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REVIEW OF THE LATE OLIGOCENE FLORA OF MATRÝ NEAR SEBUZÍN (ČESKÉ STŘEDOHOŘÍ MTS., THE CZECH REPUBLIC)

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Abstract: The Oligocene palaeontological locality on Matrý Hill near Sebuzín in the České středohoří Mts., North Bohemia, belongs to the Děčín Formation and is dated to 30.8–24.7 Ma according to the regional stratigraphy. It has yielded, in addition to insects from the Heteroptera group, a fossil bee *Apis petrefacta* and palaeobatrachid frogs, also numerous plant remains. Their recovery began in 1996. The plant fossil assemblage consists mostly of leaf impressions, occasionally accompanied by casts or impressions of fruits. Noteworthy are records of a fern *Woodwardia muensteriana*, conifers *Pinus* cf. *rigios*, *P.* cf. *hepios*, *Calocedrus suleticensis*, *Tetraclinis salicornioides*, *Torreya bilinica*, cf. *Cephalotaxus parvifolia* and numerous angiosperms, e.g. *Liriodendron haueri*, *Daphnogene cinnamomifolia*, *Platanus neptuni*, *Cercidiphyllum crenatum*, *Sloanea artocarpites*, *Ulmus pyramidalis*, *Celtis pirskenbergensis*, *Carya fragiliformis*, *C. quadrangula*, *Betula brongniartii*, *B. dryadum*, *Alnus rhenana*, *A.* cf. *kefersteinii*, *Carpinus grandis*, *Ostrya atlantidis*, *Acer crenatifolium*, *A.* cf. *palaeosaccharinum*, *A. integrilobum* and *Craigia bronnii*. Several angiosperm foliage specimens of both monocots and dicots have not yet been identified to a particular genus and species. The fossil plant assemblage at Matrý corresponds to two vegetation types, i.e. azonal riparian forest and zonal mixed mesophytic forest, as corroborated by the Integrated Plant Record vegetation analysis. The vegetation thrived undera humid climate, characterized by average values of MAT (13.4 °C), WMMT (23.8 °C), CMMT (3.6 °C) and MAP (1,117 mm). The Matry fossil flora is similar in composition to the flora of Žichov from the same Oligocene Děčín Formation in the České středohoří Mts.

Key words: plant, animal, fossils, České středohoří Mts., North Bohemia, late Oligocene

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Introduction

The palaeontological locality on the slope of Matrý Hill near Sebuzín in the North Bohemian volcanic belt of the České středohoří Mts. has been known since its discovery by Miroslav Radoň in 1996 (Radoň 2001, 2002, Radoň et al. 2006). This relatively new site in North Bohemia has not yielded numerous fossils but may fill the gap in the stratigraphical succession of palaeontological localities in Central Europe (see Akhmetiev et al. 2009). So far, several monographic treatments of the flora of the České středohoří Mts. have been produced (e.g. Kvaček 2002, Kvaček and Teodoridis 2007) and may serve as a basis for wider comparisons of environment changes during the Palaeogene in Central Europe.

Collecting activities in this locality have continued since its discovery in 1996 until the present. Radoň (2002) reported on the flora of the area and gave a detailed account on the so far recovered fossils together with geological and palaeontological data from the adjacent sites of Holý Kluk, Kundratice, Roudný, Trupelník, Řisuty, Sedlo, Rytina, Skalice, Větruše and Žežice. Later, Sedláčková (2004) produced an idealized geological section of the outcrop and described in detail sedimentology. Soukupová (2004) published the first evaluation of the vegetation and environment, and Akhmetiev et al. (2009) published a review of the flora together with that from the adjacent sites and compared it with similar volcanic floras of the Sikhote Alin' in the Far East of Russia. Since 2009 no further detailed study has appeared characterizing this interesting palaeontological locality. Before a monograph of the palaeontology of the České středohoří Mts. can be published for the wider audience in the Czech Republic

Text-fig. 1. (a) View downslope from the Matrý Hill (locality indicated by red arrow). (b) Sampling outcrop of tuffitic aleuropelite rich in plant macrofossils.

(Dvořák and Radoň in prep.), the present study is required as it contributes new material on the characteristics of the Palaeogene, namely its flora in this region (see Radoň 2001, 2002, Radoň et al. 2006).

Geological and palaeontological overview

The site at Matrý (formerly Marterey, Matrai; GPS: 50°36'8.475"N, 14°5'20.183"E) is on a small volcanic hill of height 593.9 m. It is situated 2.5 km NE of the village of Sebuzín and 5.5 km SSE of the town of Ústí nad Labem (Kvaček and Walther 1998: 3, text-fig. 2). It is formed by effusions of compact and alternate-brecciaed olivine basaltoids and non-olivinic basalts intruded into volcaniclastic rocks. The locality belongs to the Děčín Formation (sensu Cajz 2000) and is assigned to the upper Oligocene part of the České středohoří volcanic complex. The fossiliferous layers crop out on the slope within trachybasaltic pyroclastics in interchanging grey, fine grained tuffite and thinly bedded diatomite (see Text-fig. 1). According to Sedláčková (2004), the sedimentation is cyclic due to volcanic activity and climate changes. Three regular cycles and one uppermost inverse cycle could be identified here (Sedláčková 2004). Each cycle began with coarse-grained tuffitic psammite. Upwards various numbers of rhythms have been laid down in positive gradation. The top of the cycles are represented by red to brown silty tuffite which were deposited in calm water containing thin layers of diatomite. The third cycle includes a layer of tuffitic psammite with silty lenses which may indicate the beginning of the inverse cycle. This cycle also includes the fossiliferous layer formed by tuffitic diatomite.

The Děčín Formation, dated to 30.8–24.7 Ma, on Matrý Hill is overlain at the top of the hill by olivine-rich lava flow of the Dobrná Formation, which is 24.0–19.3 Ma in age (Cajz 2000), however it covers the fossiliferous layer. Radiometric dating of the rocks directly connected to the fossiliferous layer, which was deposited shortly before the upper limit of the Děčín Formation, is still required. Freshwater sedimentation can be proven by the presence of fossil crayfish fauna and the not yet worked out Heteroptera insects belonging to either Notonectidae or Corixidae (J. Prokop, pers. com.). A fossil honeybee *Apis petrefacta* Radoň (Radoň 2014) must be added to the list of fauna which also includes three incomplete frog skeletons belonging, according to Z. Roček (pers. com.), to palaeobatrachids (*Palaeobatrachus* sp.). In the diatom flora, centric types of *Melosira* dominate (Řeháková 1967). Sedláčková (2004) also noted *Campelodiscus* sp. (determination by Dr. Václav Houk).

Material and methods

The fossil leaves studied are preserved as impressions. Attempts to obtain epidermal structures from these impressions failed. Identifications of the palaeobotanical material relies on gross morphological features. A small part of the plant fossils represents fruits, often preserved as casts. Most of the material was collected by the third author with the aid of collaborating colleagues over several visits to the site from 2000 until the present. The studied specimens are housed in the Regional Museum in Teplice and partly illustrated by Radoň (2002: photos 4–6, pls 1–3). The collections used by Soukupová (2004), who participated in collecting and described some material in her PhD thesis, is partly housed in the Regional Museum in Teplice. The palaeozoological part of the collection was partly published as noted above, and further will be described separately in collaboration with specialists from abroad.

The first preliminary lists of fossil plant taxa appeared in a review of the flora of the České středohoří Mts. by Radoň (2001, 2002). Kvaček and Walther (1998: 3) noted younger aspects of this flora recovered by Radoň near the top of Matrý Hill. This was later the subject of Soukupová's PhD thesis (2004) and a collaborative account by Akhmetiev et al. (2009). In her thesis, Soukupová (2004) lists 21 taxa with specimen frequencies. The present treatment is based on the collection made by the third author including recent additions.

Systematic palaeobotany

The arrangement of taxa follows the system introduced by the Angiosperm Phylogeny Group IV (APG IV 2016).

Ferns
Blechnaceae C.Presl

Woodwardia Sm.

Woodwardia muensteriana (C.Presl in Sternb.) Kräusel
Pl. 1, Figs 1–2

1838 *Pecopteris muensteriana* C.Presl in Sternb., p. 154, pl. 36, fig. 2.
1921 *Woodwardia muensteriana* (C.Presl in Sternb.) Kräusel, p. 336, pl. 11, figs 2, 6–8, pl. 12, fig. 4.
2009 *Woodwardia muensteriana* (C.Presl in Sternb.) Kräusel; Akhmetiev et al., pp. 96, 117, pl. 12, fig. 10.

Material studied. Sterile pinna PA 1428.1, 1428.2 (counter-impression).

Description. A fragmentary serrate pinna which shows characteristic areolation of the medial venation and thus allows safe identification of this sterile fern fragment.

Discussion. This fern was occasionally noted in the Palaeogene of the České středohoří Mts. in tuffitic deposits near Březiny (Birkigt) – see the published, but not illustrated, records by Engelhardt (1891; as *Woodwardia roessneriana* Heer). Its main record in the Czech Republic is centred in the early Miocene deposits of the Most Basin, namely in the Most Formation (Bůžek 1971, Hurník 1978).

Conifers
Pinaceae Spreng. ex F.Rudolphi, nom. cons.

Pinus L.

Pinus cf. *rigios* (Unger) Ettingsh.
Pl. 1, Figs 5–6

cf. 1850 *Pinites rigios* Unger, p. 362.
cf. 1852 *Pinites rigios* Unger; Unger, p. 25, pl. 13, fig. 3 (holotype).
cf. 1866 *Pinus rigios* (Unger) Ettingsh., p. 41, pl. 13, figs 11–12.
2009 *Pinus rigios* (Unger) Ettingsh.; Akhmetiev et al., p. 96, pl. 12, fig. 1.

Material studied. Needle leaves PA 1159.1, 1159.2, 1348.

Description. Needles in fascicles of three were recovered from several impressions. The longest incomplete needles attain well over 100 mm in length; the cross section is triangular, the largest diameter being ca. 1mm. The sheath is over 10 mm.

Discussion. Such needles occur associated with seed cones of *Pinus engelhardtii* Menzel in the early Miocene of the Most Formation ("Břešťany Clay") (see Kvaček et al. 2004). The fossil species from there was described by Unger (1850, 1852; as *Pinites rigios* – see Hably et al. 2001) and reported repeatedly from the early Miocene deposits of North Bohemia. The occurrence of pine foliage in ternate fascicles from the České středohoří Mts. is rare, namely found at Žichov (Ettingshausen 1866: 41, pl. 13, fig. 11; as *Pinus taedaeformis* (Unger) Ettingsh., frequently assumed as a synonym of *P. rigios* – e.g. Mai 1999).

Pinus cf. *hepios* (Unger) Heer
Pl. 1, Figs 3–4

1850 *Pinites hepios* Unger, p. 362.
1855 *Pinus hepios* (Unger) Heer, p. 57, pl. 21, fig. 1.

Material studied. Needle leaves PA 1160.1, 1188.1, 1185.1, 1328, 1347.

Description. Several needles over 100 mm long, half-moon in cross section and joined in fascicles of two and partly attached to a short sheath.

Discussion. Similar sterile needles attached to shoots are known from the Doupovské hory Mts. recovered at Valeč (Menzel 1901; as *Pinus hepios* Unger; Brabenec 1909: 48, text-fig. 29; as *Pinus hepios* Unger. sp.).

Cupressaceae Gray, nom. cons.

Calocedrus Kurz

Calocedrus suleticensis (Brabenec) Kvaček
Pl. 1, Figs 12–13

1909 *Libocedrus suleticensis* Brabenec, p. 60, text-fig. 42.
1999 *Calocedrus suleticensis* (Brabenec) Kvaček, p. 241, figs 1–6, 16–26.
2009 *Calocedrus suleticensis* (Brabenec) Kvaček; Akhmetiev et al., p. 96, pl. 12, fig. 6.

Material studied. Seed cone PA 1173.1.

Description. A fragmentary seed cone with a short stalk fragment.

Discussion. The single specimen at hand shows the typical characters of this rare fossil conifer, namely the oval part of the seed cone and decussate phyllotaxy of broad, but not fused scale leaves. This incomplete specimen clearly matches the type material from Suletice, a site not far from Matrý (Kvaček and Walther 1995, Kvaček 1999), from where more complete material of this species is known.

Tetraclinis Masters

Tetraclinis salicornioides (Unger) Kvaček
Pl. 1, Figs 10–11

1989 *Tetraclinis salicornioides* (Unger) Kvaček, p. 48, pl. 1, fig. 11, pl. 2, figs 2–14, pl. 3, figs 1–4, pl. 7, figs 3–4, text-fig. 1.
2002 *Tetraclinis salicornioides* (Unger) Kvaček; Radoň, p. 170, pl. 1, fig. 9.
2009 *Tetraclinis salicornioides* (Unger) Kvaček; Akhmetiev et al., p. 117.

