus* sp.; Bertini and Martinetto, p. 110, pl. 1, fig. 9.

Material. An impression and its counterpart of an incomplete palm leaf (Capo di Fiume) and one incomplete palm leaf (Pollenzo near Alba).

Description. Leaves pinnately dissected (feather palm), simple. Midrib 179 and 297 mm long, straight, at least 3 and 5 mm wide, not tapering significantly over its last quarter. Segments often fragmentary, reduplicate on axial surface, decurrent, sessile, lanceolate to rarely oblong, up to 175 and 164 mm long, up to 12 mm wide, alternate to (sub)opposite in apical part of the blade, originating at an angle of 40° to 55°, irregularly spaced between 2 to 17 mm. Segment bases asymmetrical and cuneate, apices attenuate and often blunt, margin entire, venation poorly preserved, central segment vein distinct, straight, about 1.5 mm wide, venation network thin, parallel, almost indistinct.

Discussion. Fossil evidence of palm remains from the Palaeogene and Neogene of Europe is relatively common and represented by isolated stems, spikes, fruits, seeds and leaves. Read and Hickey (1972) revised the classification of fossil palm and palm-like leaves and provided a key for the nine palm genera including the lists of synonyms. The studied material shows distinct reduplicate and entire leaf segments; hence, it is possible to assign the specimens to the fossil-genus *Phoenicites*. Read and Hickey (1972, p. 134) also revised the original palm leaf material from Italy and synonymised *Geonomites saturnia* VISIANI (Visiani 1864, pl. 21, fig. 1) and *Hemiphoenicites dantesiana* VISIANI (Visiani 1864, p. 451, pl. 18) with *Phoenicites danteana* MASSALONGO (Massalongo 1858, p. 774) from the Eocene sediments in the surroundings of Verona. Similarly Read and Hickey (1972, p. 134) re-assigned foliage of *Kentites pratecinensis* BUREAU (Bureau 1896, p. 285) known from the Tertiary sediments of Pratecini, and *Pritchardites wettinioides* (MASSALONGO) BUREAU (Bureau 1896, p. 284) to the genus *Phoenicites*. The revised specimens included the type material of *Phoenicites wettinioides* MASSALONGO (Massalongo 1858, p. 772). Still not revised are the abundant feather palm leaves (incl. *Phoenicites*) from the Oligocene locality Santa Giustina in NW Italy (Bonci et al. 2011).

The genus *Phoenicites* was typified by *Phoenicites pumila* BRONGNIART (Brongniart 1828, p. 121) plant material described from the above-mentioned Eocene deposit in Chartreuse-de-Brivés, France. Similar Eocene finds from the Eocene sites of Schkopau (Friedrich 1883, p. 17, pl. 3), Knau, Nobitz, Klaus, Haselbach and Frohnsdorf (Mai and Walther 1985, pp. 132–133, pl. 35, figs 5–6, pl. 36) and Geiseltal – Kayna (Rüffle 1976, p. 391, pl. 44, fig. 3, pl. 46, figs 1–5, text-fig. 10), Germany are described as *P. borealis* FRIEDRICH. In addition to the leaf morphology, this material is also partly characterized by the anatomical structure which suggests closer affinity to the living genus *Chamaedorea* WILLDENOW (Rüffle 1976). However, such an affinity has not been proven for the other material described by Friedrich (1883) and Mai and Walther (1985, p. 133). Other feather palm foliage from

the Eocene, Oligocene and Miocene of Europe (e.g., Knobloch et al. 1996 – Staré sedlo, as *P. salicifolius* (K. PRESL) UNGER, Kvaček 2004 – Flörsheim, as ? *Phoenicites* sp. etc.) have been assigned to *Phoenicites*. Morphologically similar leaves and fragments are also known as *Calamus noszkyi* JABLONSKY (Jablonszky 1914, pp. 236–244, pl. 9, figs 1–3) from the early Miocene sites of the Czech Republic (Kvaček and Hurník 2000), Hungary (Jablonszky 1914, Hably 1983) and Slovakia (Sitár and Kvaček 1997). In these cases the leaf segments are fine serrate and often associated with sheath fragments and spines of *Calamus daemonorops* (UNGER) CHANDLER. However, *Calamus* LINNAEUS is a living genus and its fossil records require revision. The morphologically preserved leaf impressions or compressions such as those from Capo di Fiume and Pollenzo do not exhibit sufficient traits that would allow assignment of these remains to living genera (Read and Hickey 1972). Therefore the assignment to a fossil-genus is appropriate by virtue of the definite morphological features observed in the fossils.

