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THE LATE OLIGOCENE MACROFLORA OF ZSÁMBÉK, CENTRAL HUNGARY

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Abstract: Fossil plants were discovered by geologists in the dolomite quarry on Strázsa Hill, west of Zsámbék, central Hungary, during December, 2020. The analysis of the plant remains and subsequent field studies suggest that the fossil plants are preserved in sediments of the Mány Member of the Törökbálint Formation and the sandy-clayey layers overlying Mesozoic dolomites were formed during the Oligocene. The fossil plant assemblage includes a small number of taxa with a relatively high frequency of gymnosperms. Among the gymnosperms taxodiaceous twigs, assigned to ?*Taxodium*, are dominant. Angiosperms are represented by the family Lauraceae (*Daphnogene* and *Laurophyllum*), Betulaceae (cf. *Alnus*), Ulmaceae (cf. Ulmaceae gen. et sp.), and "*Rhamnus*" *warthae*, a taxon with unknown systematic relations and a putative endemic element of the Intra-Carpathian area of the Central Paratethyan region. The flora is dominated by gymnosperms and "*Rhamnus*" *warthae*, other taxa are present but at lower frequency. Although the plant fossils of Zsámbék represent wetland vegetation types, less suitable for climate reconstruction, the relatively high ratio of lauraceous elements suggests a frostfree, warm climate. The floristic composition of the Zsámbék flora is clearly comparable to other late Oligocene floras of Hungary, therefore earlier climate estimates based on other similar-aged floras may also be considered for Zsámbék.

Key words: Chattian, Egerian, Kiscellian, taxodiaceous gymnosperms, Lauraceae, *Daphnogene*, "*Rhamnus*" *warthae*, wetland, Transdanubian Range, Törökbálint Formation

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Introduction

The flora of the late Oligocene (Chattian, regional stratigraphy: Egerian) is well represented in Hungary, plant remains have been recovered in most of the area where Egerian strata have been recorded. The majority of the fossil plant localities were discovered during the last two decades of the 20th century. Some sites, however, were well known much earlier (e.g., Csörög, from where János Tuzson collected in the 1910s). The most well-known locality, in Eger-Wind brickyard, yielded a diverse flora, which was first studied by Andreánszky (1966) followed by Kvaček and Hably (1991). The fossil assemblages from Környe (Hably et al. 2015), Tarján (Hably et al. 2017), and Vértesszőlős (Hably 1990) were excavated from sediments of the Mány Member of the Törökbálint Formation (formerly Mány Formation), sharing many species, such as *Glyptostrobus europaeus* (Brongn.) Unger, *Daphnogene cinnamomifolia* (Brongn.) Unger, and *Alnus oligocaenica* Andr. Although the Zsámbék flora, fossilized in sediments of the Törökbálint Formation, is of relatively low diversity, its discovery turned out to be significant for the elaboration and interpretation of local stratigraphy.

In December 2020, fossil plant remains were discovered by geologists Gábor Héja, László Fodor, and Szilvia Kövér in the eastern part of the dolomite quarry on Strázsa Hill, west of the town of Zsámbék, central Hungary (Text-fig. 1.). The fossil plants are preserved in fine-grained siliciclastic rocks overlying Mesozoic dolomites. A recent publication has already considered the western wall of the quarry, where bio- and lithostratigraphic observations classified the clastic cover sequence to the Middle and Upper Miocene (Kercsmár et al. 2020). The analysis of fossil plants preserved at the site and subsequent field studies by Héja, Fodor, and Kövér, however, suggest that the sandy-clayey layers overlying dolomites were formed during the Oligocene. A detailed elaboration of the local stratigraphy and structure of the Strázsa Hill quarry by Héja, Fodor, and Kövér is in progress. After finding the

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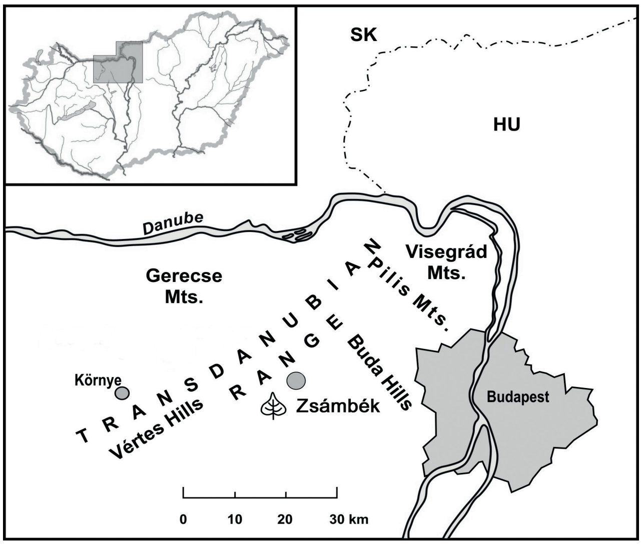

Text-fig. 1. Location of the study area.

first plant remains, a more extensive collection was made. Fossil plant remains collected by Erdei, Hably, and György Szakmány are housed in the Hungarian Natural History Museum, Budapest, Hungary. Fossil floras comparable to the Zsámbék fossil plant assemblage are known from upper Oligocene sediments, e.g., Környe (Hably et al. 2015), where fossil plants are preserved in layers of the Mány Member of the Törökbálint Formation (formerly Mány Formation).