Material studied. Seed PA 1177 and a fragment of leaf segment, PA 1427.

Description. The seed showing two basally orientated wings, a fragment of the cladode-like leaf segment with fully fused decussate scale leaves.

Discussion. This well-known fossil conifer occurs but rarely in other Palaeogene sites of North Bohemia (Kučlín, Valeč, Kundratice, Suletice – see Kvaček and

Teodoridis 2011) and more abundantly in the Miocene deposits connected with the climatic optimum (e.g. Holý et al. 2012).

Taxaceae Gray

Torreya Raf.

Torreya bilinica Saporta et Marion
Pl. 1, Figs 8–9

1876 *Torreya bilinica* Saporta et Marion, p. 221.
2009 *Torreya bilinica* Saporta et Marion; Akhmetiev et al., p. 96, pl. 12, fig. 8.

Material studied. Needle leaf impressions PA 1358, PA 1392.1, PA 1584.

Description. Isolated needles which are rounded on the apex, flat and characterized by distinct very narrow longitudinal stomatal bands on the abaxial side.

Discussion. This conifer was recovered in several other Palaeogene sites in North Bohemia and the surrounding areas, e.g. at Seifhennersdorf, Saxony, Germany (Walther and Kvaček 2007). It is typified by a leafy twig from Žichov with attached needles of the same kind (Kvaček 1984, Hably et al. 2001).

Cephalotaxus Siebold et Zuccarini ex Endl.

cf. *Cephalotaxus parvifolia* (H.Walther) Kvaček et H.Walther
Pl. 1, Fig. 7

? 1964 *Amentotaxus parvifolia* H.Walther, p. 8, pl. 1, figs 1–5.
? 1998 *Cephalotaxus parvifolia* (H.Walther) Kvaček et H.Walther, p. 11, pl. 4, figs 1–3.

Material studied. Needle leaf PA 1393.

Description. A flat lineal needle, 2.5 mm wide and 15 mm long with an acute apex and no traces of stomatal areas.

Discussion. The single specimen at hand matches the type from the early Oligocene site Seifhennersdorf (Walther and Kvaček 2007) in overall morphology. The identification is uncertain without anatomical evidence. This conifer occurs but rarely in the neovolcanic area of North Bohemia (Kundratice) to Saxony (Seifhennersdorf).

Angiosperms
Magnoliaceae Juss., nom. cons.

Magnolia L.

aff. *Magnolia seifhennersdorfensis* H.Walther et Kvaček
Pl. 2, Figs 1–3

2002 cf. *Magnolia* sp.; Radoň, p. 171, pl. 2, fig. 6.
2007 *Magnolia seifhennersdorfensis* H.Walther et Kvaček, p. 94, pl. 3, figs 1–2, pl. 22, figs 8–10.

Material studied. Leaf impressions PA 1195.1–3, 1367, 1371, 1448.

Description. The leaf impressions are entire-margined, all incomplete and without cuticles. All have a narrow elliptical blade, about 20–35 mm wide, short petiole, with cuneate base and acute apex and with eucamptodromous venation.

Discussion. The affinity to *Magnolia seifhennersdorfensis* is suggested on type locality by the occurrence of seeds described as *Magnolia* cf. *denudataeformis* P.I.Dorof. (Walther and Kvaček 200: pl. 2, figs 3–4). Identification of the leaf material at hand is not quite certain because various Lauraceae leaves are similar in gross morphology.

Liriodendron L.

Liriodendron haueri Ettingsh.
Pl. 2, Figs 4–8

1976 *Liriodendron haueri* Ettingsh.; Bůžek et al., p. 84, pl. 2, figs 12–15, pl. 3, figs 1–8, pl. 15, figs 3–4, text-figs 3, 4a–c.
2002 *Liriodendron procacinii* Unger; Radoň, p. 171, pl. 2, fig. 9.
2009 *Liriodendron haueri* Ettingsh.; Akhmetiev et al., p. 96, pl. 12, fig. 7.

Material studied. Leaves PA 1187, 1357, 1399, 1400, 1401.1, 1440.1 and fruitlets PA 1359.1, 1359.2, 1426.1, 1442.

Description. The leaves are short petiolate, lamina shallowly bilobate, 40–60 mm long, 30–60 mm wide, lobes at wide angles, entire-margined, acuminate, base widely rounded. Associated fruitlets represent isolated winged samaras, with elongate wing and basally positioned, 2 mm long spindle-shaped seed part.

Discussion. The recovered foliage is a complete record of *Liriodendron haueri* from North Bohemia. This fossil species is based on a single fragmentary leaf of the same kind recovered at Žichov (Ettinghausen 1869, Hably et al. 2001). Associated fruitlets correspond to those described in detail from the Oligocene site Markvartice (Bůžek et al. 1976).

Lauraceae Juss., nom. cons.

Laurophyllum Göpp.

Laurophyllum sp.
Pl. 3, Figs 1–7

2002 *Laurophyllum* sp.; Radoň, pp. 170–171, pl. 1, fig. 6, pl. 2, figs 1–2.

Material studied. Leaf impressions PA 1158.2, 1158.6, 1158.7, 1158.8, 1182.1 1182.3, 1189.2, 1189.4, 1349, 1383.1, 1398, 1584.

Description. Impressions of entire-margined pinnately veined leaves with lanceolate blade, acuminate apices and narrow cuneate bases.

Discussion. Such leaf remains occur but rarely in the Matrý plant assemblage. They resemble various fossil species based on details of cuticle structure, such as *Laurophyllum pseudoprinceps* Weyland et Kilpper, *Laurophyllum medimontanum* Bůžek, Holý et Kvaček and *Laurophyllum acutimontanum* Mai (Kvaček and Walther 1998).

Daphnogene Unger

Daphnogene cinnamomifolia (Brongn.) Unger f. *lanceolata* (Unger) Kvaček et H.Walther

Pl. 4, Figs 1–4

1998 *Daphnogene cinnamomifolia* (Brongn.) Unger forma *lanceolata* (Unger) Kvaček et H.Walther, p. 13, pl. 5, figs 6–7, text-fig. 13.8.
2002 *Daphnogene cinnamomifolia* (Brongn.) Unger; Radoň, p. 164, photo 6 below, pl. 1, figs 4–5, pl. 2, fig. 8.
2009 *Daphnogene cinnamomifolia* (Brongn.) Unger; Akhmetiev et al., pp. 96, 170–171, pl. 12, fig. 9.

Material studied. Leaf impressions PA 1153.1–2, 1167.1–6, 1174.1–4, 1345, 1346, 1350, 1363.1 (leafy twig), 1373, 1376.1–2, 1395, 1408.

Description. The leaves are alternately attached, short petiolate, lamina narrow lanceolate, with suprabasal acrodromous venation. Broader leaf forms (PA 1174.1, 1395) are the exception.

Discussion. This laurophyllous representative of Lauraceae occurs quite commonly and in leaf morphology fits within this narrow-leaved lauroid fossil species, usually assigned to *Cinnamomum* Schaeff. It is widely distributed in the Palaeogene localities in North Bohemia.

? Typhaceae Juss., nom. cons.

? *Sparganium* L.

? *Sparganium* sp.

Pl. 4, Fig. 5

Material studied. Leaf impression PA 1424.1., 1424.2.

Description. The leaf fragments are parallel veined, comprising a 2 mm thick main vein and regularly spaced parallel lateral veins 1–2 mm thick. The veins are denser near the margin which is smooth. No cross veins were observed.

Discussion. Such leaf impressions have only rarely been encountered in the plant assemblages of the České středohoří Mts. Such monocot leaf remains cannot be safely identified to a particular genus but indicate the possible proximity of an aquatic environment. Similar but much wider leaf remains from the Miocene deposits of North Bohemia and elsewhere are often assigned to the fossil species *Typha latissima* A.Braun (Kvaček and Hurník 2000).

? Gramineae Juss., nom. cons.

? Gramineae gen. et sp. indet.

Pl. 4, Fig. 6

Material studied. Leaf impression PA 1168.1.

Description. Parallel-veined grass-like leaf fragments have been found very rarely in the Matrý leaf assemblage. They are irregularly split along the length.

Discussion. The fossil at hand resembles the foliage of Gramineae. An affinity to any particular genus of other monocots is uncertain.

Platanaceae T.Lestib., nom. cons.

Platanus L.

Platanus neptuni (Ettingsh.) Bůžek, Holý et Kvaček

Pl. 4, Figs 7–10

1866 *Sparganium neptuni* Ettingsh., p. 31, pl. 7, figs 9–15.
1967 *Platanus neptuni* (Ettingsh.) Bůžek, Holý et Kvaček, p. 205, pls 1–4.
2002 *Platanus neptuni* (Ettingsh.) Bůžek, Holý et Kvaček; Radoň, p. 170, pl. 1, figs 7–8, pl. 2, figs 3–4.

Material studied. Leaves PA 1157.4, 1179.1, 1180.1, 1180.2, 1355, 1362, 1417, 1447, 1450; infructescences PA 1434, 1435; stipules PA 1364.1, 1179.2.

Description. The fragmentary leaves are simple or ? trifoliate (Pl. 4, Fig. 7), obovate, 37–42 mm long and 7–11 mm wide, on the margin widely blunt regularly toothed, partly entire, venation semicraspedodromous, partly eucamptodromous. Female infructescence globular, ca. 10 mm in diameter, composed of narrow fruitlets projected by a short style out of the infructescence. Strap-like stipules parallel-veined, cut at the base.

Discussion. The record of *Platanus neptuni* from Matrý includes mostly simple leaves, in one case a trifoliate foliage is also recognized in some other sites, e. g. at Kučlín (Kvaček and Teodoridis 2011). The infructescences corroborate the wide distribution of this element in other Palaeogene sites in Central Europe (Kvaček and Manchester 2004).

Cercidiphyllaceae Engl., nom. cons.

Cercidiphyllum Siebold et Zucc.

Cercidiphyllum crenatum (Unger) R.W.Br.

Pl. 5, Fig. 1

1850 *Dombeyopsis crenata* Unger, p. 448.
1935 *Cercidiphyllum crenatum* (Unger) R.W.Br., p. 575, pl. 68, figs 1, 6, 8–10.

Material studied. Leaf impressions PA 1352, 1406, 1581.

Description. The isolated leaves are deeply cordate, widely elliptic to round with finely crenate to crenulate margin.

Discussion. The recovered foliage in gross morphology clearly matches the other records widely distributed in the Oligocene floras of the České středohoří Mts. and elsewhere (see Jähnichen et al. 1980, Kvaček and Konzalová 1996).

? Leguminosae Juss.

? Leguminosae gen. indet.

Pl. 5, Figs 2–4

Material studied. Leaflet impressions PA 1176, 1371, 1381, 1391, 1405.1, 1411.1, 1439.

Description. Isolated leaflets, some with a short petiolule.

Discussion. Such legume-like foliage is rarely present in the Matrý plant assemblage. Some match the legume leaflets occurring in other volcanic floras (e.g. PA 1176 forma 3 sensu Kvaček and Walther 1998 at Kundratice), but some others are larger (e.g. PA 1371 – cf. *Trigonobalanopsis*; PA 1411.1 – cf. *Sapindus*) and may belong to other groups of angiosperms.

Elaeocarpaceae Juss., nom. cons.

***Sloanea* L.**

***Sloanea artocarpites* (Ettingsh.) Kvaček et Hably**
Pl. 5, Fig. 5

1869 *Quercus artocarpites* Ettingsh., p. 63, pl. 55, figs 19–19b.
1976 *Dicotylophyllum sparsidentatum* Bůžek, Holý et Kvaček, p. 105, pl. 10, figs 1–7, pl. 20, figs 5–6, pl. 21, figs 1–6, text-fig. 8.
2001 *Sloanea artocarpites* (Ettingsh.) Kvaček et Hably in Kvaček et al., p. 117.

Material studied. Foliage impression PA 1410.1.

Description. An incomplete leaf, without a base, elongate, over 80 mm long, 40 mm wide, on margin minutely sparsely denticulate, venation campto-semicraspedodromous, secondaries at base at wider, high up under regular angles.

Discussion. The identification is not corroborated by epidermal structure typical for this fossil species which is often met found in the Oligocene floras of Central Europe (Walther and Kvaček 2007). Similar foliage is known in the early Oligocene sites of Hungary and Slovenia accompanied by fruits of the *Sloanea*-type (Kvaček et al. 2001).

Ulmaceae Mirb.

***Ulmus* L.**

***Ulmus pyramidalis* Göpp.**
Pl. 5, Figs 6–8

1855 *Ulmus pyramidalis* Göpp., p. 28, pl. 13, figs 10–12.
2002 *Ulmus pyramidalis* Göpp.; Radoň, p. 162, photo 4 below, p. 170, pl. 1, fig 10.
2009 *Ulmus pyramidalis* Göpp.; Akhmetiev et al., p. 96, pl. 12, fig. 12.