A further example of this scenario was provided by Ettingshausen (1887, 1891, p. 261, pl. 24, fig. 25), who assigned a fossil leaf from early Miocene deposits of New Zealand (*Seaforthia zeelandica* ETTINGSHAUSEN, a synonym of *Ptychosperma elegans* (R. BROWN) BLUME) to the living genus *Seaforthia* R. BROWN. The original material was supplemented by new specimens of foliage, inflorescences and fruits from the Manuhierikia Group and reassigned as *Phoenicites zeelandica* (ETTINGSHAUSEN) POLE (Pole 1993, pp. 287–288, figs 2–3). Pole (1993) compared this species with the extant New Zealand palm *Rhopalostylus sapida* H. WENDLAND et DRUDE, however he concluded that the fossil palm is significantly different in leaf venation and in the shape of the nuts from both *Rhopalostylus* H. WENDLAND et DRUDE and *Ptychosperma* LABILLARDIÈRE (syn. *Seaforthia* R. BROWN). Likewise, the morphological features of the European Miocene fossils are comparable with at least two modern genera documented in the Cainozoic of this continent by fossils more reliable than leaves (*Calamus* sheath fragments and spines and *Phoenix* seeds – e.g., Bůžek 1977, Hably 1983, Sitár and Kvaček 1997, Kvaček and Hurník 2000). A precise determination of the Capo di Fiume and Pollenzo fossils at the species level is also problematic because of the numerous fossil-species which have been described in the area (Massalongo 1858, Visiani 1864, Bonci et al. 2011), but which have not yet been revised. Hence the use of the open nomenclature *Phoenicites* sp. is preferable in our case.

The associated flora of Capo di Fiume

We offer a preliminary review of the flora of Capo di Fiume, Palena, to accompany the above treatment of the *Phoenicites* sp. specimen.

Conifers Pinaceae LINDLEY

Pinus LINNAEUS subgen. *Pinus* LINNAEUS, is represented by the remains of an incomplete seed cone identified as *P. cf. hampeana* (UNGER) HEER, ca. 50 mm long and 15 mm wide (Pl. 3, Fig. 3) with its external mould. The material is not well

preserved, quite abraded and without details of the apophyses. It is similar to pine cones of this fossil species widely distributed in the Miocene (see Mai 1986), and also present in the upper Miocene of Greece (Vegora) and in the Pliocene of Italy. The associated needles in fascicles of two (Pl. 3, Fig. 4) are best assigned to a separate fossil-species, *Pinus hepios* (UNGER) HEER, even if possibly produced by the same plant. The foliage of another co-occurring pine species, assigned to *Pinus rigios* (UNGER) ETTINGSHAUSEN (Pl. 3, Fig. 5), differs in its much longer needles found in fascicles of three. This fossil species is also widely distributed in the European Miocene, mainly in the lignite facies.

Cupressaceae GRAY

Tetraclinis brachyodon (BRONGNIART) MAI et WALTHER was recovered as an almost complete foliage shoot with flattened leafy segments (Pl. 3, Fig. 1). It is a xeromorphic species ancestral to the living Mediterranean *Tetraclinis articulata* (Vahl) Masters, which is a relict conifer that has survived since the Eocene (Kvaček et al. 2000). It was rarely recorded in late Miocene floras (Givulescu 1975).

Cupressus rhenana (KILPPER) MAI et E. VELITZELOS, (Pl. 3, Fig. 2) was recovered as foliage shoots with decussate, isomorphic scale-like leaves and apically attached pollen cones. This conifer is typically represented in the Miocene flora of Kymi and Vegora (Kvaček et al. 2002) in addition to a few other occurrences in Western Europe (Kilpper 1968, as *Cupressoconus rhenanus* KILPPER).

Chamaecyparis sp. is represented by foliage shoots with decussate, scale-like, imbricate, adpressed and persistent leaves (Pl. 3, Fig. 6).

Angiosperms

Magnoliaceae JUSSIEU

The morphotype assigned here to *Magnolia* cf. *liblarensis* (KRÄUSEL et WEYLAND) KVAČEK (Pl. 3, Fig. 7) is characterized by a simple elliptic entire-margined leaf with cuneate base and relatively dense brochidodromous venation. Its definite identification requires anatomical characteristics, including mesophyllous lens-shaped oil cells and other details of the cuticle structure which are not available in the Capo di Fiume material. It is common in the Miocene of Europe, mainly in the lignite basins (Schneider 2007) and compares well with the living small-leaved magnolias growing in wet habitats, e.g., *M. virginiana* LINNAEUS.

Monocotyledonae DE CANDOLLE

In addition to the palm foliage treated in the previous section of this text, fragments only of monocot foliage have been recovered. Some are provisionally assigned to *Typha* sp. (Pl. 3, Fig. 8), although other affinities are possible for such strap-like leaf fragments.

? Fagaceae DUMORTIER

One morphotype of entire-margined petiolate leaf is assigned here to cf. *Trigonobalanopsis rhamnoides* (ROSSMÄSSLER) KVAČEK et WALTHER (Pl. 3, Fig. 9). It is an incomplete elliptic petiolate leaf with entire margin and

brochidodromous venation. The leaf form resembles foliage with rhamnoid venation produced by regularly spaced secondaries so typically developed in this fossil fagaceous element, distributed in the Eocene to Pliocene of Europe (Kvaček and Walther 1988). For a definite attribution of the material it is necessary to have evidence of the epidermal anatomy which is not available in the examined specimen. *Trigonobalanopsis rhamnoides* was well represented in the Neogene of Italy having been previously called *Castanopsis toscana* (BANDULSKA) KRÄUSEL et WEYLAND (Kräusel and Weyland 1950, Fischer and Butzmann 2000).

