DOI: 10.17110/StudBot.2024.55.2.189 Studia bot. hung. 55(2), pp. 189–203, 2024

# FOSSIL PALM STEMS FROM LOWER MIOCENE DEPOSITS OF NORTHERN HUNGARY

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Erdei, B., Fodor, R. & Prakfalvi, P. (2024): Fossil palm stems from Lower Miocene deposits of Northern Hungary. – *Studia bot. hung.* **55**(2): 189–203.

**Abstract**: Fossil stem pieces assigned to palms (Arecaceae) have recently been discovered in Lower Miocene sediments of N Hungary, in the Ilona Valley near Parádfürdő, Mátra Mts and in the Majkász Valley near Bátonyterenye. The stems are silicified to varying degrees. The stem from Ilona Valley – *Palmoxylon* sp. 1. – represents the upper portion of a stem close to the apical meristem and the crown of leaves, whereas that from the Majkász Valley – *Palmoxylon* sp. 2. – is a strongly compressed and eroded fraction of a stem. Based on thin sections made of the stems, both display typical palm anatomy showing dispersed fibrovascular bundles in the central cylinder. Since both palm stems had likely been exposed to a longer or shorter transport, the plant association and the palaeoenvironment they thrived in are highly unclear. The occurrence of palms is well in line with previous accounts of the family in coeval localities of the region, e.g. Ipolytarnóc and Salgótarján.

**Key words**: Heves, Mátra Mts, Neogene, Nógrád, *Palmoxylon*, silicified stem, thin section

## INTRODUCTION

Palm fossils have frequently been recorded in the Cenozoic floras of Europe (Harley 2006). In Hungary, the oldest fossils assigned to palms have been recorded in Eocene sediments. Rásky (1956) described three-dimensional endocarps (*Actinorhytis eocenica* (Tuzson) Rásky) from Bartonian-Priabonian limestones (Szépvölgy Limestone; Gyalog *et al.* 2016, Babinszky *et al.* 2023) of the Kis-Sváb Hill, Budapest (named Martinovics Hill in the second half of the 20th century) and a fruit remain of *Nypa* (*Nipadites burtini* (Brongn.) Hook. f. in Lyell; Rásky 1948) from upper Lutetian–lower Bartonian sediments of Dudar, Bakony Mts, west of Budapest (Csernye Formation, Babinszky *et al.* 2023). Palms were relatively frequent members of fossil floras during the early and late Oligocene (e.g. Andreánszky 1949, 1955, Hably 1982, Kvaček and Hably 1991, Hably and Erdei 2023) and Early Miocene (e.g. Hably 1985), however, disappeared from the fossil record by the Late Miocene, with the last occurrence of palmate leaves in the late Middle Miocene (late Serravallian/Sarmatian, reg. strat.) locality of Erdőbénye-Ligetmajor, NE Hungary (Erdei 1995). Fossil stems of palms have been described from several, mostly Early Miocene locations in Hungary (e.g. Greguss 1969). Noteworthy examples are *Palmoxylon dorogense* Greguss from Oligocene sediments near Dorog, and two Early Miocene fossil stems, *P. hungaricum* Greguss from a locality near Salgótarján, and *P. sabaloides* Greguss from Ipolytarnóc (Greguss 1969). This study is a preliminary account of additional palm stem remains recently discovered in two Early Miocene localities in North Hungary. The results of a more detailed anatomical study are going to be published in a subsequent paper.

## MATERIAL AND METHODS

Pieces of fossil stems have been discovered in N Hungary, in the Ilona Valley near Parádfürdő, Mátra Mts and in the Majkász Valley near Bátonyterenye (Fig. 1). Both stems are silicified, however to varying degrees. The stem from Parádfürdő is partly silicified and coalified, whereas that from the Majkász Valley is strongly silicified.