Material studied. Foliage impressions PA 1154.1–2, 1162.1–2, 1163.6–10, 1170.10 (two leaves on a twig), 1191.2, 1368, 1370, 1379, 1429.

Description. The leaves are shortly petiolate, petiole max. 4 mm long, blade lanceolate, often slightly asymmetric at base, apex acute, base rounded to shallow cordate, margin finely double serrate to serrate, 40–80 mm long and 10–20 mm wide, venation craspedodromous, secondaries quite dense, at an angle of 30–60°.

Discussion. *Ulmus pyramidalis* is a common Miocene element in North Bohemia (Bůžek 1971), which replaces *Ulmus fischeri* Heer, a characteristic element in the early Oligocene (e. g. Bechlejovice – Kvaček and Walther 2004) and in the late Oligocene volcanic floras of the České středohoří Mts. The occurrence of *Ulmus pyramidalis* at Matrý is one of the earliest records in this area.

Cannabaceae Martinov

***Celtis* L.**

***Celtis pirskenbergensis* (Erw.Knobloch) Kvaček et H.Walther**
Pl. 5, Figs 9–10

1961 *Celtis begonioides* Göpp. var. *pirskenbergensis* Erw. Knobloch, p. 273, pl. 6, figs 3, 5, 8 (holotype).
2006 *Celtis* sp.; Radoň et al., p. 101, pl. 5, figs 5–7.
2007 *Celtis pirskenbergensis* (Erw.Knobloch) Kvaček et H.Walther; Walther and Kvaček, p. 101, pl. 7, figs 1–8, text-fig. 4a–c.

Material studied. Foliage impressions PA 1353, 1438.

Description. The two studied leaves are shortly petiolate, with an ovate to elongate blade; one is oblique at the base, the other slightly asymmetrical, margin coarsely crenate-serrate. Three basal veins arise at acute angles from the lamina base. Details of venation are poorly visible.

Discussion. The material matches other *Celtis* foliage recovered elsewhere in a few of the volcanic sites of North Bohemia and Saxony (Radoň et al. 2006, Walther and Kvaček 2007). We follow the treatment proposed by Walther and Kvaček (2007) and leave separately other fossil species known from the Neogene, such as *Celtis trachytica* Ettingsh.

Juglandaceae DC. ex Perleb, nom. cons.

***Carya* Nutt.**

***Carya fragiliformis* (Sternb.) Kvaček et H.Walther**
Pl. 6, Figs 1–3

1825 *Phyllites fragiliformis* Sternb., p. 42, index iconum, pl. 50, fig. 1.
2002 *Carya serrifolia* (Göpp.) Kräusel; Radoň, p. 171, pl. 2, figs 11–12.
2007 *Carya fragiliformis* (Sternb.) Kvaček et H.Walther; Walther et Kvaček, p. 110, pl. 11, figs 1–3, pl. 23, figs 8–10, text-fig. 6b.

Material studied. Leaflet impressions PA 1170.6, 1190.1, 1190.2, 1338.1, 1340, 1351, 1385, 1390.1, 1390.2, 1409, 1418, 1339.2 (cf.), 1363.2 (cf.).

Description. Numerous leaflets with oblong, slightly asymmetrical falcate blade, sharply serrate on the margin and with semicraspedodromous to craspedodromous venation.

Discussion. The material corresponds with the holotype of this fossil species based on a single specimen from Žichov (J. Kvaček and Straková 1997, Walther and Kvaček 2007). It is obviously a part of the whole plant that produced fruits described below as *Carya quadrangula* (Kirchh.) J.-F.Leroy.

***Carya quadrangula* (Kirchh.) J.-F.Leroy**
Pl. 6, Figs 4–6

1866 *Carya bilinica* (Unger) Ettingsh., p. 46, pro parte, pl. 51, figs 4–5.
1978 *Carya quadrangula* (Kirchh.) J.-F.Leroy; Mai and Walther, p. 79, pl. 32, figs 16–19.

2002 *Carya* sp.; Radoň, pp. 134, 164, photo 6 above, pl. 2, fig. 10.

Material studied. Fruit casts PA 1338.1–2, 1164.1, 1365, 1580.

Description. Casts of fruits three-dimensionally preserved, partly split into halves, ovoid, some apically acuminate, 25–30 mm long and 15–30 mm wide.

Discussion. Such fruits were compared with *Carya quadrangula* by Mai (1981) in his revision of fossil *Carya* fruits recovered from various sites of the European Palaeogene and *Carya rostrata* (Schloth.) Schimp. in his revision of the late Oligocene flora of the Rhön Mts. (Mai 2007).

Juglandaceae genus indet.

***Cyclocarya* sp. vel *Carya* sp.**
Pl. 6, Figs 7–9

Material studied. Foliage impressions PA 1170.1, 1170.7, 1170.8, 1366, 1419.

Description. Leaflet impressions similar to the above described specimens, on the margin denticulate, venation semicraspedodromous.

Discussion. The above listed foliage impressions differ from *Carya* foliage by the finely denticulate margin and regularly semicraspedodromus venation. The difference between the impressions and *Carya fragiliformis* is not so pronounced as to lead to an unequivocal identification.

Betulaceae Gray, nom. cons.

***Betula* L.**

***Betula brongniartii* Ettingsh.**
Pl. 7, Figs 1–4

1866 *Betula brongniartii* Ettingsh., p. 46, pro parte, pl. 46, figs 3–4, pl. 47, fig. 1.
2002 *Betula brongniartii* Ettingsh.; Radoň, p. 170, pl. 1, figs 12–13, photo 4 above.
2009 *Betula brongniartii* Ettingsh.; Akhmetiev et al., pp. 96, 117, pl. 12, fig. 3.

Material studied. Leaf impressions PA 1152.1–2, 1155.1–5, 1157.1–2, 1184, 1196.1–2, 1341, 1342, 1381, 1582.

Description. The leaves are petiolate, lamina broadly ovate, rounded at base, acute at apex to shortly attenuate, double sharply serrate on margin, ca. 80 mm long and 50 mm wide.

Discussion. Leaves from Zichov assigned to *Betula brongniartii* (Hably et al. 2001) match the birch foliage recovered at Matrý, particularly the strongly double serrate margin. In this way the fossil species differs from the smaller delicate leaves of *Betula alboides* Engelh. (syn. *B. buzekii* Kvaček et H.Walther) described from the sites at Kundratice and Seifhennersdorf (cf. Kvaček and Walther 1998, Walther and Kvaček 2007).

***Betula dryadum* Brongn.**
Pl. 7, Figs 5–6

1976 *Betula dryadum* Brongn.; Bůžek et al., p. 93, pro parte, pl. 6, figs 4–6.

Material studied. Bracts and fruitlets PA 1420.1, 1432, 1437, 1446.

Description. The bracts are tripartite at the very apex, narrow, up to 10 mm long, 2 mm wide, fruitlets double winged, 3 mm long, 4 mm wide.

Discussion. The bracts and fruitlet associated with the above foliage obviously belong to the same birch foliage as mentioned above. Bůžek et al. (1976) assigned them to the same fossil species as leaves co-occurring in the diatomite of the locality Markvartice.

***Alnus* Mill.**

***Alnus rhenana* (P.Wessel et C.O.Weber) Winterscheid et Kvaček**
Pl. 7, Figs 7–9

1856 *Corylus rhenana* P.Wessel et C.O.Weber, p. 134, pl. 22, fig. 5.
2002 *Alnus* cf. *rostaniana* Saporta; Radoň, p. 170, pl. 1, fig. 11.
2009 *Alnus rostaniana* Saporta; Akhmetiev et al., p. 117, pl. 12, fig. 11.
2014 *Alnus rhenana* (P.Wessel et C.O.Weber) Winterscheid et Kvaček, p. 22, pl. 4, figs 1–5, pl. 11, figs 4–6.

Material studied. Leaf impressions PA 1166.1, 1172.4, 1175.2, 1343, 1372, 1375, 1380, 1403, 1404, 1414, 1423.

Description. The leaves are ovate to obovate, over 150 mm long, 50 mm wide, incompletely preserved, acute at apex, rounded to shallow cordate at base, finely widely serrate on margin.

Discussion. The alder foliage recovered at Matrý is for the first time compared with *Alnus rhenana*, which is typically long petiolate, obovate and varying in shape from broadly obovate to ovate (Winterscheid and Kvaček 2014). A fossil species based on the leaf impression of *Sorbus palaeoaria* Ettingsh. (Ettingshausen 1869) from Žichov also belongs to *Alnus rhenana*. It differs in the shape of the blade from the narrow elliptic alder leaves assigned to *Alnus gaudinii* (Heer) Erw.Knobloch et Kvaček from Seifhennersdorf (Walther and Kvaček 2007) and Kundratice (Kvaček and Walther 1998). The previously used fossil taxon *Alnus rostaniana* Saporta (Akhmetiev et al. 2009) falls into the synonymy of *A. rhenana* together with another alder foliage from the late Oligocene site of Manosque, France (Saporta 1891).

***Alnus* sp.**
Pl. 8, Figs 1–3

? 1971 *Alnus* sp.; Bůžek, p. 48, pl. 13, fig. 13, pl. 15, figs 1–6.
2009 *Alnus gaudinii* (Heer) Erw.Knobloch et Kvaček; Akhmetiev et al., p. 117.

Material studied. PA 1172.4, 1403, 1404, 1423, 1436, 1578, 1579.1.

Description. The leaves are oblong elongate, petiolate, with fine denticulate margin.

Discussion. These morphotypes are associated with the above larger leaf forms and may represent only smaller variants of *Alnus rhenana*. A resolution of its position cannot be made without epidermal studies. Similar leaf forms also occur in the Oligocene site Valeč in the Doupovské hory Mts., where they are associated with alder infructescences described as *Steinhauera oblonga* C.Presl in Sternb. (J. Kvaček and Straková 1997: 111, pl. 40, fig. 4).

Alnus cf. *kefersteinii* (Göpp.) Unger
Pl. 7, Fig. 10

? 1836 *Alnites kefersteinii* Göpp., p. 564–566, pl. 41, figs 1–5, 15–16, 18.
? 1845 *Alnus kefersteinii* (Göpp.) Unger, p. 78.
2009 *Alnus kefersteinii* (Göpp.) Unger; Akhmetiev et al., p. 117.

Material studied. PA 1161.1–2, 1444.1, 1576.

Description. Ovoid and strongly compressed infructescences.

Discussion. The material at hand is very poorly preserved. Only its overall form allows identifying it as alder female infructescences. The association with foliage of *Alnus rhenana* suggests that both organs may belong to the same plant element.

Carpinus L.

Carpinus grandis Unger
Pl. 8, Figs 4–6

1850 *Carpinus grandis* Unger, p. 408, pro parte (only folia).
2002 *Carpinus grandis* Unger; Radoň, p. 171, pl. 2, fig. 5.

Material studied. Leaf impressions PA 1158.9, 1163.8, 1344, 1384, 1388, 1402, 1574.

Description. The leaves are oblong oval with fine serrate-dentate margin, venation craspedodromous, secondaries mostly simple, dense, regularly orientated.

Discussion. The above listed impressions in morphology match other records of *Carpinus grandis* in adjacent sites in North Bohemia (e.g. Kvaček and Walther 1998, Walther and Kvaček 2007). No associated fruit remains have been recovered at Matrý.

Ostrya Hill

Ostrya atlantidis Unger
Pl. 8, Figs 7–10

1850 *Ostrya atlantidis* Unger, p. 50.
2002 *Ostrya atlantidis* Unger; Radoň, p. 171, pl. 2, fig. 13.

Material studied. Leaf impressions PA 1163.1, 3, 5, 1181.1–2, 1377, 1397.1, 1441, 1442, 1577, involucre PA 1583.

Description. Leaf impressions similar to the above morphotypes but differing in prominently mucronately serrate margin. A single fruit remain of the same fossil species representing an ovate, compressed parallel-veined involucre was recovered in association.

Discussion. Foliage of this fossil species can easily be mistaken for that of *Carpinus* with only bluntly finely serrate margin (Kvaček and Walther 1998, 2004). A single involucre of the same fossil species of *Ostrya* was recovered at Matrý and matches other fossils of this sort occurring at Kundratice and Bechlejovice (Kvaček and Walther 1998, 2004).

Sapindaceae Juss., nom. cons.

Acer L.