Rhamnaceae JUSSIEU

A single leaf impression is attributable to *Paliurus tiliaefolius* (UNGER) BŮŽEK, although this ovate leaf with widely cuneate base and blunt apex differs in its entire margin from most records occurring in the European Miocene (see Bůžek 1971). The type population from the middle Miocene of Parschlug (Kovar-Eder et al. 2004) confirms the foliage variation of this plant. It is a mesophytic Miocene element contrary to the extant Mediterranean *Paliurus spina-christi* Miller that adapted as a relict to the present summer dry climate in southern Europe.

Myricaceae RICHARD ex KUNTH

The morphotype assigned here to *Myrica* cf. *lignum* (UNGER) SAPORTA (Pl. 3, Fig. 11) represents a simple, petiolate elliptic leaf with entire margin and regular eucaptodromous secondaries. The genetic affinity is somewhat doubtful, not supported by epidermal traits characteristic of this species, namely biseriate stalks of glandular trichomes (Kovar 1982).

Juglandaceae de CANDOLLE ex PERLEB

A leaflet fragment is attributable to *Engelhardia orsbergensis* (WESSEL et WEBER) JÄHNICHEN, MAI et WALTHER on account of its finely serrate margin and sessile asymmetrical base. This extinct mesophytic element accompanies late Palaeogene and Neogene floras of Europe (Jähnichen et al. 1977) mostly comprised of thermophilous aspects (mastixioid assemblages). It is rare in the late Miocene and Pliocene deposits of Europe (e.g., Kvaček et al. 1995).

Berberidaceae JUSSIEU

Berberis sp. is a small simple sub-sessile and spatulate leaf with fine venation. In this aspect it is similar to the much larger foliage of *Berberis berberidifolia* (HEER) PALAMAREV et PETKOVA known from the European Miocene (Li et al. 2010).

Aquifoliaceae BERCHTOLD et J. PRESL

An almost complete leaf with coarsely simple dentate margin is assigned to *Ilex* sp. and comparable with *Ilex geissertii* KVAČEK, TEODORIDIS et WANG (Kvaček et al. 2009) and morphologically similar fossil species known from the Pliocene of Europe.

? Sapindaceae JUSSIEU

An incomplete basal part of an oval leaflet with relatively long petiolule is identified here with some hesitation to cf. *Sapindus falcifolius* (A. BRAUN) A. BRAUN. Such morphotypes occur commonly in the Miocene of Europe (e.g., Bůžek 1971) but their affinities to the genus *Sapindus* LINNAEUS have not been proved so far.

Leguminosae JUSSIEU

Several morphotypes of legume leaflets were recognized here: *Leguminosites* sp. 1 (Pl. 3, Fig. 16, relatively large obovate leaflet, very shortly petiolulate, emarginate at apex and slightly cordate at base), *Leguminosites* sp. 2, (Pl. 3, Figs 17, 18, complete, shortly petiolulate oval leaflets), *Leguminosites* sp. 3 (Pl. 4, Fig. 1, complete, shortly petiolulate oval leaflet with asymmetric widely cuneate base and shortly attenuate apex), *Leguminosites* sp. 4, (Pl. 4, Fig. 2, complete, shortly petiolulate oval leaflet with cuneate base and blunt apex), and *Leguminosites* sp. 5 (Pl. 4, Figs 3, 4 incomplete, widely oval to obovate leaflets with brochidodromous venation). The exact affinities within the Leguminosae remain open.

Angiosperms incertae sedis

A monopodially branched inflorescence/infructescence (Pl. 4, Figs 5, 6) with densely, regularly disposed alternate sessile bodies on its branches, each supported by a small bract. At first sight it resembles a fragmentary palm inflorescence but the presence of bracts supporting each flower is an uncommon feature in palms. Another umbel-like inflorescence (Pl. 4, Figs 7–8) resembles *Butomus* LINNAEUS. It differs from a similar “*Butomus*” *heerii* ETTINGSHAUSEN (Kvaček and Teodoridis 2011, Eocene of North Bohemia) by flower-like terminations of the branches. In both cases the affinity to the Butomaceae MIRBEL is improbable but can not be ruled out.

Some morphotypes of foliage assigned to *Dicotylophyllum* SAPORTA obviously belong to eudicots but their affinities can not be more exactly identified: *Dicotylophyllum* sp. 1 (Pl. 4, Fig. 9, complete longely petiolate widely elliptic leaf with brochidodromous venation and entire margin resembling “*Celastrus*” *persei* UNGER), *Dicotylophyllum* sp. 2 (Pl. 4, Fig. 10, complete petiolate/petiolate obovate leaf/leaflet with rounded apex, narrowed base and entire margin) and *Dicotylophyllum* sp. 3 (Pl. 4, Fig. 11, complete long petiolate oblong entire-margined leaf, rounded at apex and cuneate at base).