Geological setting

Strázsa Hill, west of the town of Zsámbék, is part of the Transdanubian Range of central-western Hungary, and has a complex structure, regarding both the Mesozoic and Cenozoic sequence. The quarry is located along major structures which played a crucial role in both the stratigraphy and structural evolution. The Middle and Upper Triassic rocks are juxtaposed along a major E-W trending Cretaceous thrust fault (Budai et al. 2015). This fault had been reactivated as normal and dextral faults during the Eocene and Oligocene and regionally named as the Zsámbék or Környe-Zsámbék Fault (Balla and Dudko 1989, Bada et al. 1996, Fodor 2008). This faulting put the investigated site in the footwall of the Zsámbék multiphased fault (Végh-Neubrandt and Mensáros 1986). This footwall block was covered by two brackish to marine sequences, Oligocene and Miocene in age, which were separated by a denudation phase of long duration during the Early Miocene. The erosion denudated the Oligocene cover in the northwestern part of the quarry where only the Middle to Late Miocene sequence could be documented (Kercsmár et al. 2020). This sequence is composed of coarse- to fine-grained siliciclastics (breccia, sand(stone), sandy gravel, sandy siltstone), with subordinate intercalations of calcareous mud and freshwater limestone in the earliest Late Miocene (Kercsmár et al. 2020).

Considering further the Oligocene sequence in the eastern part of the quarry, the lower few meters are composed

Text-fig. 2. Moderately dipping Oligocene layers of the Mány Member in the eastern part of the Strázsa Hill quarry, SW of Zsámbék. The claymarl and siltstone layers cover sandstone and conglomerate. The arrow indicates the position of fossiliferous layers. Photo: László Fodor.

of variegated clays, conglomerate, and sandstone. These coarse-clastics have red, lilac and pinkish white colour, possibly connected to terrestrial weathering, which, in nearby locations resulted in bauxite deposition (Óbarok Formation, Mindszenty et al. 2002). The overlying fine-grained sandstone, siltstone, claystone, claymarl, containing the plant remains, are typical sediments of the Mány Member of the Törökbálint Formation (Text-fig. 2) (Korpás 1981, Báldi 1986, Hably et al. 2015). After a long period of denudation and eventual terrestrial sedimentation of early Oligocene age, the Mány member represents the transgressive sediments of a new marine flooding. The depositional environment of the sequence could be shallow lagoons characterized by variably brackish salinities, alternating with local swamps and shoreface sandy beaches. The deposition of the Mány Member may have already started during the late Kiscellian (standard stratigraphy: Rupelian, early Oligocene) and lasted into the late Oligocene (Selmeczi and Fodor 2008). Fossil assemblages predominantly comprise variably preserved molluscs (Janssen 1981, Báldi 1986) and plant remains (Hably et al. 2015), which are the focus of this study.

Material and methods

Collecting activities resulted in nearly 90 exclusively leaf specimens being excavated. Collecting was partly limited by mining activities in the quarry which quickly reached and destroyed the sampling site and also by winter conditions. The fossil assemblage is stored in the Palaeobotanical Collection of the Hungarian Natural History Museum, Budapest, Hungary, inventoried with the prefix "HNHM-PBO".

The plant remains are fossilized as imprints, no organic matter was preserved. The leaves are heavily fragmented and display a litter-like accumulation, overlapping each other. The leaves appear to have been fragmented before sedimentation. Since no cuticular details were preserved, similarly as in most Egerian floras in Hungary, identification of leaves was based solely on macromorphological details. Reference specimens comparable to the specimens described here are listed under the taxon names.

Fossil remains were studied using macromorphological methods. Descriptions followed Dilcher (1974) and Ellis et al. (2009). To observe finer details, an Olympus SZX9 dissecting microscope was used and photos were taken using a Nikon D3200 camera.

Systematic palaeobotany

Order Pinales Gorozh., 1904
Family Cupressaceae Gray, 1822 s.l. nom. cons.

Genus *Taxodium* Rich., 1810

?*Taxodium dubium* (Sternb.) Heer, 1853
Pl. 1, Figs 1–6

2015 ?*Taxodium dubium* (Sternb.) Heer; Hably et al., p. 291, fig. 4: 3, 4.

M a t e r i a l. HNHM-PBO 2021.160.1.–2021.179.1., HNHM-PBO 2021.207.1.

D e s c r i p t i o n. Leafy shoots with taxodioid type leaves. Leaves are helically arranged, partly distichous and appear very shortly petiolate. Length and width of leaves are up to 12 mm, and 1.5 mm, respectively. Lamina is linear in shape, partly ovate. Leaf apex is acute, often mucronate. Base is slightly rounded to acute. Margin is entire.

D i s c u s s i o n. The systematic affinity of the taxodioid leaf remains could not be corroborated by cuticular studies. In the quite similar flora of Környe, gymnospermous twigs were identified partly as *Glyptostrobus* Endl. and partly as ?*Taxodium* (Hably et al. 2015). Since seeds and cones assignable to *Glyptostrobus* were recorded in the flora of Környe, gymnosperm shoots with cupressoid and cryptomerioid leaf morphotypes were assigned to the *Glyptostrobus* genus. Shoots with taxodioid type leaves in Környe, which seem identical to those described from Zsámbék, were assigned to *Taxodium* with a question-mark.

In the flora of Zsámbék shoots with cupressoid or cryptomeroid leaf morphotypes were not recorded, neither were reproductive structures which could assist in identification of the vegetative remains. Leaves found in Zsámbék are of the taxodioid morphotype, linear or partly ovate, similar to those of *Taxodium* and *Sequoia* Endl., but with a much broader lamina than the linear taxodioid type leaves of *Glyptostrobus* (Farjon 2005, LePage 2011). On short shoots of modern *Glyptostrobus* trees, somewhat bilaterally flattened leaves may also develop and are arranged spirally and in a partly distichous manner (Farjon 2005). Unfortunately, leaf bases are only faintly visible and details of leaf attachment, which may aid identification (LePage 2011), are unclear in the shoots from Zsámbék. Until reproductive structures or cuticular details corroborate a more formal identification, the leaves from Zsámbék, are considered as quite comparable to those from Környe (Hably et al. 2015), and are treated similarly and assigned to ?*Taxodium*.