Acer crenatifolium Ettingsh.
Pl. 9, Figs 1–2

1869 *Acer crenatifolium* Ettingsh., p. 20, pl. 45, figs 1, 4.
1975 *Acer tricuspidatum* Bronn forma *crenatifolium* (Ettingsh.) M.Proch. et Bůžek, pp. 26, 47.
2002 *Acer* cf. *tricuspidatum* Bronn; Radoň, p. 134, photo 5 above, text-fig. 1.3.
2009 *Acer crenatifolium* Ettingsh.; Akhmetiev et al., pp. 96, 117, pl. 12, figs 2, 5.

Material studied. PA 1186.2, 1189.3 (?), 1359.2 (?), 1361.1, 1374 (?), 1407 (?).

Description. Trilobate maple leaves, with crenate margin.

Discussion. Such maple leaves from Žichov have been described as an independent species *Acer crenatifolium* Ettingsh. Procházka in his revision reduced it to a form of *Acer tricuspidatum* Bronn forma *crenatifolium* (Ettingsh.) M.Proch. et Bůžek (Procházka and Bůžek 1975). No leaf anatomical evidence is so far available to prove the affinity to *A. crenatifolium* or *A. tricuspidatum*.

Acer cf. *palaeosaccharinum* Stur
Pl. 9, Figs 3, 4, 6

? 1867 *Acer palaeosaccharinum* Stur, p. 177, pl. 5, fig. 8.
? 1869 *Acer dasycarpoidesc* Heer; Ettingshausen, p. 19, pro parte, pl. 40, fig. 3.
2002 *Acer* cf. *palaeosaccharinum* Stur; Radoň, p. 134, photo 5 below, text-fig. 1.2.
2009 *Acer crenatifolium* Ettingsh.; Akhmetiev et al., p. 117, pl. 12, fig. 2.

Material studied. Leaf impressions PA 1184.1–2, 1189.1, 1356.

Description. The leaves are deeply tricuspidate, blades from 19 mm to more than 65 mm in length and 22 mm to 74 mm in width, lobes of almost the same width, with subparallel margins, widely simple to irregularly double dentate.

Discussion. We follow the treatment proposed by Walther and Kvaček (2007: 117) stressing that foliage from the České středohoří Mts. assigned to *A. angustilobum* is difficult to differentiate from some forms of *A. palaeosaccharinum*. Maple leaves with a prominently double dentate middle lobe have usually been assigned to *Acer palaeosaccharinum* Stur but transitional forms connect them with typical *Acer angustilobum* with only simple dentation on the main lobe. Both fossil morphotypes are connected with a transition phase.

Acer integrilobum C.O.Weber

Pl. 9, Fig. 8

1852 *Acer integrilobum* C.O.Weber, p. 196, pl. 22, fig. 5a–b (non fig. 5c).

2009 *Acer integrilobum* C.O.Weber; Akhmetiev et al., p. 96, pl. 12, fig. 4.

Material studied. Leaf impressions PA 1189.2, 1449.

Description. The leaves are trilobate, ca. 20 mm long and fragmentary in width, lobes entire-margined.

Discussion. Such maple leaves with an almost entire margin are rare in the Oligocene leaf assemblages of the České středohoří Mts. (Walther 1972, Kvaček and Walther 1998).

Acer sp.

Pl. 9, Figs 5, 7

2002 *Acer* sp.; Radoň, p. 134, pl. 1, fig. 1.

Material studied. Fruits PA 1413.1, 1416, 1575.

Description. Winged double samaras, partly isolated mericarps, 22–45 mm long, 8–35 mm wide, seed part rounded, 5–7 mm in diameter.

Discussion. The connection between fossil maple fruits and foliage has not so far been firmly resolved.

Malvaceae Juss., nom. cons.

Craigia W.W.Sm. et W.E.Evans

Craigia bronnii (Unger) Kvaček, Bůžek et Manchester

Pl. 10, Figs 5–6

1845 *Ulmus bronnii* Unger, p. 79, pro parte, pl. 25, figs 2–4 (non fig. 1).

1948 *Pteleaecarpum bronnii* (Unger) Weyland, p. 130, pl. 21, fig. 5, text-figs 5–9.

1991 *Craigia bronnii* (Unger) Kvaček, Bůžek et Manchester, p. 522.

Material studied. Fruits PA 1156.1–2, 1360, 1386.1–2, 1387 (cf.).

Description. Winged broadly oval to rounded fruit valves 10–12 mm wide and 12–17 mm long with spindle-shaped medial locule, rarely with a small ovate seed inside. Venation of the wing composed of narrow elongated fields radiating from the locule, steeper in the upper part.

Discussion. These fruit remains conform in size and morphology with other records of the same species, commonly recovered in the Oligocene and Miocene of Central Europe (Kvaček et al. 2004).

Angiosperms inc. fam.

Pungiphyllum Frankenhäuser et V.Wilde

Pungiphyllum cf. *cruciatum* (A.Braun) Frankenhäuser et V.Wilde

Pl. 10, Fig. 2

? 1851 *Quercus cruciata* A.Braun; Stizenberger, p. 76.

? 1995 *Pungiphyllum cruciatum* (A.Braun) Frankenhäuser et V.Wilde, p. 101.

Material studied. Leaf impression PA 1340.

Description. Leaf over 100 mm long and 40 mm wide, oblong, at the base the margin is entire, towards the apex it is coarsely widely dentate, venation eucamptodromous to craspedodromous, secondaries at wide angles, intersecondaries exceptional.

Discussion. The same morphotypes occur singly in several Oligocene sites of Europe, in the Czech Republic e.g. at Kundratice, Bechlejovice, Suletice-Berand, and rarely also in the Miocene (see Kvaček and Walther 1981, 2004). Affinities have not been resolved so far. The above described morphotype differs from other records of this peculiar fossil species by its shallow dentate margins and matches *Quercus buchii* C.O.Weber (Weber 1852) from the late Oligocene site Rott in Germany.

Dicotylophyllum Saporta

Several morphotypes in the Matrý plant assemblage are not assignable to any well-known fossil genus or species of angiosperm foliage.

Dicotylophyllum sp. 1

Pl. 10, Figs 3–4

Material studied. Leaf impressions PA 1188.1, 1412.2 (cf. *Dicotylophyllum* 13 sensu Kvaček and Walther 1998).

Description. The leaves are petiolate, petiole ca. 15 mm long, basally broadened, lamina elliptical, apex missing, base rounded, margin entire, venation brochidodromous, midrib stout, straight, secondaries regularly bent at medium angle, intersecondaries exceptional.

Discussion. The foliage described above is difficult to identify with a particular angiosperm genus due to its uniform morphology, even when the epidermal anatomy is known (Kvaček and Walther 1998: 17; as *Dicotylophyllum* 13).

Dicotylophyllum sp. 2

Pl. 10, Figs 7–8

Material studied. Leaf impressions PA 1363.2, 1425.1, 1431.

Description. The leaves are oblong, apex acute, base narrow cuneate, margin sharply densely dentate, venation craspedodromous, midrib straight, secondaries dense, at leaf base at wide angles, higher up at narrower angles.

Discussion. Such sharply and finely dentate leaf fossils have been assigned to *Prinsepia serra* (Unger) Kovar-Eder et Kvaček in the Miocene flora of Parschlug (Kovar-Eder et al. 2004).

Dicotylophyllum sp. 3

Pl. 10, Figs 1, 9

2002 "*Viburnum*" *atlanticum* Ettingsh.; Radoň, p. 171, pl. 2, fig. 7.

Material studied. Leaf impressions PA 1163.1 (cf. *Viburnum atlanticum*), 1431.

Description. The leaves are narrow ovate, shortly petiolate, lamina 60 mm long, 30 mm wide, ovate to widely lanceolate, base cuneate, apex acute, margin coarsely, partly double serrate, venation semicraspedodromous.

Discussion. Similar leaf forms have been assigned to *Ternstroemites* spp. (Winterscheid and Kvaček 2014) but a more precise identification would require information on epidermal anatomy.

***Dicotylophyllum* sp. 4**
Pl. 10, Figs 10–11

Material studied. Leaf impressions PA 1182.3, 1430, 1585.1.

Description. The leaves are shortly petiolate, lamina 40–50 mm long, 20–30 mm wide, obovate, base cuneate, apex bluntly acute, margin entire, venation brochidodromous, secondaries regularly spaced.

Discussion. Similar leaf forms occurring at Bechlejovice and Seifhennersdorf have been assigned to *Diospyros* (Kvaček and Walther 1998, Walther and Kvaček 2007). They may belong to the characteristic quadrisepalous calyces co-occurring at several sites.

Vegetation and palaeoclimatic signals

The flora of Matrý, preserved as leaf and carpological material, so far includes 34 vascular plant taxa – 1 fern, 5 conifers, 28 angiosperms (26 dicots and 2 monocots). According to Soukupová (2004), the fossil plant assemblage at Matrý corresponds to two vegetation types – riparian forest and mixed mesophytic forest. In both vegetation types, taxa producing foliage with dentate margin prevailed (73.5%). In her analysis she considered 7 and 11 taxa, respectively. Most elements have been suggested to represent trees. Scarcity of Fagaceae could be explained, in her opinion, by high fertility of the substrate and the presence of *Carpinus*. Teodoridis and Kvaček (2015) evaluated the plant assemblage of Matrý using the Integrated Plant Record (IRP) vegetation analysis (see Kovar-Eder et al. 2008, Teodoridis et al. 2011a, b), which predicted broad-leaved deciduous vegetation. This predicted zonal vegetation which is characterized by anomalously high percentage of broad-leaved deciduous components (81 %) in contrast to the other early late Oligocene assemblages studied. This fact, also indicated by palaeoclimatic proxies, verified a "riparian effect" (see Mach et al. 2014) as known from floras of Hlavačov Gravel and Sand (Teodoridis and Kvaček 2015). The above mentioned vegetation analysis carried out by Soukupová (2004) and Teodoridis and Kvaček (2015) is affected by a deficiency of studied taxa, i.e. 18 and 21. The new study presented here permits the use of 34 taxa and predicted quite different results which are more comparable with the results of IPR vegetation analysis from the late Oligocene of Central Europe (Teodoridis and Kvaček 2015). The latest results of IPR vegetation analysis for the Matrý plant assemblage shows the following ratio of key components, i.e. broad-leaved deciduous (BLD) – 70.5 %, broad-leaved evergreen (BLE) – 25.0 %, sclerophyllous + legume-like (SCL+LEG) – 4.6 % and dry herbaceous + mesophytic herbaceous /zonal herbaceous/ (D-HERB + M-HERB / ZONAL HERB/) – 7.0 %. According to the thresholds for the key components (sensu Teodoridis et al. 2011b), the results predict a Mixed Mesophytic Forest vegetation type, which shows a closer affinity to other late Oligocene plant assemblages at Kleinsaubernitz, Počerny-Podlesí, Bockwitz and Borna-Ost which were mainly estimated as Broad-leaved Evergreen Forest (see Teodoridis and Kvaček 2015: tab. 3). Generally, the vegetation from Matrý can be characterized by a relatively high frequency of zonal elements and conifers. Similarly, as in Soukupová (2004), two specific vegetation assemblages can be distinguished based on the phytosociological approach. The vegetation assemblages differ in their plant compositions (depending on specific ecological conditions of the biotopes) and mutually integrate on their ecotons. The first vegetation assemblage is riparian vegetation preferring a waterlogged substrate. It includes mainly azonal elements such as *Ulmus pyramidalis* (E2–3), *Platanus neptuni* (E3), *Craigia bronnii* (E3), *Betula dryadum*/*B. brongniartii* (E3), *Alnus* cf. *kefersteinii*/*A. rhenana* (E3), *Carpinus grandis* (E3), ?Leguminosae gen. indet. (E3), *Woodwardia muensteriana* (E1), ?*Sparganium* sp. (E1) and ?Gramineae gen. et sp. indet. (E1). The second vegetation assemblage, limited to well-drained habitats, is a zonal mesophytic (mesic) assemblage characterized by the associated occurrence of the following conifers and angiosperms: *Pinus* cf. *rigios* (E3), *Pinus* cf. *hepios* (E3), *Tetraclinis salicornioides* (E2–3), *Calocedrus suleticensis* (E3), cf. *Cephalotaxus parvifolia* (E3), *Torreya bilinica* (E3), aff. *Magnolia seifhennersdorfensis* (E3), *Liriodendron haueri* (E3), *Laurophyllum* sp. (E3), *Daphnogene cinnamomifolia* (E3), ?Leguminosae gen. indet. (E3), *Sloanea artocarpites* (E3–4), *Celtis pirskenbergensis* (E3), *Carya quadrangula*/*C. fragiliformis* (E3–4), *Cyclocarya* sp. vel *Carya* sp. (E3), *Alnus* sp. (E3), *Ostrya atlantidis* (E3), *Acer crenatifolium* (E2–3), *Acer* cf. *palaeosaccharinum* (E3), *Acer* sp./*Acer integrilobum* (E2–3), *Pungiphyllum* cf. *cruciatum* (E2–3), *Dicotylophyllum* spp. (E2–3) and *Woodwardia muensteriana* (E1). Teodoridis and Kvaček (2015: tab. 5) published palaeoclimatic estimates for Matrý derived from the Coexistence Approach (sensu Mosbrugger and Utescher 1997) which are as follows: mean annual temperature (MAT) 11.2–15.6 °C, warmest month mean temperature (WMMT) 24.0–26.8 °C, coldest month mean temperature (CMMT) −1.6–5.0 °C and mean annual precipitation (MAP) 879–1,355 mm. Similarly, palaeoclimatic proxies derived from Climate Leaf Multivariate Program (CLAMP sensu Wolfe and Spicer 1999) are MAT 13.6 °C, WMMT 20.7 °C and CMMT 7.4 °C. (Teodoridis and Kvaček 2015: tab. 4).