Two disseminules were assigned to *Carpolites* sp. 1 (Pl. 4, Fig. 12, impression of a flattened oval seed) and *Carpolites* sp. 2 (Pl. 4, Fig. 13, an incomplete elliptic fruit with indistinct central axis and eight pairs of oval seeds oppositely attached).

The leaf assemblage from the locality Capo di Fiume, Palena is characterized by the absence of deciduous broad-leaved elements (e.g., *Fagus* LINNAEUS, deciduous *Quercus* LINNAEUS, *Alnus* MILLER) as well as lauroid elements (e.g., *Laurophyllum* GOEPPERT, *Daphnogene* UNGER) and swampy conifers (e.g., *Taxodium* RICHARD, *Glyptostrobus* ENDLICHER and *Sequoia* ENDLICHER). It typically shows a predominant occurrence of sclerophyllous

to mesophytic elements including conifers, such as *Tetraclinis brachyodon* (BRONGNIART) MAI et WALTHER, *Cupressus* LINNAEUS, *Chamaecyparis* SPACH, *Pinus* sp. div., five morphotypes of Leguminosae sp. div., *Ilex* sp., cf. *Berberis* LINNAEUS, *Paliurus*. A few other elements, such as *Magnolia* LINNAEUS, cf. *Trigonobalanopsis* KVAČEK et WALTHER, cf. *Sapindus* and *Engelhardia* as well as *Dicotylophyllum* sp. div. can be interpreted as mesophytic elements. *Myrica* LINNAEUS, *Salix* LINNAEUS and *Typha* LINNAEUS represent azonal wet soil (riparian) to swamp elements. Also one inflorescence and one infructescence of unknown angiosperms, respectively showing some morphological affinity to Butomaceae (Pl. 4, Figs 7–8) and to an unknown palm (Pl. 4, Figs 5–6). As we mentioned above, the floristic composition of Capo di Fiume shows a higher abundance of elements characteristic of sub-humid vegetation. However, it also includes common mesophytic elements which are also known from the other Messinian floras from Italy (Bertini and Martinetto 2008, 2011, Sami et al. 2014), France (Roiron 1991) and Greece (Kvaček et al. 2002).

Palaeoenvironmental signals

According to the composition of the associated flora and sedimentological signals it is possible to interpret the general vegetational character of the Capo di Fiume plant assemblage as coastal non-swampy, wet soil (riparian) vegetation with high abundance of woody elements growing under semi-arid to sub-humid climatic conditions. The closest palaeoecological affinity of the Capo di Fiume vegetation may be found in the early Miocene plant assemblage of Kymi (Evia, Greece) originally described by Unger (1867) and partly revised by Velitzelos et al. (2002, 2014).

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Explanations to the plates

PLATE 1

Phoenicites sp., Capo di Fiume, Palena, MGPA, no. PalB7

1. Impression of incomplete pinnate leaf, scale bar 30 mm.
2. Counterpart of the leaf, scale bar 30 mm.
3. Detail of the pinnae venation with distinct midribs and almost indistinct parallel venation network, scale bar 10 mm.
4. Detail of the leaf basal part with thick rachis and decurrent, alternate attachment of reduplicate pinnae with asymmetric cuneate base and distinct midrib, scale bar 10 mm. Photo M. A. Rossi.

PLATE 2

Phoenicites sp., Pollenzo near Alba, ALB, no. P01110

1. Impression of incomplete pinnate leaf, scale bar 50 mm.
2. Detail of the leaf basal part with thick rachis and decurrent, alternate to subopposite attachment of reduplicate pinnae with asymmetric cuneate base, distinct midrib and parallel venation, scale bar 10 mm. Photo O. Cavallo.

PLATE 3

Associated flora of Capo di Fiume, Palena, MGPA

1. *Tetraclinis brachyodon* (BRONGNIART) MAI et WALTHER, almost complete foliage shoots with flattened leafy segments, no. PalB30, scale bar 10 mm.