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

Genus *Daphnogene* Unger, 1850

***Daphnogene* sp.**
Pl. 2. Figs 1, 3–4

M a t e r i a l. HNHM-PBO 2021.191.1., HNHM-PBO 2021.198.1., HNHM-PBO 2021.199.1., HNHM-PBO 2021.200.2., HNHM-PBO 2021.201.2., HNHM-PBO 2021.205.2.

D e s c r i p t i o n. Fragments of simple leaves. Length of lamina is up to 6.4 cm, width is up to 3.5 cm. Lamina is wide ovate in shape (Pl. 2, Figs 1, 3) or wide lanceolate (Pl. 2, Fig 4). Base is acute, apex is not preserved. Leaf margin is entire. Venation is suprabasal acrodromous. Suprabasal veins are perfect or imperfect. Midvein is strong. Secondaries reach the upper third of the lamina, forming loops. Interior secondary veins are dense. Tertiary veins emerge toward the margin, also forming loops.

D i s c u s s i o n. Based on the pair of strong suprabasal veins the leaves are assigned to *Daphnogene*. At Zsámbék the leaves are fragmented, but very probably belong to the species *Daphnogene cinnamomifolia* (Brongn.) Unger. On a morphological basis, Kvaček and Walther (1974) distinguished two forms of the species, the putative sun and shade leaves, forma *lanceolate* and forma *cinnamomifolia*. In the Zsámbék flora, the wide and slender leaves of *Daphnogene* may represent these forms, however, poor preservation of the fossil leaves does not allow precise identification. In the Egerian floras of Hungary, species of *Daphnogene* seem to be frequent members of wetland vegetation, but their remains are also recorded in mesophytic associations, e.g., in the flora of Pomáz (Hably 1994). *Daphnogene* leaves are relatively decay resistant and have a higher chance of fossilization than leaves of most other taxa, even those in coarse-grained sediments with high carbonate content (Hably and Szakmány 2006).

cf. Lauraceae gen. et sp.
Pl. 2, Fig. 2

Material. HNHM-PBO 2021.192.1.

Description. A fragment of a simple leaf. Margin is entire, venation is brochidodromous.

Discussion. As the cuticle is not preserved, micromorphological details are not available for identification purposes. The entire margin and venation type, however, suggest the Lauraceae family. Leaves of Lauraceae, including the fossil genus *Daphnogene*, are frequent elements in the Egerian floras of Hungary.

Order Rosales Bercht. et J.Presl, 1820
Family Ulmaceae Mirb., 1815 nom. cons.

cf. Ulmaceae gen. et sp. 1
Pl. 2, Fig. 5

Material. HNHM-PBO 2021.180.1., HNHM-PBO 2021.183.1.

Description. Fragmentary leaves. Length and width of the fragments are up to 5 cm, and 3.5 cm, respectively. One of the leaves (Pl. 2, Fig. 5) appears basally slightly asymmetric in shape. Apex and base are damaged, and the margin is poorly preserved. Venation is craspedodromous. Secondary veins emerge at an acute angle (at 40–45°) from the midvein. Secondaries are straight, quite regularly spaced, and run parallel to each other.

Discussion. The leaves are heavily fragmented, but the gross venation pattern of the leaves is recognizable even in coarse-grained sedimentary matrix (Hably and Szakmány 2006). The venation and the basally slightly asymmetric lamina shape resemble the species *Ulmus pyramidalis* Göpp., one of the most frequent species of elm in the Egerian floras of Hungary (Pl. 2, Fig. 6; a leaf from Pomáz) occurring in nearly all localities. The species appeared in the Pannonian region mainly in the wetland environments. Similar leaves were recorded in younger localities of Europe, e.g., in the Neogene flora of Wollbach (Kelber 2020).

cf. Ulmaceae gen. et sp. 2
Pl.3, Fig. 1

Material. HNHM-PBO 2021.185.2.

Description. A small leaf, lamina is 2.4 cm long, and 1.6 cm wide. Lamina is elliptic, slightly asymmetric in shape, margin is toothed. Teeth are small. Venation is craspedodromous, tertiary veins are not visible.

Discussion. The fragment resembles a small-leaved form of elm, different from leaves of the above described cf. Ulmaceae gen. et sp. 1 (probably comparable to *U. pyramidalis*). In the Hungarian Egerian similar leaves were published from Pomáz locality as *Ulmus braunii* Heer where it is relatively frequent (Hably 1994). It was also recorded in Late Miocene floras of Hungary (Hably 2013). Since details of margin pattern and tooth morphology are not clearly visible, the leaf is tentatively assigned to Ulmaceae.

Fagales Engl., 1892
Betulaceae Gray, 1822 nom. cons.

Genus *Alnus* Mill., 1754

cf. *Alnus* sp.
Pl. 3, Fig. 2–4

Material. HNHM-PBO 2021.181.1. HNHM-PBO 2021.182.1., HNHMn-PBO 2021.186.2–2021.188.1., HNHM-PBO 2021.190.1., HNHM-PBO 2021.194.2., HNHM-PBO 2021.202.2.–2021.205.2.

Description. Leaves are simple, petiolate. Lamina is broadly ovate in shape. Its length is up to 8 cm, width is up to 5 cm. Apex is acute. Base is acute to obtuse or slightly cordate. Margin is toothed with rarely spaced small teeth. Apical side of teeth is shorter than the basal side. Venation appears to be semicraspedodromous. Midvein is strong. Secondary veins emerge from the midvein at acute angles (~70°) and seem to form loops near the margin.

Discussion. Although the leaves are poorly preserved, their gross morphology resembles leaves of *Alnus* described from Egerian floras of Hungary, e.g., *Alnus oligocaenica* Andr. (Eger-Wind brickyard; Andreánszky 1966). The species appeared in several Egerian localities in Hungary. The genus was an important element of the Környe flora (Pl. 3, Fig. 5), which is also supported by the presence of fossils of its female inflorescence (Hably et al. 2015). It was accompanied by other swamp elements, thus it presumably occupied wetland habitats.