Comparison with other plant assemblages in the České středohoří Mts., adjacent Saxony and the Doupovské hory Mts.

Kvaček and Walther (in Akhmetiev et al. 2009: 79–84) attempted to characterize the position of the Matrý plant assemblage within the České středohoří Mts. They stressed the changing aspects of the flora, in which broad-leaved woody elements started to prevail. Representatives of the Betulaceae,

Ulmaceae, *Acer* and *Liriodendron* constitute the majority of angiosperms, while more thermophilic plants, such as Lauraceae, *Sloanea* and *Platanus neptuni* are less common, some others, e.g. *Engelhardia*, are absent. Modernization of the flora of Matrý is apparent from the immigration of new elements, such as *Woodwardia muensteriana*, *Pinus rigios*, *Ulmus pyramidalis* and *Acer crenatifolium*.

The preliminary succession of the fossils plant assemblages in the České středohoří Mts., according to geological ages (Kvaček and Walther 2004), recognizes five vegetation levels starting with the Eocene, represented by the *Doliostrobus* flora and Oligocene floras with *Juniperus*, taxads, *Calocedrus* and *Pinus*. The Matrý flora falls into the upper levels in which *Calocedrus* is associated with *Pinus*. The Žichov flora (Schichow), although not yet fully revised (see Hably et al. 2001) represents the second site sharing both aspects and elements with Matrý. Such a trend corresponds with the recently obtained fish fauna data and the so far published syntheses (Kvaček and Teodoridis 2007).

Several connecting links can be recognized in the late Oligocene flora of Rhineland (Winterscheid and Kvaček 2014), where vegetation was apparently more thermophilic due to different palaeogeography. The coal-forming vegetation represented by Fagaceae and developed in the Oligocene and Miocene of the adjacent Sokolov Basin and the Doupovské hory Mts. left no traces in the České středohoří Mts.

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Explanations of plates

PLATE 1

1. *Woodwardia muensteriana* (C.Presl in Sternb.) Kräusel. Fragment of pinna, PA 1428.1, scale bar 5 mm.
2. *Woodwardia muensteriana* (C.Presl in Sternb.) Kräusel. Detail of venation, PA 1428.1, scale bar 5 mm.
3. *Pinus hepios* (Unger) Heer. Binate needle fascicle, PA 1188.1, scale bar 10 mm.
4. *Pinus hepios* (Unger) Heer. Binate needle fascicle, PA 1382, scale bar 10 mm.
5. *Pinus rigios* (Unger) Ettingsh. Ternate needle fascicle, PA 1159.2, scale bar 10 mm.
6. *Pinus rigios* (Unger) Ettingsh. Ternate needle fascicle, PA 1348, scale bar 10 mm.
7. *Cephalotaxus parvifolia* (H.Walther) Kvaček et H.Walther. Needle leaf, PA 1393, scale bar 5 mm.
8. *Torreya bilinica* Saporta et Marion. Needle leaf, PA 1358, scale bar 5 mm.
9. *Torreya bilinica* Saporta et Marion. Needle leaf, PA 1584, scale bar 5 mm.
10. *Tetralinis salicornioides* (Unger) Kvaček. Seed, PA 1177, scale bar 5 mm.
11. *Tetralinis salicornioides* (Unger) Kvaček. Leaf segment, PA 1427, scale bar 5 mm.
12. *Calocedrus suleticensis* (Brabenec) Kvaček. Seed cone with fragmentary stalk, PA 1173.1, scale bar 10 mm.
13. *Calocedrus suleticensis* (Brabenec) Kvaček. Detail of seed cone, PA 1173.1, scale bar 5 mm.

PLATE 2

1. ? *Magnolia seifhennersdorfensis* H.Walther et Kvaček. Incomplete leaf, PA 1448, scale bar 10 mm.
2. ? *Magnolia seifhennersdorfensis* H.Walther et Kvaček. Apical part of leaf, PA 1195.3, scale bar 10 mm.
3. ? *Magnolia seifhennersdorfensis* H.Walther et Kvaček. Basal part with fragmentary petiole, PA 1367, scale bar 10 mm.
4. *Liriodendron haueri* Ettingsh. Incomplete bilobate leaf, PA 1187, scale bar 10 mm.
5. *Liriodendron haueri* Ettingsh. Incomplete bilobate leaf, PA 1399, scale bar 10 mm.
6. *Liriodendron haueri* Ettingsh. Complete bilobate leaf, PA 1440.1, scale bar 10 mm.
7. *Liriodendron haueri* Ettingsh. Winged samara, PA 1359.1, scale bar 5 mm.
8. *Liriodendron haueri* Ettingsh. Winged samara, PA 1426.1, scale bar 5 mm.

PLATE 3

1. *Laurophyllum* sp. Complete leaf with petiole, PA 1398, scale bar 10 mm.
2. *Laurophyllum* sp. Incomplete leaf with petiole, PA 1158.6, scale bar 10 mm.
3. *Laurophyllum* sp. Incomplete leaf, PA 1158.8, scale bar 10 mm.
4. *Laurophyllum* sp. Complete leaf with petiole, PA 1383.1, scale bar 10 mm.
5. *Laurophyllum* sp. Incomplete leaf, PA 1182.3, scale bar 10 mm.
6. *Laurophyllum* sp. Incomplete leaf, PA 1189.4, scale bar 10 mm.
7. *Laurophyllum* sp. Incomplete apical part of leaf, PA 1584, scale bar 10 mm.

PLATE 4

1. *Daphnogene cinnamomifolia* (Brongn.) Unger forma *lanceolata* (Unger) Kvaček et H.Walther. Incomplete leaf with petiole, PA 1153.2, scale bar 10 mm.
2. *Daphnogene cinnamomifolia* (Brongn.) Unger forma *lanceolata* (Unger) Kvaček et H.Walther. Incomplete leaf with petiole, PA 1153.1, scale bar 10 mm.
3. *Daphnogene cinnamomifolia* (Brongn.) Unger forma *lanceolata* (Unger) Kvaček et H.Walther. Incomplete leaf with petiole, PA 1346, scale bar 10 mm.
4. *Daphnogene cinnamomifolia* (Brongn.) Unger forma *lanceolata* (Unger) Kvaček et H.Walther Incomplete leaf with petiole, PA 1350, scale bar 10 mm.
5. ? *Sparganium* sp. Leaf fragment with parallel venation, PA 1424.1, scale bar 10 mm.
6. ? Gramineae gen. et sp. indet. Parallel-veined grass-like leaf fragment, PA 1168.1, scale bar 10 mm.
7. *Platanus neptuni* (Ettingsh.) Bůžek, Holý et Kvaček. Group of incomplete leaflets possibly from a compound leaf, PA 1362, scale bar 10 mm.
8. *Platanus neptuni* (Ettingsh.) Bůžek, Holý et Kvaček. Strap-like stipule, PA 1179.1, scale bar 5 mm.
9. *Platanus neptuni* (Ettingsh.) Bůžek, Holý et Kvaček. Globular infructescence, PA 1435, scale bar 5 mm.
10. *Platanus neptuni* (Ettingsh.) Bůžek, Holý et Kvaček. Complete leaf with long petiole, PA 1157.4, scale bar 10 mm.

PLATE 5

1. *Cercidiphyllum crenatum* (Unger) R.W.Br. Almost complete leaf, PA 1581, scale bar 5 mm.
2. ? Leguminosae gen. indet. Isolated leaflet with short fragmentary petiolule, PA 1391, scale bar 10 mm.
3. ? Leguminosae gen. indet. Isolated leaflet with short fragmentary petiolule, PA 1411.1, scale bar 10 mm.
4. ? Leguminosae gen. indet. Isolated leaflet with short fragmentary petiolule, PA 1405.1, scale bar 10 mm.
5. *Sloanea artocarpites* (Ettingsh.) Kvaček et Hably. Incomplete leaf, PA 1410.1, scale bar 10 mm.
6. *Ulmus pyramidalis* Göpp. Two complete attached leaves, PA 1191.1, scale bar 10 mm.
7. *Ulmus pyramidalis* Göpp. Complete leaf with fragmentary petiole, PA 1429, scale bar 10 mm.
8. *Ulmus pyramidalis* Göpp. Incomplete leaf, PA 1162.2, scale bar 10 mm.
9. *Celtis pirskenbergensis* (Erw.Knobloch) Kvaček et H.Walther. Incomplete leaf, PA 1353, scale bar 10 mm.
10. *Celtis pirskenbergensis*(Erw.Knobloch) Kvaček et H.Walther. Detail of leaf bases, PA 1353, scale bar 5 mm.

PLATE 6

1. *Carya fragiliformis* (Sternb.) Kvaček et H.Walther. Complete leaflet, PA 1418, scale bar 10 mm.
2. *Carya fragiliformis* (Sternb.) Kvaček et H.Walther. Complete leaflet, PA 1340, scale bar 10 mm.
3. *Carya fragiliformis* (Sternb.) Kvaček et H.Walther. Complete leaflet, PA 1351, scale bar 10 mm.
4. *Carya quadrangula* (Kirchh.) J.-F.Leroy. Incomplete fruit, PA 1365, scale bar 10 mm.
5. *Carya quadrangula* (Kirchh.) J.-F.Leroy. Complete fruit, PA 1164.1, scale bar 10 mm.
6. *Carya quadrangula* (Kirchh.) J.-F.Leroy. Incomplete half of fruit, PA 1580, scale bar 5 mm.
7. *Cyclocarya* sp. vel *Carya* sp. Incomplete leaflet with denticulate margin, PA 1170.1, scale bar 10 mm.
8. *Cyclocarya* sp. vel *Carya* sp. Incomplete leaflet with denticulate margin, PA 1170.7, scale bar 10 mm.
9. *Cyclocarya* sp. vel *Carya* sp. Incomplete leaflet with denticulate margin, PA 1170.8, scale bar 10 mm.

PLATE 7

1. *Betula brongniartii* Ettingsh. Incomplete leaf with double sharply serrate margin, PA 1152.1, scale bar 10 mm.
2. *Betula brongniartii* Ettingsh. Incomplete leaf with double sharply serrate margin and short petiole, PA 1152.2, scale bar 10 mm.
3. *Betula brongniartii* Ettingsh. Incomplete leaf with double sharply serrate margin and short petiole, PA 1582, scale bar 10 mm.
4. *Betula brongniartii* Ettingsh. Almost complete leaf with double sharply serrate margin and shortly attenuate apex, PA 1342, scale bar 10 mm.
5. *Betula dryadum* Brongn. Double-winged fruitlet PA 1420.1, scale bar 5 mm.
6. *Betula dryadum* Brongn. Bract, PA 1446, scale bar 5 mm.
7. *Alnus rhenana* (P.Wessel et C.O.Weber) Winterscheid et Kvaček. Basal leaf part with finely widely serrate margin and fragmentary petiole, PA 1375, scale bar 10 mm.
8. *Alnus rhenana* (P.Wessel et C.O.Weber) Winterscheid et Kvaček. Incomplete leaves with finely widely serrate margin and fragmentary petiole, PA 1380, scale bar 10 mm.
9. *Alnus rhenana* (P.Wessel et C.O.Weber) Winterscheid et Kvaček. Incomplete apical leaf part with finely widely serrate margin, PA 1343, scale bar 10 mm.
10. *Alnus* cf. *kefersteinii* (Göpp.) Unger. Two infructescenses, PA 1576, scale bar 10 mm.