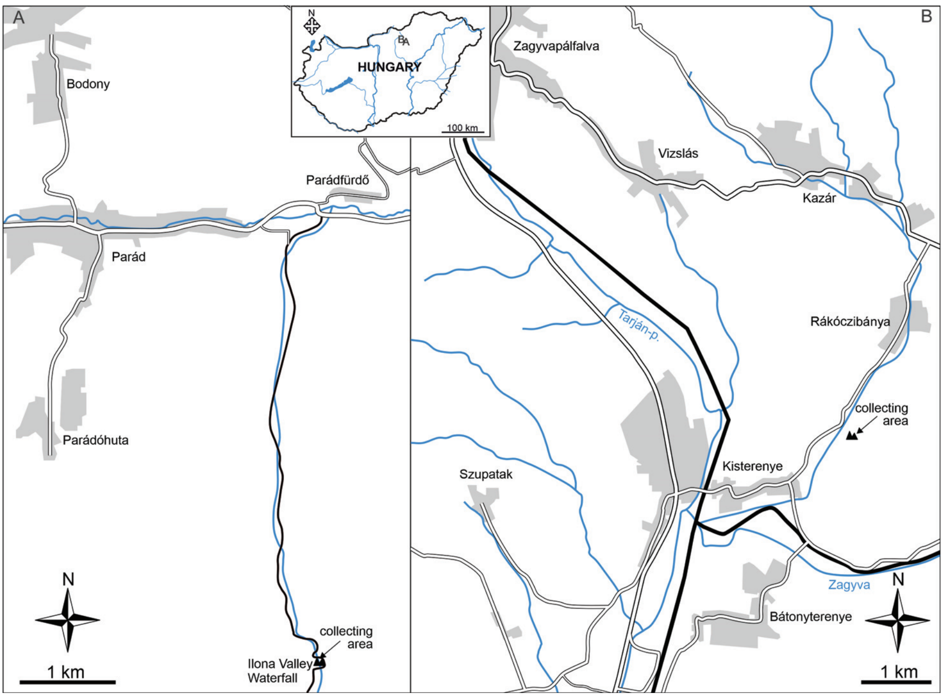


**Fig. 1**. Map of localities of the fossil stems. A = Ilona Valley; B = Majkász Valley.

Observations were made applying macro- and micro-morphological methods. Both stems were thin sectioned to show details of internal structure. Thin sections were studied with normal reflected and transmitted light microscopes (Olympus SZX9, Nikon E600). Photos of the stems were taken before and after sectioning. Microscopic images were taken using an Olympus DP72 and a Micropublisher 3.3 RTV camera (equipped with Cell$^{A}$ software) fitted to the light microscopes, respectively. Images were edited using Adobe Photoshop. Terminology follows Thomas (2011), Tomlinson *et al.* (2011), and Thomas and De Franceschi (2013). There are numerous other silicified plant fragments coming from both localities, the study of which is in progress.

## Geological background

### *Ilona Valley near Parádfürdő*

Fossil plant remains, including the one here reported, have been discovered in the bed of the Ilona creek close the Miocene sandstone outcrop of the Ilona Valley educational trail, near Parádfürdő (Hungary, Heves County, Fig. 1). Since other plant fragments were not observed in neighbouring layers of the outcropping sediments, the stem pieces might have been transported from other levels to the site of recovery. Geological formations in the close vicinity of the Ilona Valley waterfall were studied among others by Főzy and Leél-Őssy (1985). The north-sloping sequence is formed of grey micaceous sand and sandstone (Fig. 2). It is exposed in the largest thickness 5 km to the south of Parádfürdő, and 200 m to the north from the Ilona Valley waterfall. The creek incises here in Lower Miocene pebbly, sandy sediments belonging to the Ilonavölgy Member of the Pétervására Formation. Most part of the sequence is formed of sand of 1–2 mm grain-size. Sediments are getting finer upwards, at the upper 5 m, clayey and fine sandy layers are intercalated more frequently. The sequence is overlain by slightly eroded andesite. Aside from the numerous shark teeth, the layers are poor in fossils. Some molluscs, *Chlamys*, *Ostrea*, and *Balanus* fragments turn up more frequently in the upper layers of the formation (Ilonavölgy Member). The sediments were deposited in a shallow sea situated to the west of the Darnó fault zone. The age of the sediments of the Ilonavölgy Member is Early Miocene, ranging up to the Ottnangian (Babinszki *et al.* 2023).