Plantae incertae sedis

"*Rhamnus*" *warthae* Heer, 1872
Pl. 3, Figs 6, 7, Pl. 4, Figs 1–4

1962 *Rhamnus angustifrons* Andr., p. 233, text-fig. 9.
1966 *Styrax* cf. *japonica* Sieb. & Zucc.; Andreánszky, p. 85, fig. 76.
1966 *Elaeocarpus palaeolanceolatus* Kolak.; Andreánszky, p. 94, fig 87.
1988 *Symplocos* sp.; Hably, p. 44, pl. 9, fig. 6.
1989 *Symplocos* sp.; Hably, p. 89, text-figs 55, 56, 58, pl. 3, fig. 1.
1993a "*Rhamnus*" *warthae* Heer; Hably, p. 12, pl. 2, fig. 2.
2001 "*Rhamnus*" *warthae* Heer; Hably, p. 6.
2015 "*Rhamnus*" *warthae* Heer; Hably et al., p. 296, fig. 6: 2.

Material. HNHM-PBO 2021.134.1.–2021.158.1., HNHM-PBO 2021.162.3., HNHM-PBO 2021.172.3., HNHM-PBO 2021.189.3., HNHM-PBO 2021.206.1.

D e s c r i p t i o n . Leaves are simple. Lamina is lanceolate in shape. Total length of lamina is up to 10 cm, width is up to 4 cm. Apex and base are acute. Margin is toothed. Teeth are very small, acute, and thin. In a coarser-grained matrix, the teeth are not even recognizable. Venation is brochidodromous. In the upper part of the lamina, secondary veins are strongly curved (see Pl. 4, Fig. 2.), and join together forming multiply loops close to the margin. Occasional intersecondary veins are observable. Intercostal tertiary venation is percurrent, dense. Course of percurrent tertiaries is sinuous, making an acute angle with the midvein. Some of the tertiaries anastomose in the lower half of the lamina.

D i s c u s s i o n . A mass occurrence of "*Rhamnus*" *warthae* leaves has been recorded in late Oligocene localities, in the flora of the Zsil Valley, Romania (Staub 1887, Givulescu 1973) and in the floras of the Eger-Wind brickyard (Hably 2001) and Csolnok (Erdei and Wilde 2004) in Hungary. In all of these localities members of the swamp vegetation accompany the "*Rhamnus*" *warthae* leaves.

The palaeogeographic distribution of this species is limited to the Intra-Carpathian area of the Central Paratethyan region, e.g., Hungary and Romania (Hably 2001) suggesting that it was an endemic species. The appearance of "*Rhamnus*" *warthae* Heer may be correlated with the abrupt floral change at the boundary of the early and late Oligocene (Hably 1993b). Kvaček and Hably (1991) suggested an affinity to the genus *Rubus*, based on its mass occurrence in the wetland vegetation of Eger-Wind brickyard, however, the valid systematic position of "*Rhamnus*" *warthae* Heer has not so far been resolved.

Genus *Dicotylophyllum* Saporta, 1892

***Dicotylophyllum* sp. 1**
Pl. 4, Fig. 5

M a t e r i a l . HNHM-PBO 2021.161.2.

D e s c r i p t i o n . A fragmentary leaf with short, 0.4 cm long petiole. Lamina is ovate in shape and clearly asymmetric. Length of lamina is 6.3 cm, width is 4.1 cm. Base is cordate, asymmetric, apex is not preserved. Margin appears to be entire. Second order venation is probably brochidodromous. Secondary veins are spaced at about 1.2 cm from each other. They emerge at obtuse (>90°) angles on one side of the lamina whereas at acute angles on the other side of the lamina. Tertiary venation is not clearly visible.

D i s c u s s i o n . This taxon has not been recorded in other Egerian floras.

***Dicotylophyllum* sp. 2**
Pl. 4, Fig. 6

M a t e r i a l . HNHM-PBO 2021.193.1.

D e s c r i p t i o n . Fragmentary leaf. Length is 2.6 cm, width is 1.4 cm. Lamina is lanceolate in shape. Base and apex are not preserved. Margin is not clearly visible, it is entire or finely toothed. Venation is camptodromous or semicraspedodromous.

D i s c u s s i o n . Systematic affinity is unknown due to poor preservation. However, similar venation characteristics may be developed by leaves of *Quercus* L. or *Platanus neptuni* (Ettingsh.) Bůžek, Holý et Kvaček, which is a characteristic species of Egerian floras in Hungary.

***Dicotylophyllum* sp. 3**
Pl. 4, Fig. 7

M a t e r i a l . HNHM-PBO 2021.195.2.

D e s c r i p t i o n . Leaf with short petiole of 0.25 cm. Lamina is slightly ovate in shape and asymmetric. Lamina length is 7.6 cm, width is 3.5 cm. Base is significantly asymmetric, on one side it is cordate, on the other side acute. Apex is not preserved. Margin is entire. Second order venation is camptodromous. The pattern of the secondaries is asymmetric constrained by the leaf shape; on one side of the lamina secondaries are straight and emerge steeply upwards (at angles of 45–50°), whereas on the other cordate side, secondaries emerge at 80–90° and form loops close to the margin.

D i s c u s s i o n . The rather short petiole and asymmetric leaf shape suggest that the leaves were probably leaflets, part of a compound leaf. This taxon has not been recorded in other Egerian floras.