2. *Cupressus rhenana* (KILPPER) MAI et VELITZELOS, foliage shoots with decussate, scalelike leaves and apically attached pollen cones, no. PalB202, scale bar 10 mm.
3. *Pinus* subgen. *Pinus*, PalB180, incomplete seed cone remains with external impression, scale bar 10 mm.
4. *Pinus hepios* (UNGER) HEER, incomplete needles in fascicles of two, no. PalB11, scale bar 10 mm.
5. *Pinus rigios* (UNGER) ETTINGSHAUSEN, incomplete needles in fascicles of three, no. PalB10, scale bar 10 mm.
6. *Chamaecyparis* sp., foliage shoots with decussate, scale-like, imbricate, adpressed and persistent leaves, no. PalB46, scale bar 10 mm.
7. *Magnolia* cf. *liblarensis* (KRÄUSEL et WEYLAND) KVAČEK, simple elliptic leaf with cuneate base and brochidromous venation, no. PalB153, scale bar 10 mm.
8. *Typha* sp., fragment of strap-like leaf, no. PalB15, scale bar 10 mm.
9. cf. *Trigonobalanopsis rhamnoides* (ROSSMAESSLER) KVAČEK et WALTHER, incomplete elliptic petiolate leaf with entire margin and brochidromous venation, no. PalB132, scale bar 10 mm.
10. *Paliurus tiliaefolius* (UNGER) BŮŽEK, ovate leaf with widely cuneate base blunt apex and parallelodromous venation, no. PalB192, scale bar 10 mm.
11. *Myrica* cf. *lignitum* (UNGER) SAPORTA, simple, petiolate elliptic leaf with entire margin, NO. PalB208, scale bar 10 mm.
12. *Engelhardia orsbergensis* (WESSEL et WEBER) JÄHNICHEN, MAI et WALTHER, incomplete ovate leaflet with coarsely serrate teeth, no. PalB134/c, scale bar 10 mm.
13. *Berberis* sp., small simple subsessile and spatulate leaf, no. PalB12/b, scale bar 5 mm.
14. *Ilex* sp., almost complete leaf with coarsely simple dentate margin, no. PalB181, scale bar 10 mm.
15. cf. *Sapindus falcifolius* (A. BRAUN) A. BRAUN, incomplete basal part of oval leaflet with relatively long petiolule, no. PalB101, scale bar 10 mm.
16. *Leguminosites* sp. 1, relatively big petiolulate obovate leaflet with emarginate apex and slightly cordate base, no. PalB2, scale bar 10 mm.
17. *Leguminosites* sp. 2, complete shortly petiolulate oval leaflet, no. PalB220, scale bar 3 mm.
18. *Leguminosites* sp. 2, complete petiolulate oval leaflet, no. PalB196, scale bar 3 mm.

PLATE 4

Associated flora of Capo di Fiume, Palena, MGPA

1. *Leguminosites* sp. 3, complete shortly petiolulate oval leaflet with asymmetric widely cuneate base and shortly attenuate apex, no. PalB6, scale bar 10 mm.
2. *Leguminosites* sp. 4, complete shortly petiolulate oval leaflet with cuneate base and blunt apex, no. PalB152, scale bar 10 mm.
3. *Leguminosites* sp. 5, incomplete widely oval leaflet with brochidromous venation, no. PalB136, scale bar 10 mm.
4. *Leguminosites* sp. 5, incomplete obovate leaflet with blunt apex, no. PalB200, scale bar 10 mm.

5. Unspecified inflorescence resembling palms, no. PalB4, scale bar 10 mm.
6. Detail of Fig. 5, scale bar 3 mm.
7. Umbel-like inflorescence, no. PalB3, scale bar 10 mm.
8. Detail of Fig. 7, scale bar 5 mm.
9. *Dicotylophyllum* sp. 1, complete, longly petiolate widely elliptic leaf with brochidodromous venation and entire margin resembling *Celastrus persei* UNGER, no. PalB32, scale bar 10 mm.
10. *Dicotylophyllum* sp. 2, complete, petiolate/petiolulate obovate leaf/leaflet with rounded apex, narrowed base and entire margin, no. PalB221, scale bar 5 mm.
11. *Dicotylophyllum* sp. 3, complete, longly petiolate oblong leaf with rounded apex, cuneate base and entire margin, no. PalB43, scale bar 10 mm.
12. *Carpolites* sp. 1, impression of flattened oval seed, no. PalB151, scale bar 5 mm.
13. *Carpolites* sp. 2, incomplete elliptic fruit with indistinct central axis with 8 pairs of oval seeds oppositely attached, no. PalB8, scale bar 10 mm.