### *Majkász Valley near Bátonyterenye*

A strongly silicified palm stem was discovered in the Majkász Valley, near Bátonyterenye (Hungary, Nógrád County, Fig. 1). The locality, a currently closed mine, in which formerly zeolite and Na-bentonite rhyolite tuff were excavated,

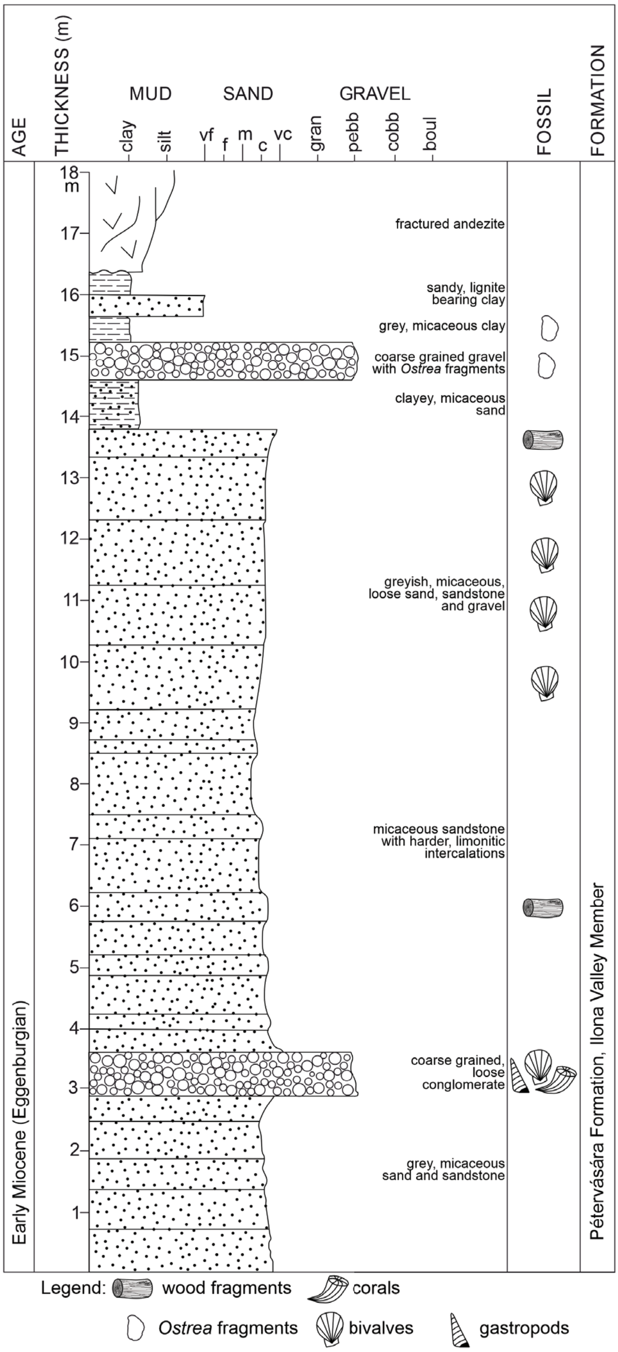


**Fig. 2**. Geological section of the Ilona Valley sequence (modified after Főzy and Leél-Őssy 1985).

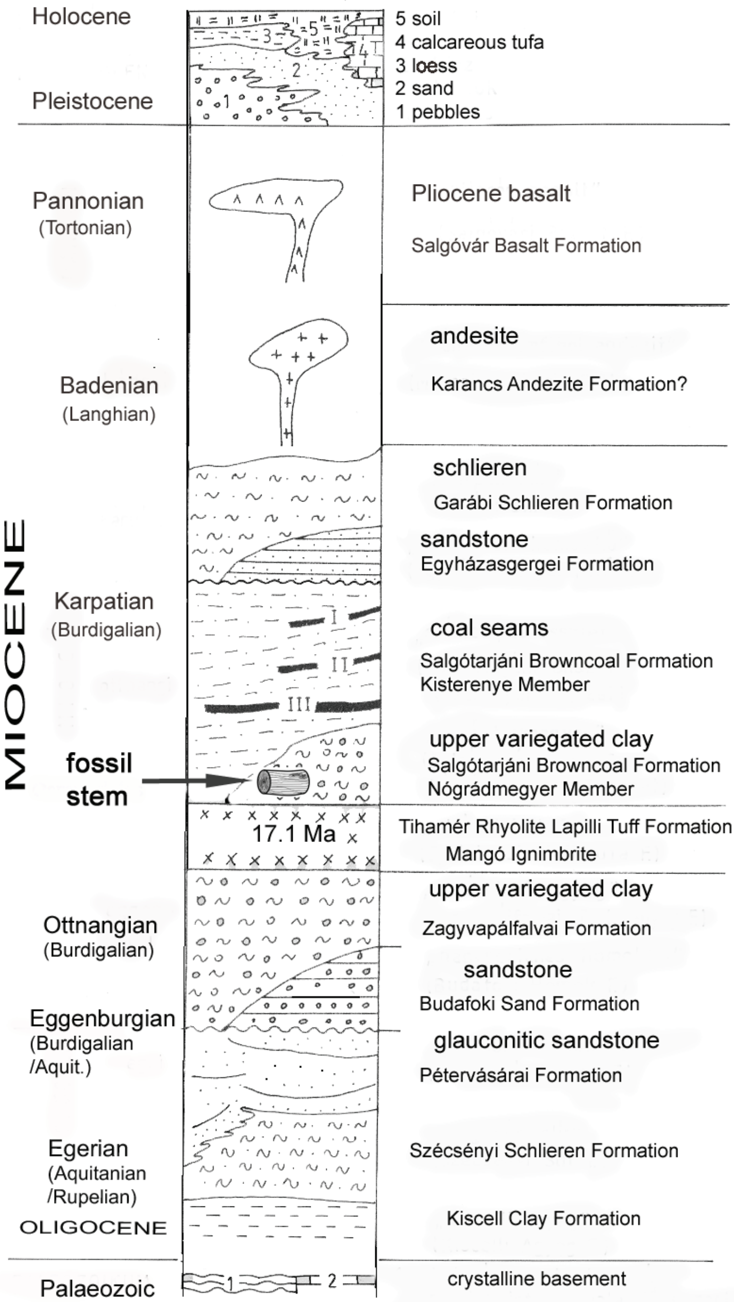


**Fig. 3.** Generalized section of the Karancs–Medves and the Heves–Borsod Hills (modified after PRAKFALVI *et al.* 2007).

signifies an important geoheritage of the Novohrad–Nógrád UNESCO Global Geopark (https://www.nogradgeopark.eu/en). The fossil was collected from the redeposited clast zone below the northern end of the mine wall. Based on its lithology, the stem originates from the late Burdigalian (late Ottnangian–early Karpatian) sediments (Salgótarján Browncoal Formation, Nógrádmegyer Member) deposited in freshwater-swamp environment above the volcanic formations (Fig. 3). The radiometric age of the rhyolite tuff is 17.1 million years (Tihamér Rhyolite Lapilli Tuff Formation, Mangó Ignimbrite; Lukács *et al.* 2021, 2022). Coal seams overlying the rhyolite tuff, which were formed of the flourishing vegetation of swamp systems, provided the basis of the intense mining activity in the recent past. The locality yielded other silicified plant fragments including an osmundaceous stem as well (Erdei and Prakfalvi 2022). The fragments are typically relatively small, with a dimension rarely reaching 20 cm. It is noteworthy that plant remains can be found only in the northern end of the north-south tending mine wall reaching a length of 250 m. This suggests that conditions enabling fossilization were probably local and fossilization might have been quite fast preventing the decay of plant fragments.

## RESULTS – DESCRIPTION OF FOSSILS

Arecales Bromhead
Arecaceae Bercht. et J. Presl
*Palmoxylon* Schenk.