The flora, vegetation, and climate of the Zsámbék locality

The fossil plant assemblage excavated near Zsámbék consists of a low number of taxa. Gymnosperms are represented by ?*Taxodium dubium* (Cupressaceae s.l.) occurring with relatively abundant shoots, which may be due to taphonomic constraints. Among angiosperms, the Lauraceae family constitutes a relatively high proportion, represented mainly by leaves of the fossil-genus *Daphnogene*. From the Betulaceae family, leaves of cf. *Alnus* sp. and from the Ulmaceae family two taxa, cf. Ulmaceae gen. et sp. 1 and 2 were described. A dominant taxon in the flora is "*Rhamnus*" *warthae*, the systematic affinity of which has not yet been resolved. Other unidentifiable angiosperm leaf types have also been recorded.

The fossil plant assemblage of Zsámbék suggests a wetland, both swamp and riparian environments similarly to other fossil floras described from the Mány Member of the Törökbálint Formation (e.g., Vértesszőlős, Környe). The relatively low number of taxa and the occurrence of swamp-riparian elements suggest that the locality, the depositional basin, was far enough from upland areas to hinder the transport of elements of mesophytic vegetation to the basin. Among the Egerian floras of Hungary the upper level flora of Eger-Wind brickyard is comprised mainly of swamp elements (Andreánszky 1966, Kvaček and Hably 1991). Similarly to the Zsámbék flora, a high number of "*Rhamnus*" *warthae*, *Taxodiaceae*, and *Alnus* (*oligocaenica*) leaves were recorded from Eger-Wind, however, that flora shows higher diversity with more swamp elements. *Ulmus pyramidalis* is a typical wetland species, a probable riparian element of the Egerian floras (in the Zsámbék flora ulmaceous specimens are described as cf. Ulmaceae gen. et sp. 1, 2). *U. pyramidalis* has been recorded in 10 out of the 14 fossil plant assemblages of the Hungarian Egerian so far studied. Its frequent occurrence in the Egerian fossil record may be attributed partly to the high frequency of this fossil-species in the Egerian floras but partly also to its resistant leaf structure which enabled its fossilization even in coarse-grained sediments (Hably and Szakmány 2006).

Although the Zsámbék assemblage does not represent a zonal association but an intrazonal one, definite conclusions may be drawn on the palaeoclimatic conditions under which the flora flourished. The presence of the Lauraceae family, represented mainly by the fossil-genus *Daphnogene* suggests subtopical – warm temperate conditions. The floristic composition of the Zsámbék flora is clearly comparable to the late Oligocene floras of Hungary, therefore earlier climate estimates based on other similar-aged floras may be considered for Zsámbék as well. Considering the numerous Egerian floras of Hungary, temperature and rainfall data were reconstructed by the Coexistence Approach (Mosbrugger and Utescher 1997). Based on these floras, a frostfree climate characterized by a mean annual temperature between 15.6–19.2 °C and a mean annual rainfall between 897–1.250 mm were estimated (Erdei et al. 2007).

Palaeogeographic and structural geological consequences

The discovery of the plant remains attests that this tiny locality avoided the Early Miocene denudation, and thus reflects the former, pre-erosional extension of the Oligocene basin. The site also plays an important role in the reconstruction of the structural evolution of the area (Héja et al., in prep.). Marine sedimentation of the Paleogene basin of Central Hungary ended in the earliest Miocene (Báldi 1986, Tari et al. 1993, Sztanó 1995). The subsequent denudation did not uniformly affect the basin sediments, although it occurred over the entire basin. In the studied site, only the basal ~15 m avoided the denudation, while in other areas (in the downfaulted block of the nearby fault) several hundred meters of Oligocene layers have been preserved (Korpás 1981, Végh-Neubrandt and Mensáros 1986, Selmeczi and Fodor 2008). The same denudation phase completely excavated the Oligocene layers from the northwestern side of the quarry, a distance of only ~200 m away (Kercsmár et al. 2020). The Middle Miocene marine transgression covered both blocks (Kercsmár et al. 2020) and is related to the formation of the Pannonian Basin. The contrasting thickness of the preserved Oligocene sequences, variably affected by the Early Miocene denudation, also points to the activity of the Zsámbék Fault, either in a syn-sedimentary manner during the late Oligocene and/or just after it, during the Early Miocene. The nature of reactivation of the Zsámbék Fault and its characteristics is the subject of further analysis (Héja et al., in prep.).

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Explanations of the plates

PLATE 1

?*Taxodium dubium* (Sternb.) Heer., twig fragments with taxodioid leaves from the flora of Zsámbék

1. HNHM-PBO 2021.161.2.
2. HNHM-PBO 2021.177.1.
3. HNHM-PBO 2021.168.2.
4. HNHM-PBO 2021.176.1.
5. HNHM-PBO 2021.166.1.
6. HNHM-PBO 2021.171.1.

Scale bars 1 cm. Photo: Éva Budai (1–6).

PLATE 2

1. *Daphnogene* sp. Fragmented leaf from Zsámbék. HNHM-PBO 2021.198.1.
2. cf. Lauraceae gen. et sp. Fragmented leaf from Zsámbék. HNHM-PBO 2021.192.1.
3. *Daphnogene* sp. Fragmented leaf from Zsámbék. HNHM-PBO 2021.199.1.
4. *Daphnogene* sp. Fragmented leaf and its counterpart from Zsámbék. HNHM-PBO 2021.201.2.
5. cf. Ulmaceae gen. et sp. 1. Fragmented leaf from Zsámbék. HNHM-PBO 2021.183.1.
6. *Ulmus pyramidalis* Göpp.. Leaf from Pomáz (Egerian, N Hungary) showing characteristic teeth on the margin. HNHM-PBO 1986.4.1.

Scale bars 1 cm. Photo: Éva Budai (1–4) and Boglárka Erdei (5, 6).