PLATE 8

1. *Alnus* sp. Almost complete leaf with fine denticulate margin and petiole, PA 1579.1, scale bar 5 mm.
2. *Alnus* sp. Almost complete leaf with fine denticulate margin and petiole, PA 1172.4, scale bar 10 mm.
3. *Alnus* sp. Almost complete leaf with fine denticulate margin and petiole, PA 1578, scale bar 10 mm.
4. *Carpinus grandis* Unger. Almost complete leaf with fine serrate-dentate margin, PA 1574, scale bar 10 mm.
5. *Carpinus grandis* Unger. Almost complete leaf with fine serrate-dentate margin, PA 1388, scale bar 10 mm.
6. *Carpinus grandis* Unger. Almost complete leaf with fine serrate-dentate margin, PA 1344, scale bar 10 mm.
7. *Ostrya atlantidis* Unger. Parallel-veined involucre, PA 1583, scale bar 5 mm.
8. *Ostrya atlantidis* Unger. Leaf with mucronately serrate margin and petiole, PA 1441, scale bar 5 mm.
9. *Ostrya atlantidis* Unger. Leaf with mucronately serrate margin and petiole, PA 1163.5, scale bar 10 mm.
10. *Ostrya atlantidis* Unger. Leaf with mucronately serrate margin and petiole, PA 1577, scale bar 5 mm.

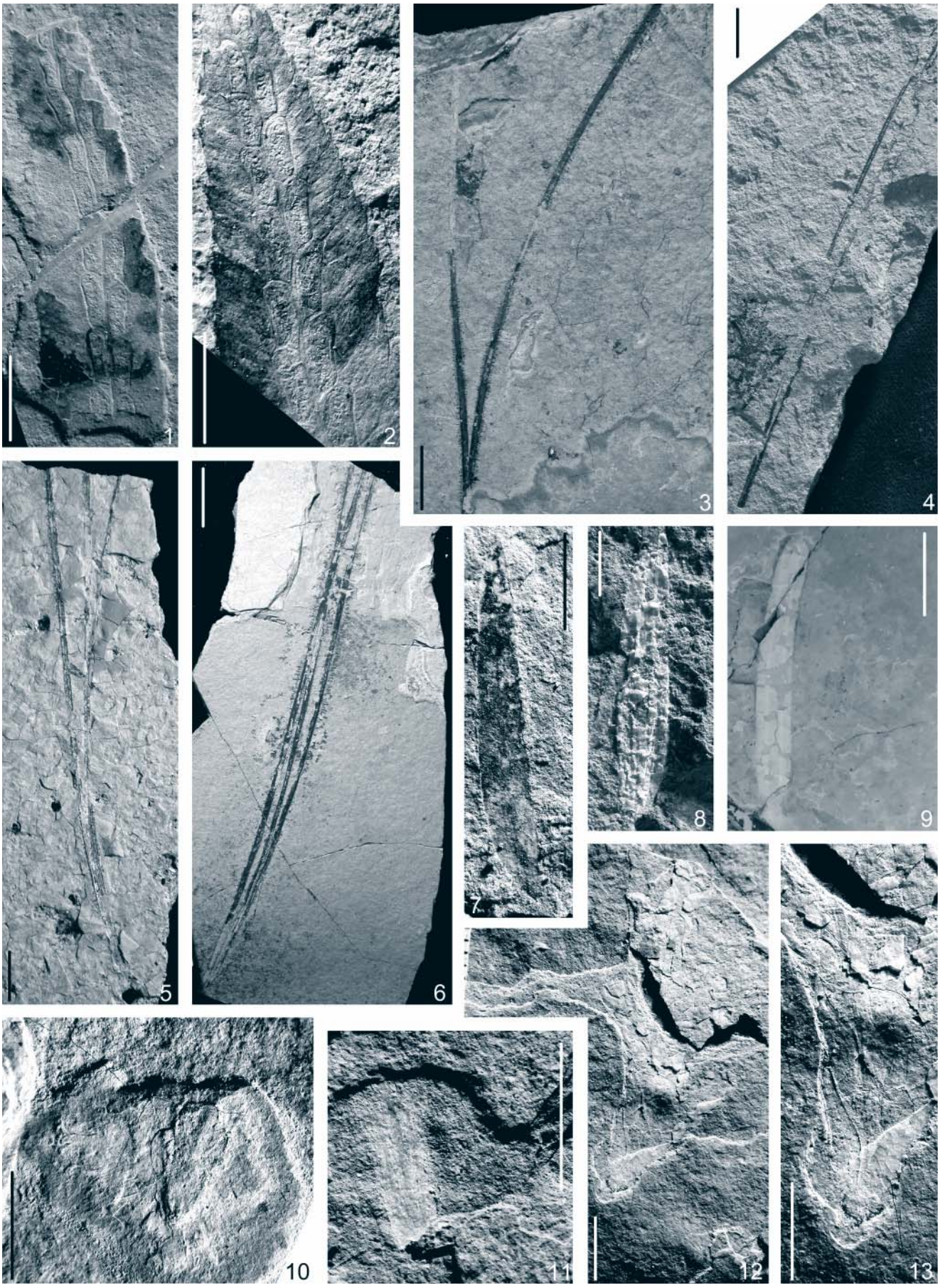
PLATE 9

1. *Acer crenatifolium* Ettingsh. Trilobate leaf fragments with crenate margin, PA 1186.2, scale bar 10 mm.
2. *Acer crenatifolium* Ettingsh. Incomplete trilobate leaf with crenate margin PA 1361.1, scale bar 10 mm.
3. *Acer* cf. *palaeosaccharinum* Stur. Complete tricuspidate leaf with widely simple to irregularly double dentate margin, PA 1356, scale bar 10 mm.
4. *Acer* cf. *palaeosaccharinum* Stur. Incomplete tricuspidate leaf with widely simple to irregularly double dentate margin, PA 1189.1, scale bar 10 mm.
5. *Acer* sp. Fruit, PA 1575, scale bar 5 mm.
6. *Acer* cf. *palaeosaccharinum* Stur. Incomplete tricuspidate leaf with widely simple to irregularly double dentate margin, PA 1184.1, scale bar 10 mm.
7. *Acer* sp. Isolated mericarp, PA 1416, scale bar 5 mm.
8. *Acer integrilobum* C.O.Weber. Incomplete trilobate leaf with entire margin, PA 1449, scale bar 10 mm.

PLATE 10

1. *Dicotylophyllum* sp. 3. Incomplete widely lanceolate leaf with coarsely serrate margin, PA 1169.1, scale bar 10 mm.
2. *Pungiphyllum* cf. *cruciatum* (A.Braun) Frankenhäuser et V.Wilde. Complete leaf with widely dentate margin on its apical part, PA 1340, scale bar 10 mm.
3. *Dicotylophyllum* sp. 1. Incomplete widely elliptic leaf with entire margin and long petiole, PA 1188.1, scale bar 10 mm.
4. *Dicotylophyllum* sp. 1. Almost complete elliptic leaf with entire margin and long petiole, PA 1412.2, scale bar 10 mm.
5. *Craigia bronnii* (Unger) Kvaček, Bůžek et Manchester. Fruit capsule, PA 1360, scale bar 5 mm.
6. *Craigia bronnii* (Unger) Kvaček, Bůžek et Manchester. Fruit capsule, PA 1156.2, scale bar 5 mm.
7. *Dicotylophyllum* sp. 2. Complete leaf with narrow cuneate base and sharply densely dentate margin, PA 1363.2, scale bar 10 mm.
8. *Dicotylophyllum* sp. 2. Basal part of leaf with sharply and densely dentate margin, PA 1425.1, scale bar 10 mm.
9. *Dicotylophyllum* sp. 3. Complete ovate leaf with coarsely serrate margin and short petiole, PA 1431, scale bar 10 mm.
10. *Dicotylophyllum* sp. 4. Complete obovate leaf with bluntly acute apex and entire margin, PA 1585.1, scale bar 10 mm.
11. *Dicotylophyllum* sp. 4. Incomplete obovate leaf with bluntly acute apex, cuneate base and entire margin, PA 1430, scale bar 10 mm.

PLATE 1



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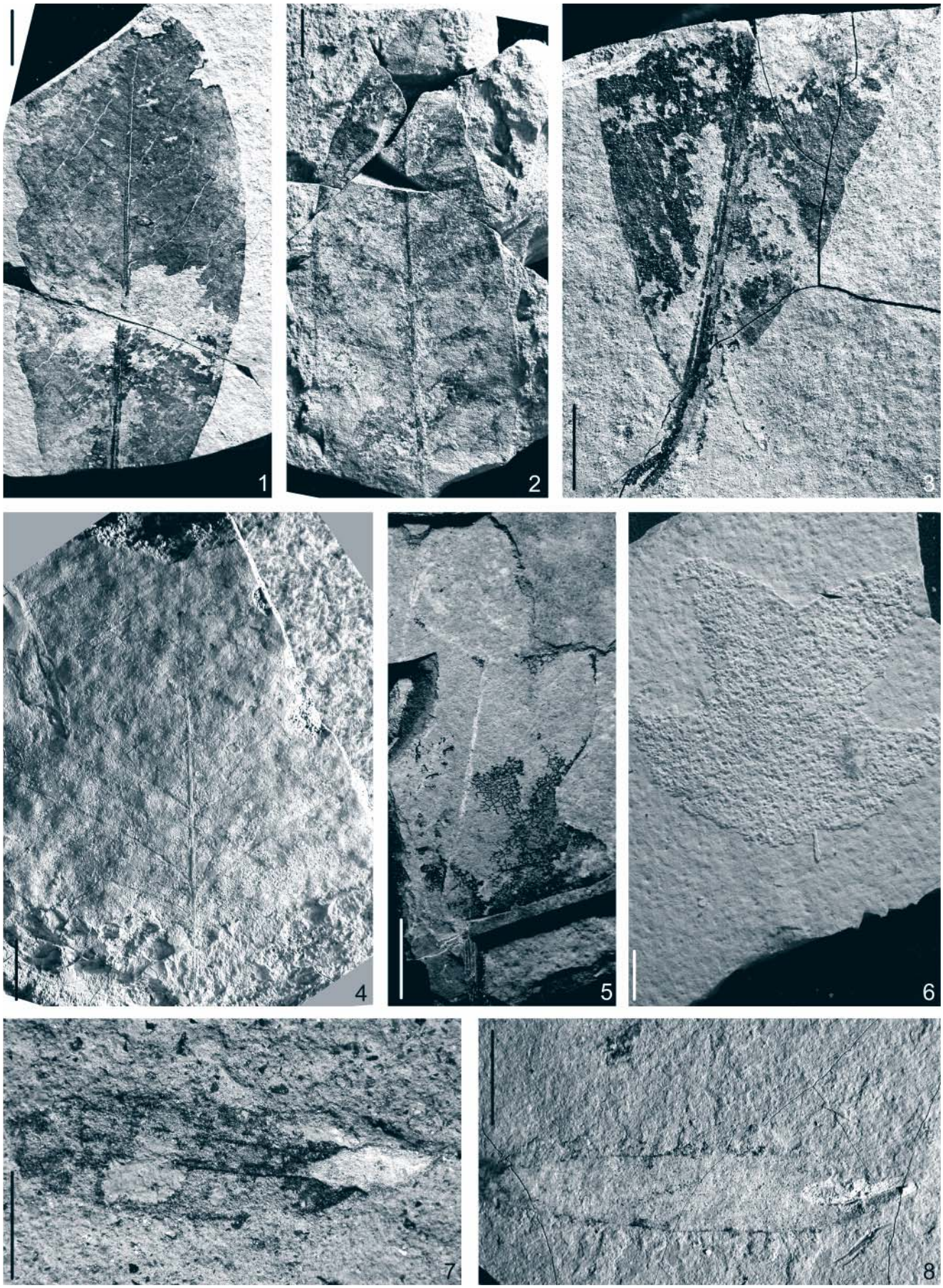