*Palmoxylon* sp. 1
(?Coryphoideae vel Arecoideae)
(Figs 4–7)

Material: HNHM-MMPAL 2019.19.1

Locality: sandstone outcrop of the Ilona Valley educational trail, Parádfürdő, ?Early Miocene

Description: The preserved length of the fossilized stem is 16.5 cm, its diameter is 13.5 cm (Fig. 4A). The stem is partly silicified and coalified with preserved internal structure. It represents a log from the upper portion of the stem below the crown of leaves. The stem has been preserved showing persistent leaf stalk bases (Fig. 4A). Leaf stalks are of 2–3 cm diameter, triangle shaped (Fig. 4B). Stem central cylinder, cortex, and dermal zone with surrounding leaf bases are preserved (Fig. 5). Cortex is about 1 cm thick, and contains fibrous strands and cortical bundles (Fig. 5). The central cylinder is terminated by a subcortical zone (Fig. 6A). In the peripheral part of the central cylinder vascular bundles are densely arranged and are embedded in the lacunose parenchyma. Vascular bundles are of 200–500 µm in diameter and are collateral with large fibrous bundle sheath joining each externally (Fig. 6B, 7A). Protoxylem is well developed and is embedded in paravascular parenchyma. Mostly one or two large metaxylem vessels are observable. In some bundles only protoxylem is present. Phloem is developed between xylem elements and the bundle sheath and it is mostly destroyed with unclear structure. Fibrous bundle sheaths are larger than the vascular bundles they join (Fig. 7B) – in cross section the bundle sheath is ca. two-third of the fibrovascular bundle – and of reniform character (Stenzel 1904, Thomas 2011). Ventral fibrous part is not differentiated. Externally in bundle sheaths echinate phytoliths of 10–20 µm diameter are observable (Fig. 7B). Among vascular bundles fibrous bundles of 60–80 µm diameter are dispersed (Fig. 7A, B). Although its cell walls are often destroyed, the lacunar ground tissue does not show expanded cells. The mostly isodiametric parenchyma cells are of 20–40 µm.