PLATE 3

1. cf. Ulmaceae gen. et sp. 2. Leaf from Zsámbék. HNHM-PBO 2021.185.2.
2. cf. *Alnus* sp. Fragmented leaf from Zsámbék. HNHM-PBO 2021.203.1.
3. cf. *Alnus* sp. Fragmented leaf from Zsámbék. HNHM-PBO 2021.190.1.
4. cf. *Alnus* sp. Fragmented leaf from Zsámbék. HNHM-PBO 2021.202.1.
5. *Alnus oligocaenica* Andr. Leaf from the late Oligocene flora of Környe. HNHM-PBO 2009.242.1.
6. "*Rhamnus*" *warthae* Heer. Leaf fragment from Zsámbék. HNHM-PBO 2021.206.1.
7. "*Rhamnus*" *warthae* Heer. Leaf fragment from Zsámbék. HNHM-PBO 2021.162.3.

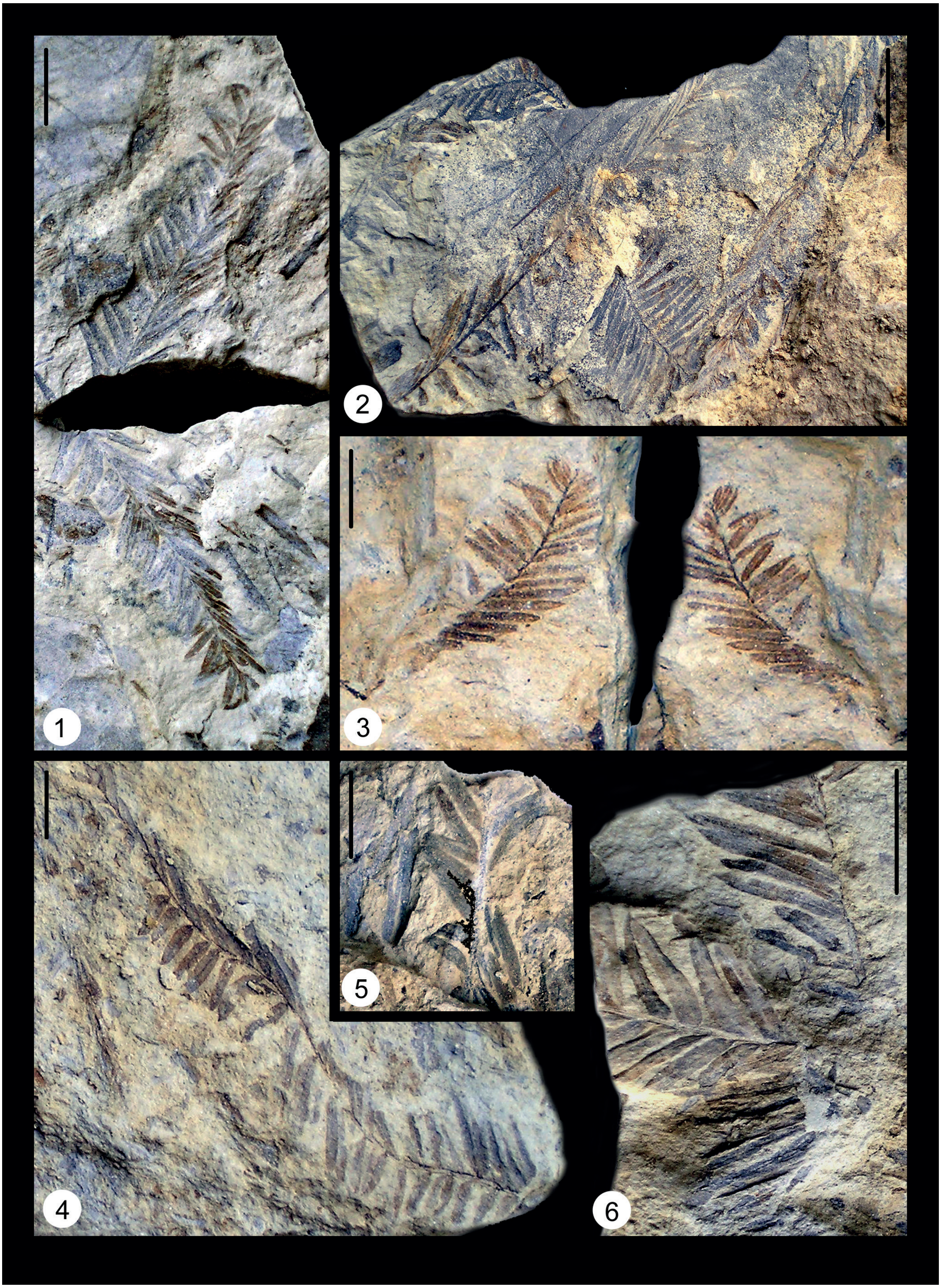
Scale bars 1 cm. Photo: Éva Budai (2–4, 6, 7), Boglárka Erdei (1) and István Rácz (5).

PLATE 4

1. "*Rhamnus*" *warthae* Heer. Leaf fragment from Zsámbék. HNHM-PBO 2021.141.1.
2. "*Rhamnus*" *warthae* Heer. Leaf fragment from Zsámbék. HNHM-PBO 2021.189.3.
3. "*Rhamnus*" *warthae* Heer. Leaf fragment from Zsámbék. HNHM-PBO 2021.149.1.
4. "*Rhamnus*" *warthae* Heer. Leaf fragment from Zsámbék. HNHM-PBO 2021.135.1.
5. *Dicotylophyllum* sp. 1. Fragmented leaf and its counterpart from Zsámbék. HNHM-PBO 2021.161.2.
6. *Dicotylophyllum* sp. 2. Fragmented leaf from Zsámbék. HNHM-PBO 2021.193.1.
7. *Dicotylophyllum* sp. 3. Fragmented leaf and its counterpart from Zsámbék. HNHM-PBO 2021.195.2.

Scale bars 1 cm. Photo: Éva Budai (1–6).