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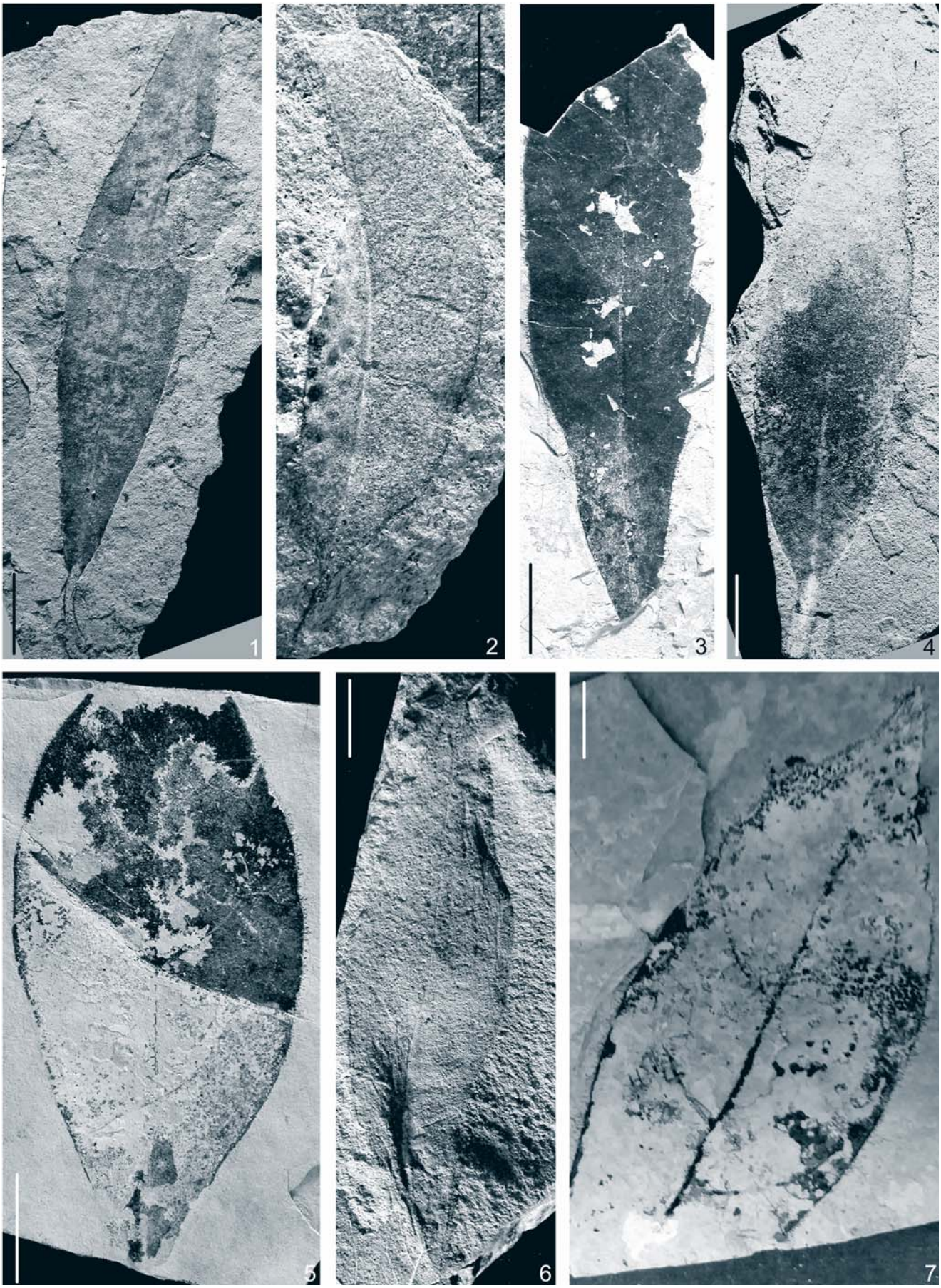

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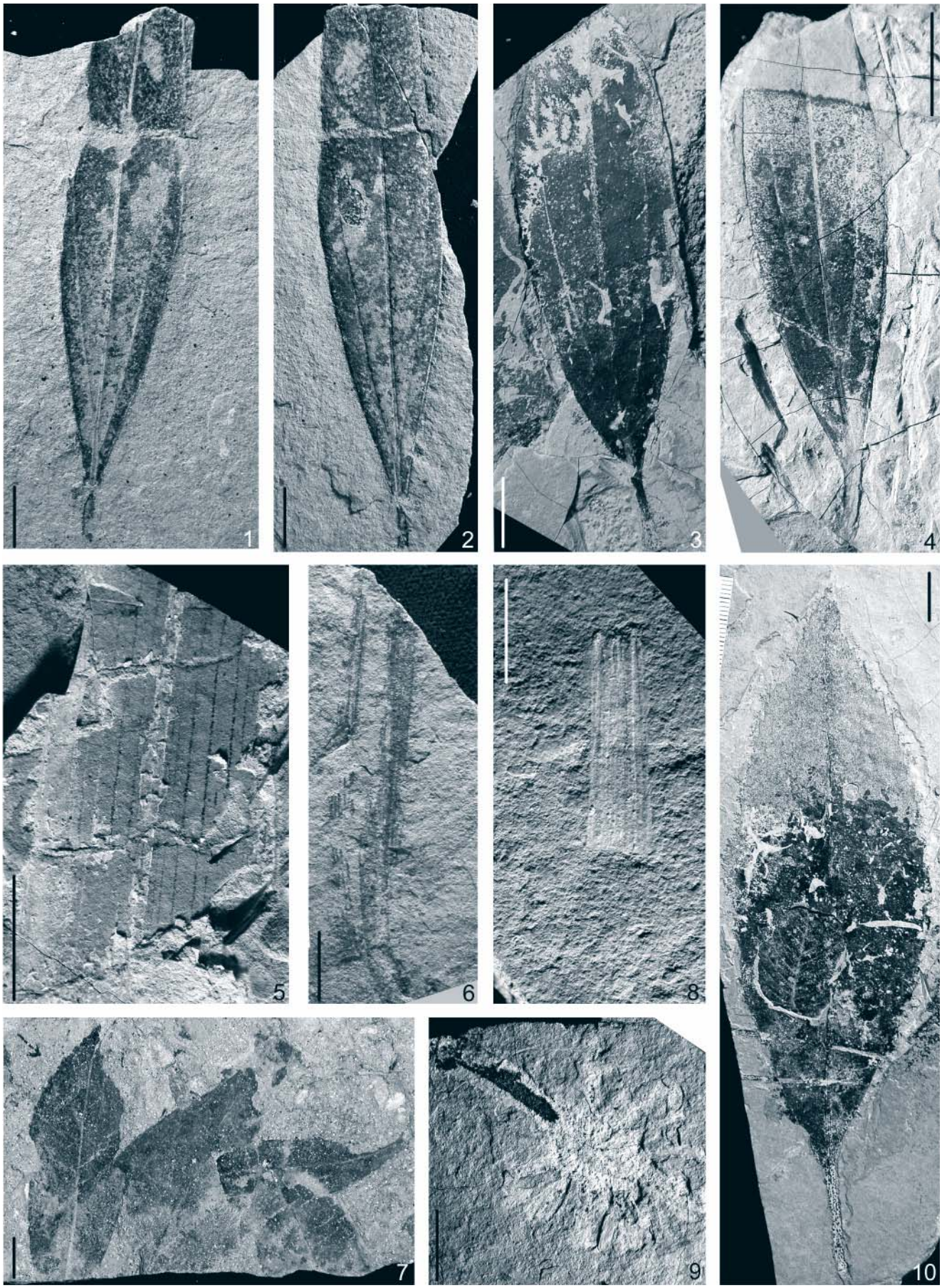

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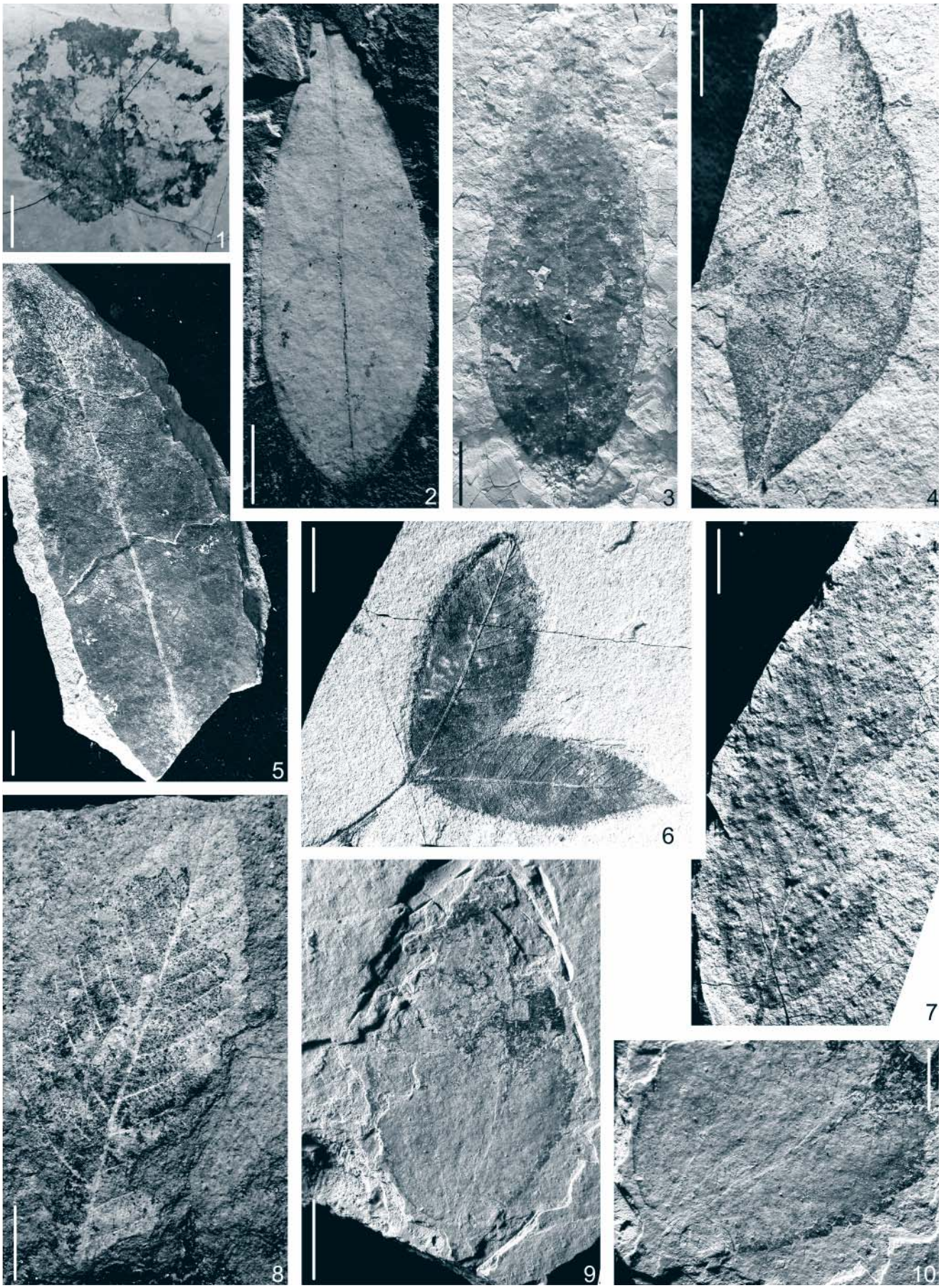

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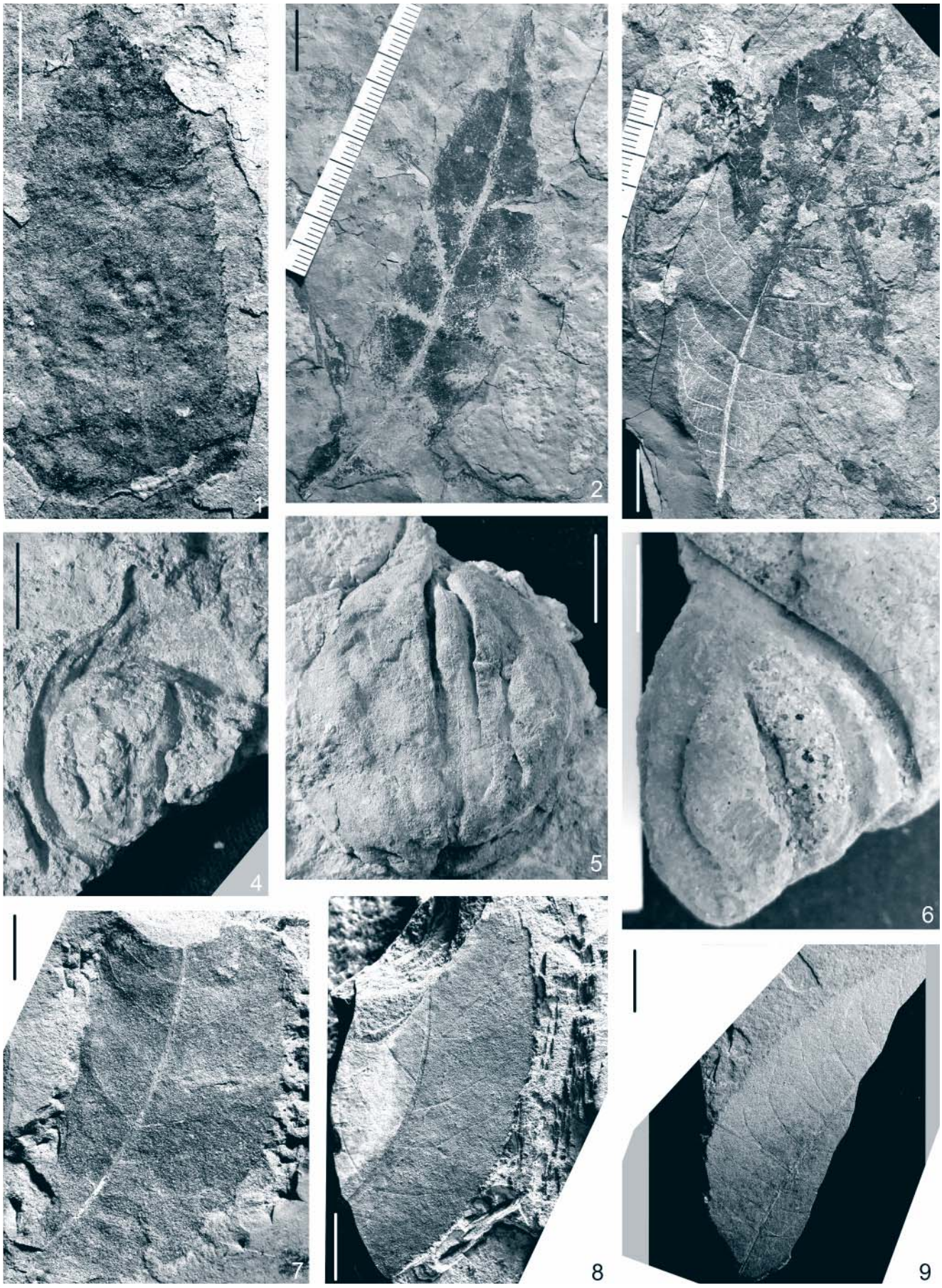