Discussion: The lack of accessory roots and the persistent leaf bases suggest that the fossil represents an aerial stem. Based on the well-developed cortex and subcortical zone, it is comparable to the Cocos-type category of von Mohl (see Thomas and De Franchesci 2012, 2013), which is found in most Coryphoideae and few Arecoideae. The stem is columnar, with persistent leaf

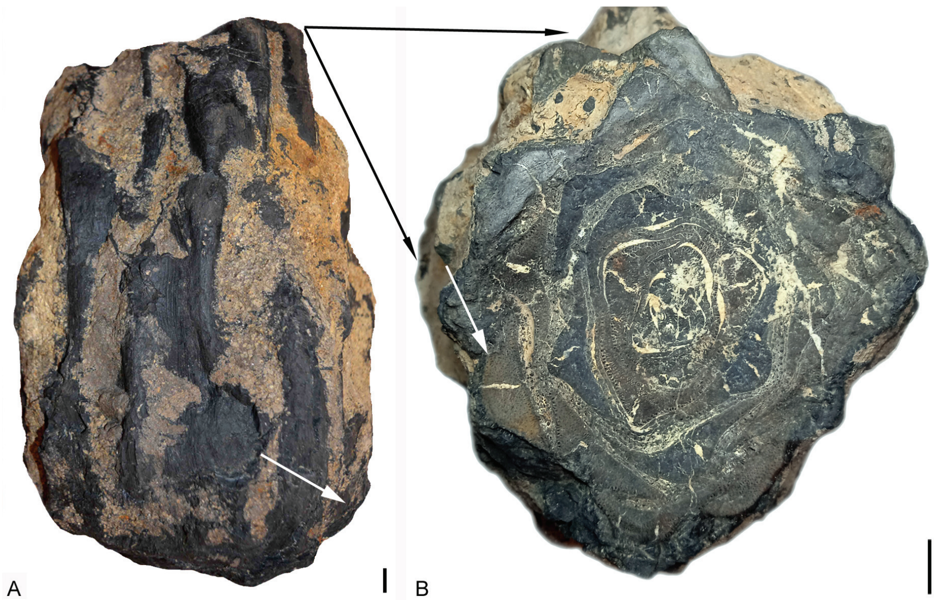


**Fig. 4.** *Palmoxylon* sp. 1. – A = Stem with the remnants of leaf stalks. White arrow shows the position of thin section shown in Figure 5 (scale bar: 1 cm). B = Upper view of stem showing leaf stalks (white arrow) in cross section (scale bar: 1 cm).

bases. No signs of a crownshaft are observable. Stem diameter does not reflect the original size or height of the plant. The fossil stem has vascular bundles crowded towards its periphery. The thick, well-developed fibrous bundle sheaths refer to a stem of tree character and suggest a non-calamoid palm. The type of phytoliths (spheroid echinate or petasoid/hat-shaped echinate) is unclear based on the thin sections. However, phytolith morphology may have limited diagnostic value (excluding the petasoid type, see Brightly *et al.* 2024), which can be clarified by subsequent studies. The palm may have been non-calamoid (?Coryphoideae vel Arecoideae), displayed a tree character and developed an aerial, columnar stem, with persistent leaf bases, without a crownshaft.