PLATE 1



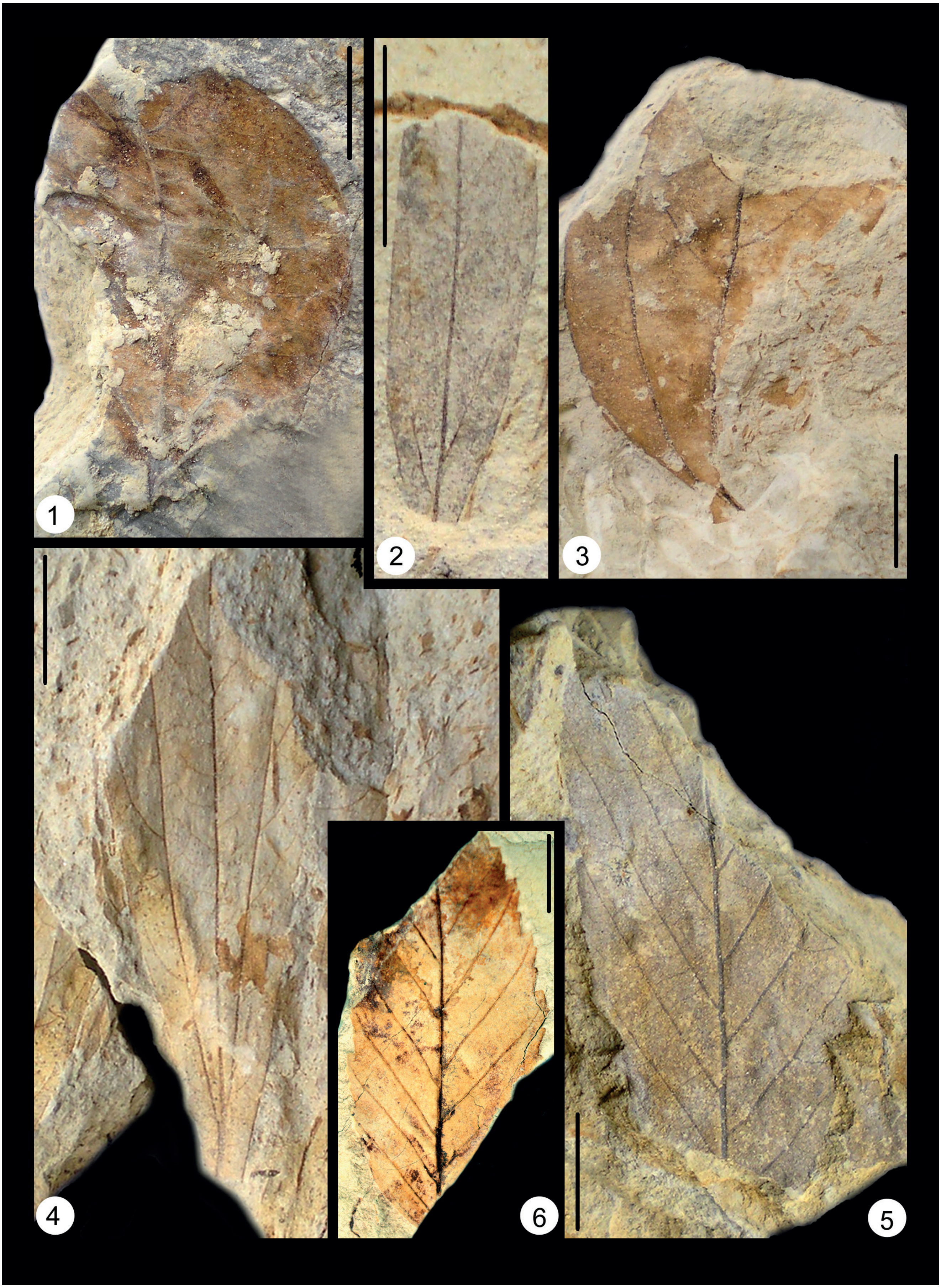

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