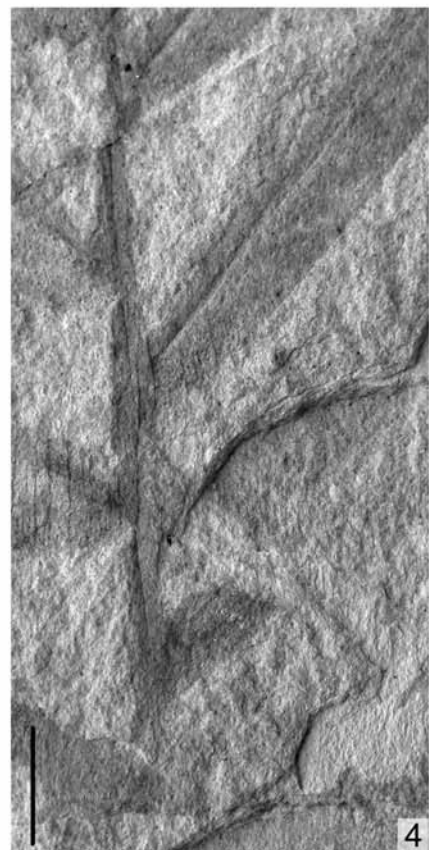
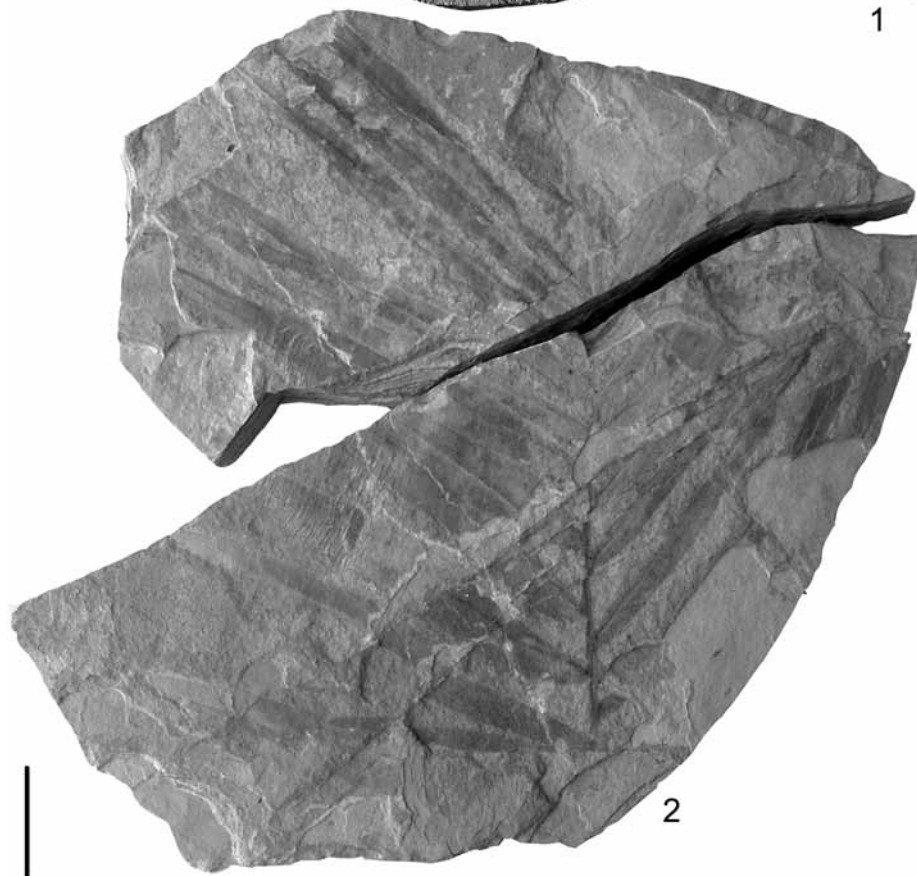
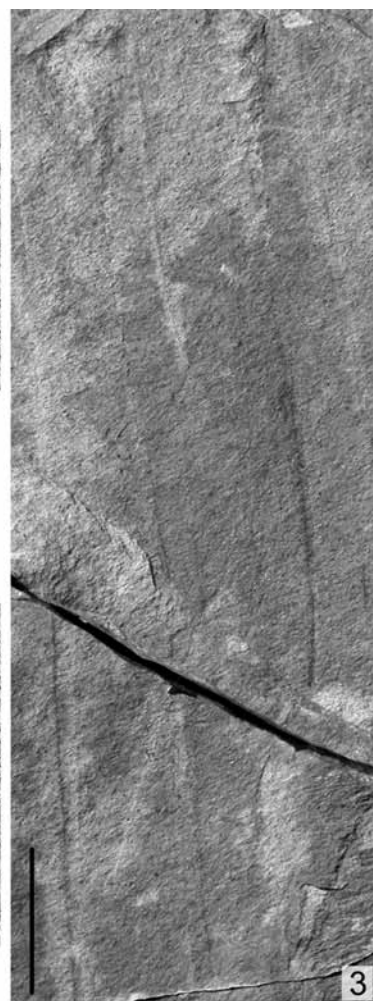