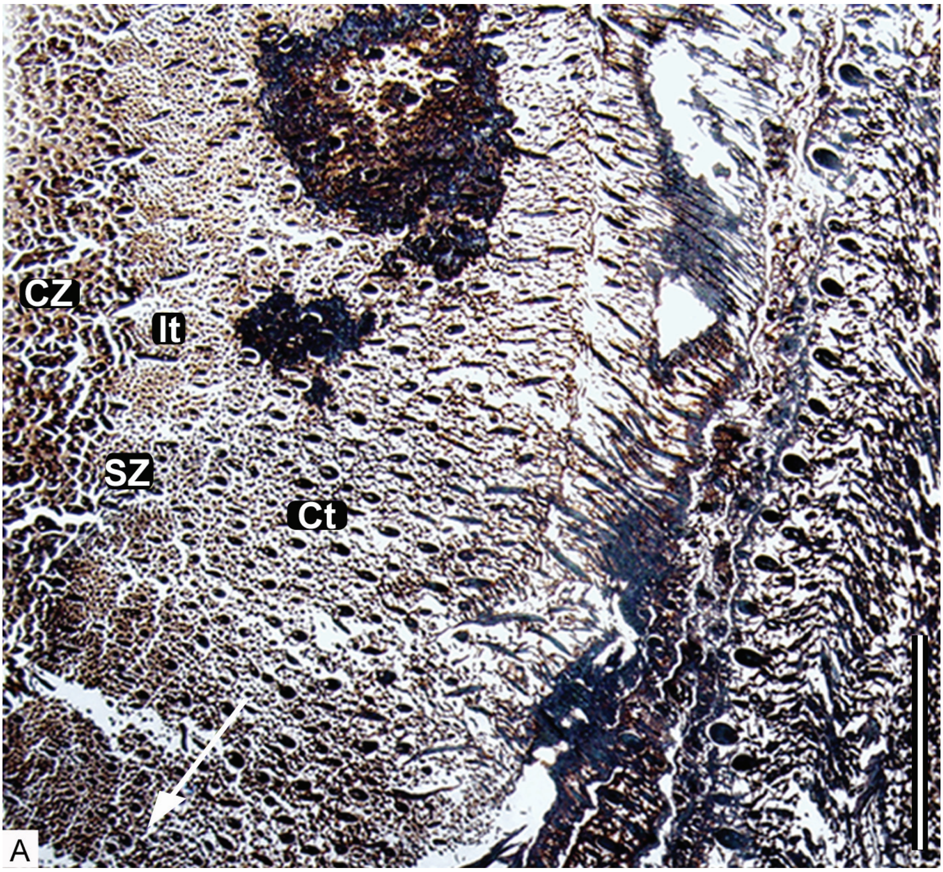


**Fig. 5**. *Palmoxylon* sp. 1. – Thin cross section from the lower peripheral part of the stem. The cortex, the subcortical zone and the central zone of the central cylinder are clearly visible. Arrow indicates the part of the section enlarged in Figure 6; Ct = cortex, SZ = subcortical zone, CZ = central zone, lt = leaf traces (scale bar: 1 cm).

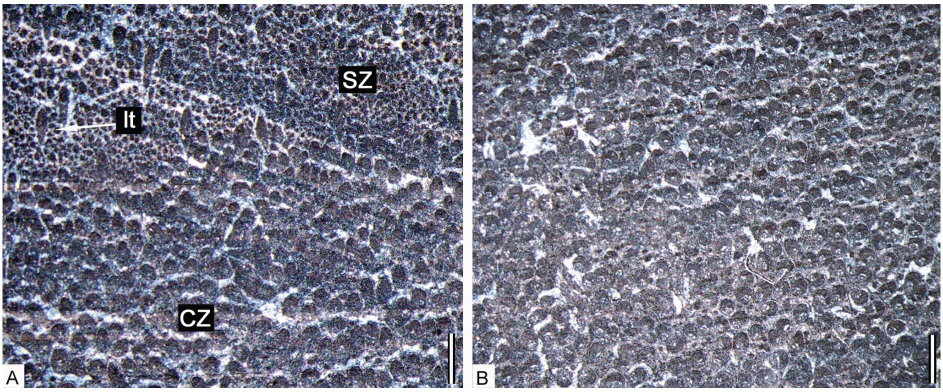


**Fig. 6**. *Palmoxylon* sp. 1. – A = The subcortical zone and the central zone of the central cylinder. Fibrous bundles are densely arranged, with leaf traces. SZ = subcortical zone, CZ = central zone, lt = leaf traces (scale bar: 1 mm). B = The central zone of the central cylinder with densely arranged vascular bundles and fibrous bundles dispersed among them (scale bar: 1 mm).