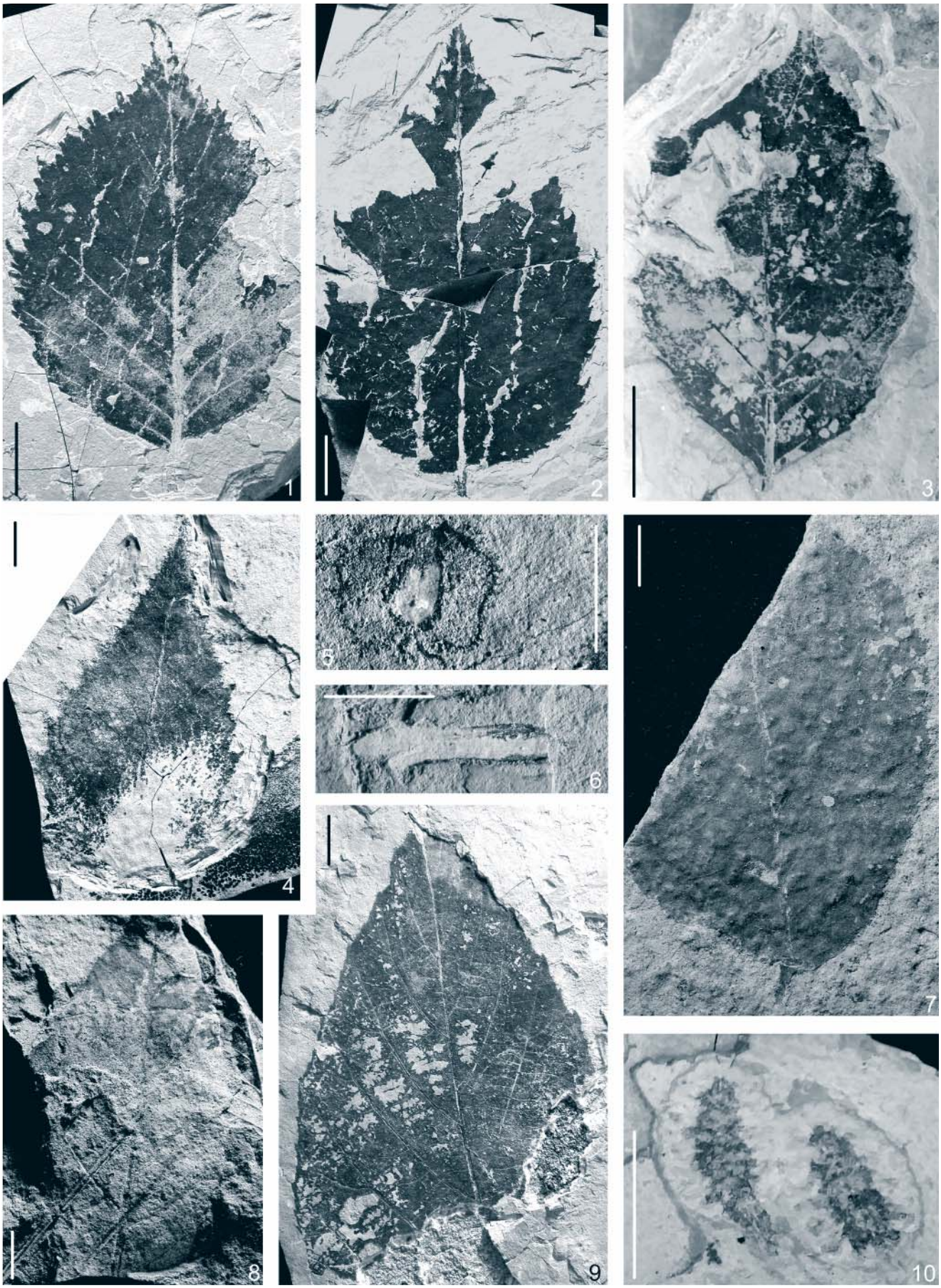
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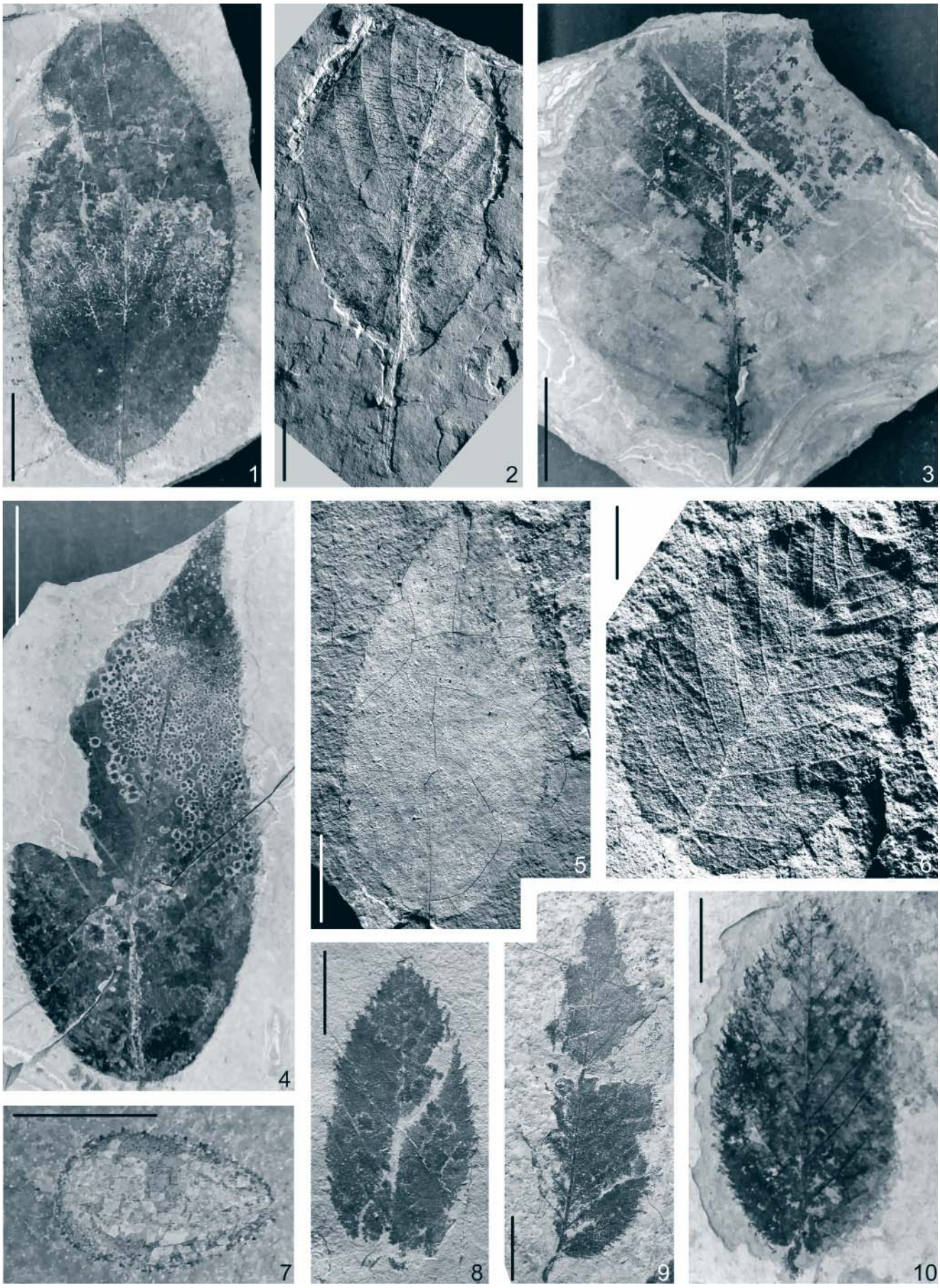
PLATE 8



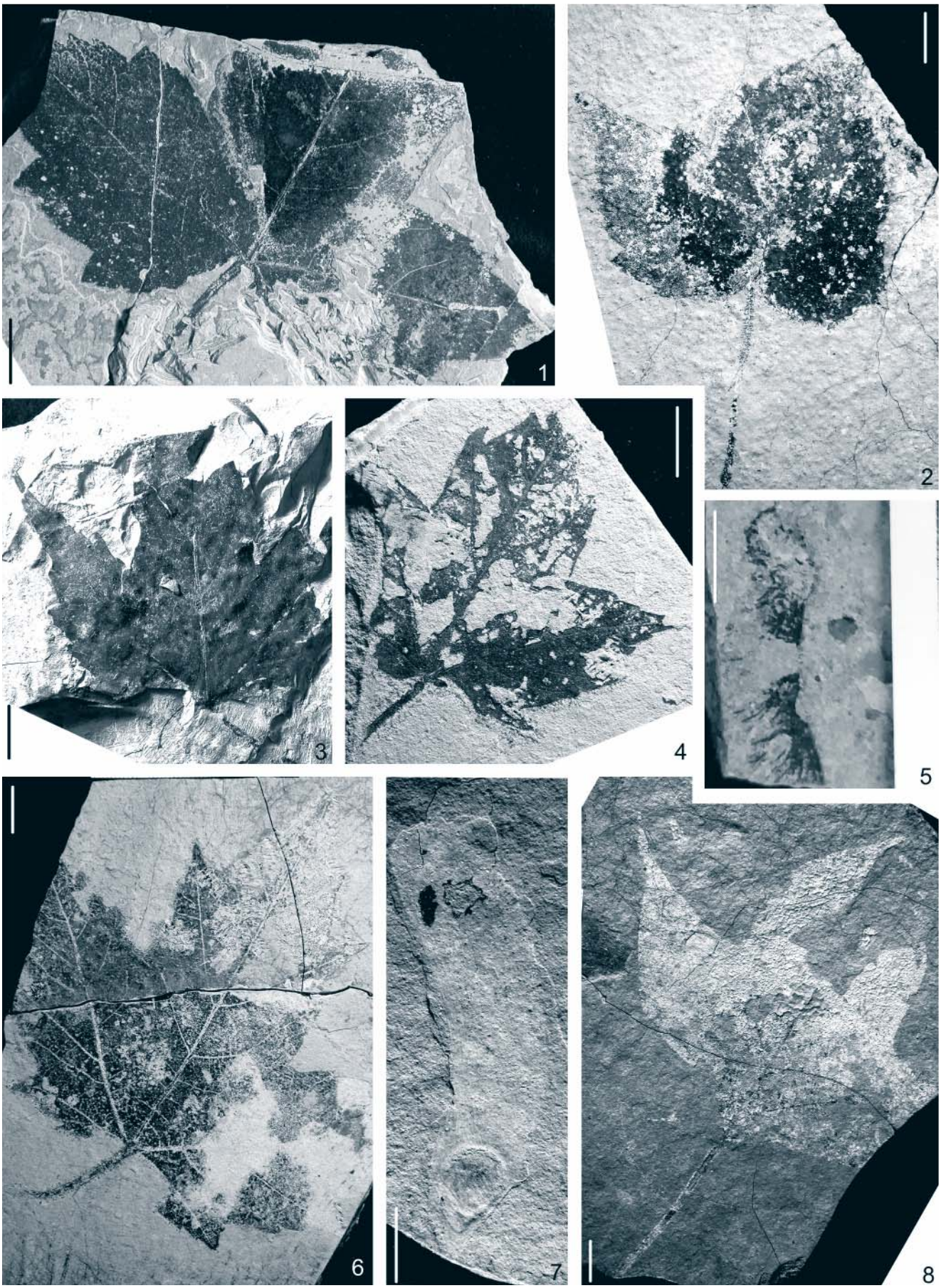

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PLATE 10