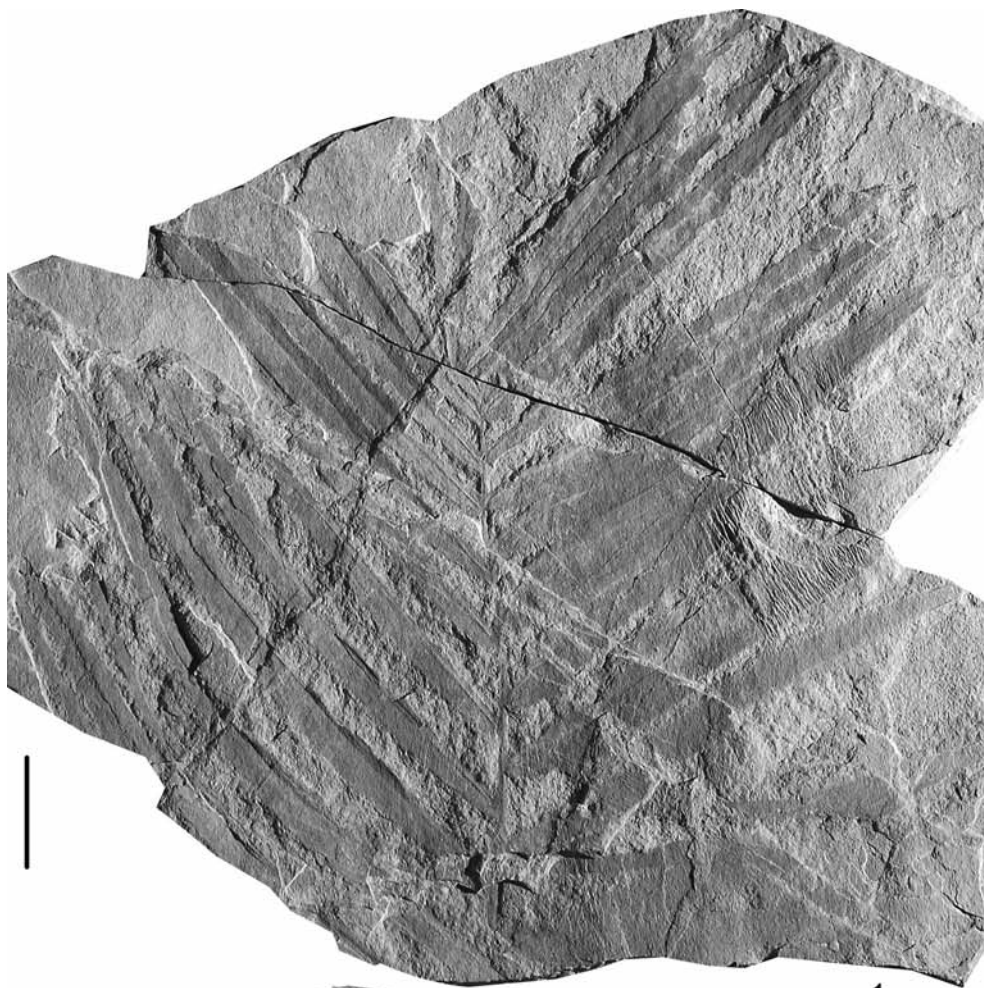
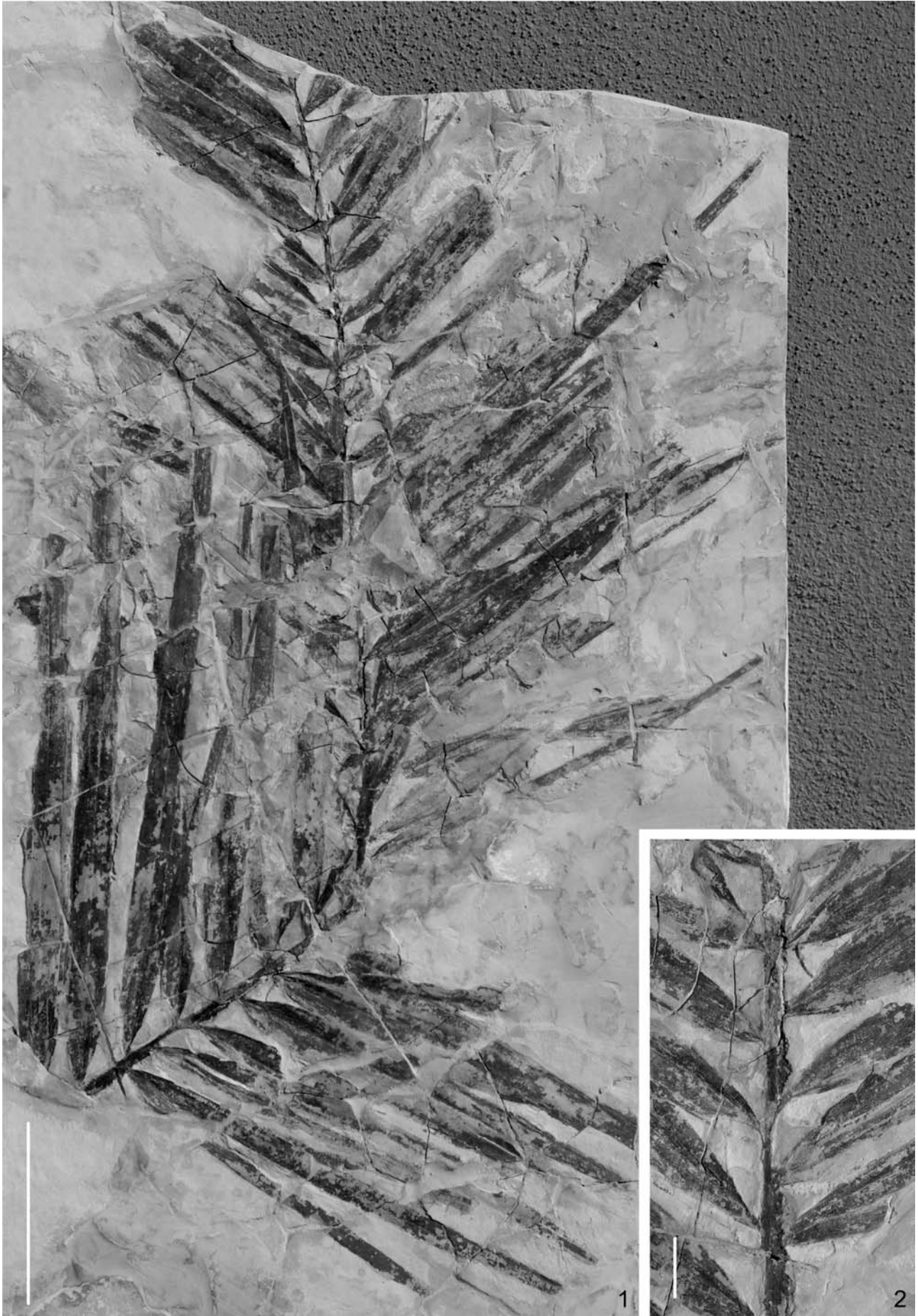