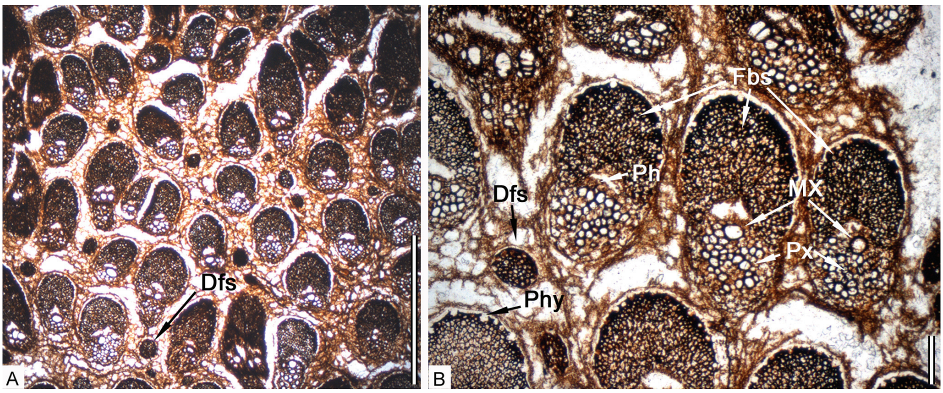


**Fig. 7**. *Palmoxylon* sp. 1. – A = Vascular bundles of the central cylinder in the peripheral part of the stem, with fibrous bundle sheaths and dispersed fibrous strands. Dfs = dispersed fibrous strand (scale bar: 1 mm). B = Vascular bundles are collateral. Large metaxylem elements, well-developed protoxylem and partly destroyed phloem are observable. Mx = metaxylem, Px = protoxylem, Ph = phloem, Fbs = fibrous bundle sheath, Phy = echinate phytoliths, Dfs = dispersed fibrous strand (scale bar: 100 μm).

Systematic assignment of palm stems is complicated by the fact that anatomy is varying inside the stem both vertically and from the centre toward the periphery. Moreover, anatomy of stem tissues also depends on the age of the stem (Kaul 1960, Tomlinson 1990, Nambudiri and Tidwell 1998, Tomlinson *et al.* 2011). The number of wide metaxylem elements, which may vary throughout the stem, has low diagnostic value. Neither the structural construction of the stem close to the apical meristem zone represents taxon-specific stem anatomy.

Nevertheless, significant contributions have been made to this topic (Thomas and De Franchesci 2013) which, in case of more information on stem morphology, may provide an opportunity of infrafamilial identification. A more precise systematic assignment of the stem is also to be expected based on the anatomical study of further sections of the stem, leaf stalks, and leaf bases, which are in progress.

The fossil-species of palms described by Greguss based on stem fossils from Hungary (Greguss 1969) seem to differ from the species from Ilona Valley, though our stem originates from right below the crown hindering a proper comparison and more thin sections are needed to have comparisons. The fibrous bundle sheaths of all the species described by Greguss, i.e. *Palmoxylon dorogense* from Dorog, *P. sabaloides* from Ipolytarnóc, and *P. hungaricum* from Salgótarján, display a shape and ratio to the vascular bundles different from those of *Palmoxylon* sp. 1. The ground tissue of *P. hungaricum* is constructed of loosely arranged parenchyma cells contrasting the parenchyma of the stem described here.

*Palmoxylon* sp. 2
(Fig. 8)

Material: without number, collection of the Novohrad–Nógrád UNESCO Global Geopark.

Locality: former zeolite and rhyolite tuff mine in the Majkász Valley, near Bátonyterenye, ?Early Miocene.

Description: The stem fragment from the Majkász valley is of 13 × 8 cm, strongly silicified, representing a stem central cylinder (Fig. 8A). Its internal structure is partly degraded and heavily compressed. Dispersed fibrovascular bundles are observable (Fig. 8B). The bundles are strongly compressed, large, are of nearly 1 mm (partly due to the oblique cross section). Details on proto- and metaxylem elements are unclear. The fibrous bundle sheaths joining the vascular bundles are well developed, seem to represent at least two-third of the fibrovascular bundle size, and are most similar to the Sagittata bundle types (Stenzel 1904, Thomas 2011). The ground parenchyma is highly compressed, and shows transversally extended (divided) cells arranged radially around vascular bundles. Some extended cells reach a length of 200–300 µm.