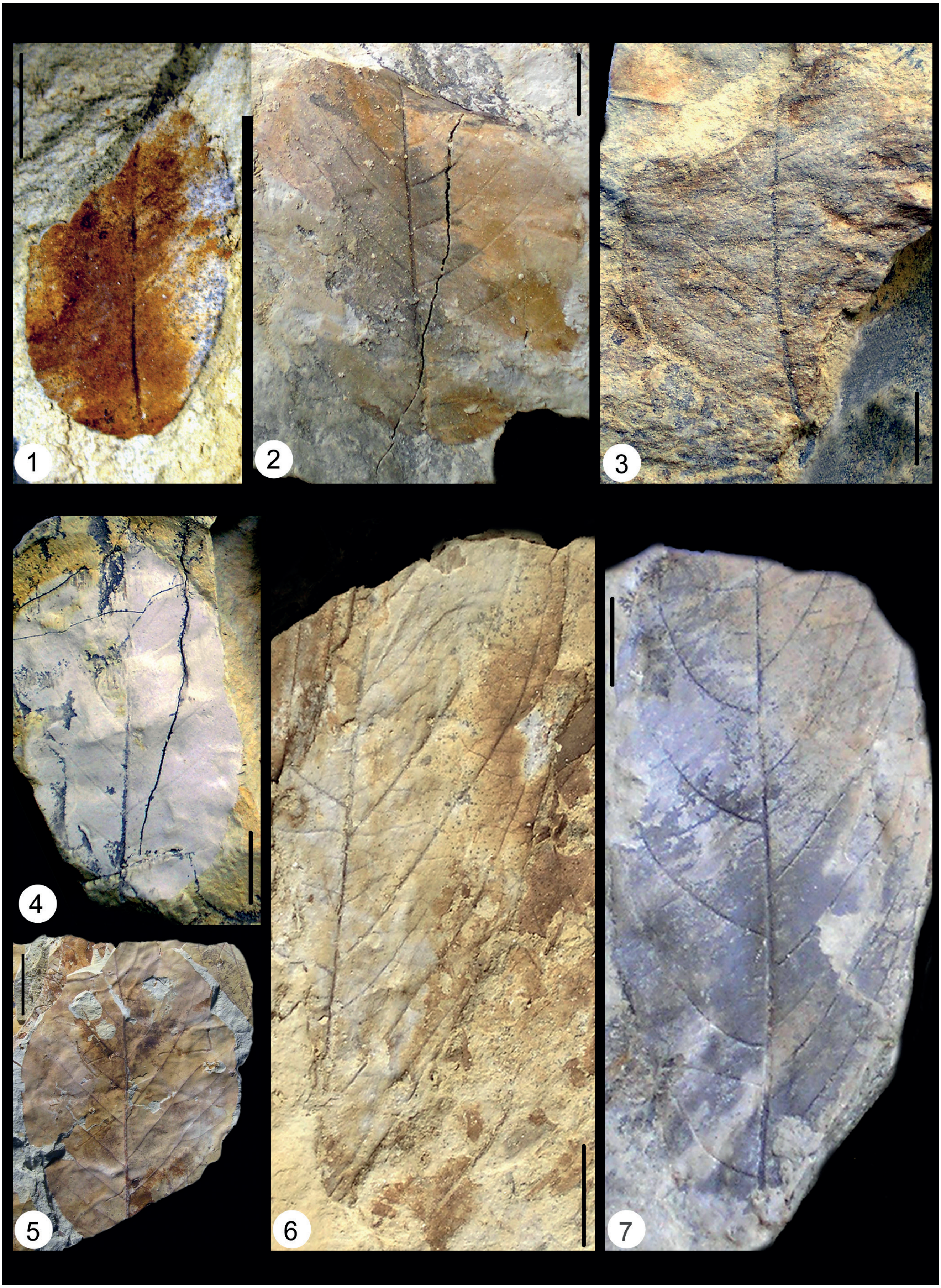
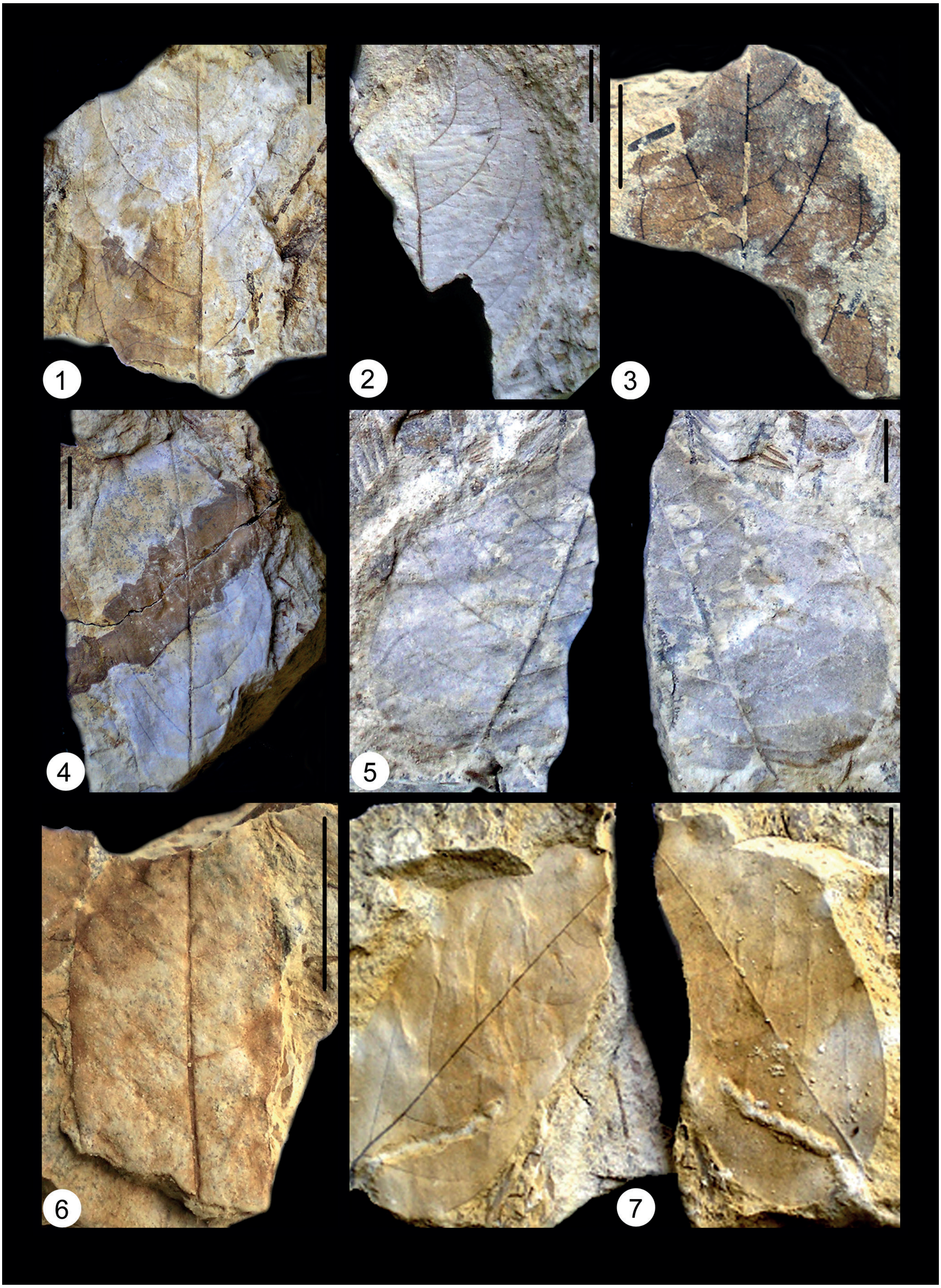
PLATE 3

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