PLATE 2



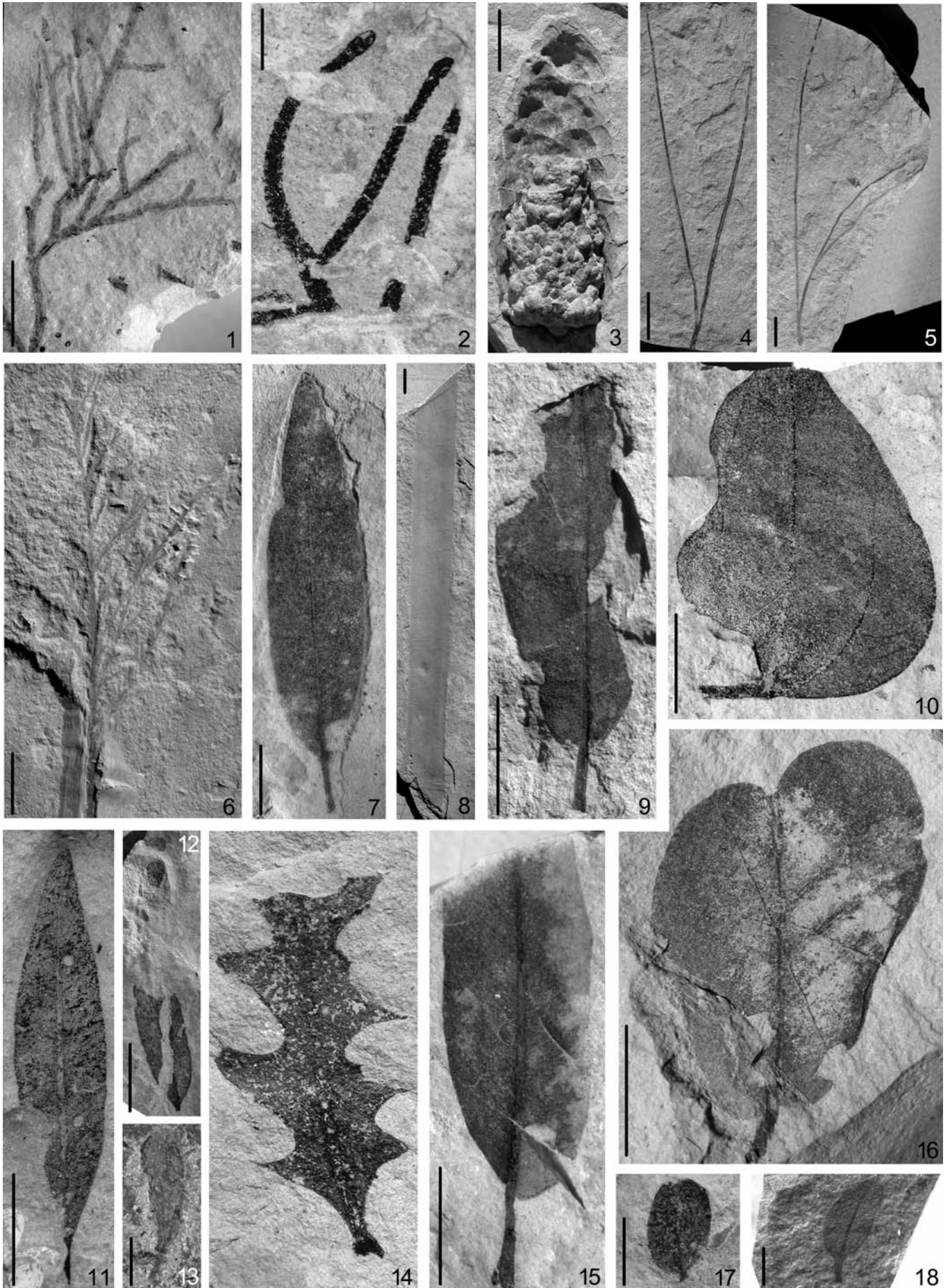


PLATE 4