Discussion: Based on the horizontally extended and often divided parenchyma cells aligned radially around fibrovascular bundles, the stem fragment seems to represent the older part of a palm stem. Such cell enlargements are part of the process observed in palm stems and referred to as sustained primary growth, which contributes to the secondary increase of palm stem diameter

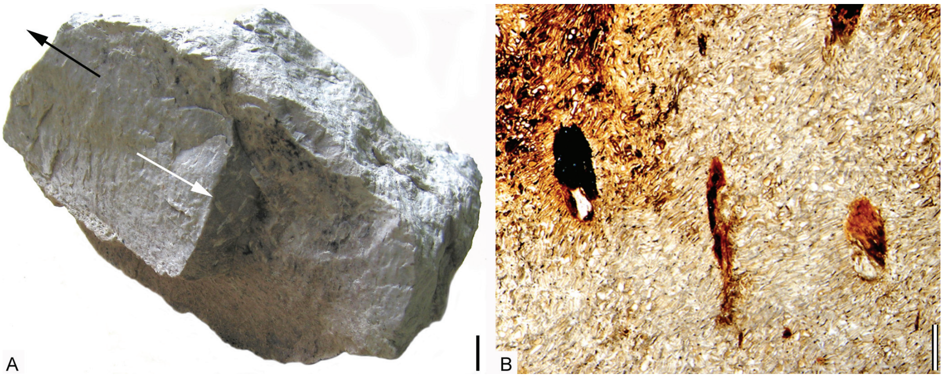


**Fig. 8**. *Palmoxylon* sp. 2. – A = Stem fragment, heavily deformed (black arrow shows the relative position of the apical part of the stem). White arrow shows the position of thin section shown in Figure 8B (scale bar: 1 cm. B = Thin (slightly oblique) cross section of stem (showing vascular bundles with well-developed fibrous bundle sheaths and heavily compressed parenchyma cells showing expansion (scale bar: 1 mm).

(Tomlinson *et al.* 2011). The stem continues growing after the establishment phase by expansion (also division) of parenchyma cells. The stem may represent the Mauritia-type (or ?Corypha type) category of von Mohl (see Thomas and De Franchesci 2013), which characterizes most Arecoideae and some Calamoideae. As compared to the stem of *Palmoxylon* sp. 1., which originates close to the apical meristem, the distinction is clear between the mostly isodiametric cells of the ground parenchyma of *Palmoxylon* sp. 1. and the extended cells of the stem of *Palmoxylon* sp. 2. The thick, well-developed fibrous bundle sheaths refer to a stem which is of tree character and may suggest a non-calamoid palm. The few preserved characters of the stem do not aid systematic assignment and hinders its comparison to Greguss' species (Greguss 1969).

## DISCUSSION

Fossils of palms have been described from diverse environments, but those from wetlands are dominating among macro-remains (e.g. Mosbrugger *et al.* 1994, Figueiral *et al.* 1999, Philippe *et al.* 2002, etc.). Since both palm stems described here had likely been exposed to a longer or shorter transport, their plant association and the palaeo-environment they thrived in are not easy to decipher. The stem *Palmoxylon* sp. 1 was collected from sand-sandstone layers and may have been transported from larger distance. As inferred from the depositional environment, the stem *Palmoxylon* sp. 2, which was lithified by solutions rich in silica, may have originated from a wetland environment as an element of the vegetation of a brown coal basin (see Fig. 3).

Palms were frequent members of Paleogene–Early Miocene flora and vegetation in the central and southeastern parts of Europe. There are many examples of fossil stems assigned to palms from nearly coeval deposits of Greece (Velitzelos *et al.* 2019) and Turkey (Akkemik *et al.* 2016, Iamandei *et al.* 2018) where palm occurrences have been interpreted as probable elements of the azonal vegetation (Denk *et al.* 2019). The importance of palms in the Pannonian region is best evidenced by the high number of remains in the late Burdigalian (Karpatian, reg. strat.) flora of Ipolytarnóc, in which calamoid and sabaloid palms (all leaf fossils) were abundant, i.e. *Calamus noszkyi*, *Sabal major* (Hably 1985). Palms of Ipolytarnóc may have thrived in riverine and upland vegetation types close to the depositional basin. Fossil stems assigned to palms had also been described from the Ipolytarnóc area by Greguss (1969; see above in "Results"). Interestingly, in the nearly coeval floras of the Mecsek area, (southern part of Hungary) palms were virtually missing from the assemblages, which may be explained by palaeo-environmental and/or tectonic evolution of the region (Erdei *et al.* 2007, Hably 2020). Among the Paleogene floras of Hungary, Eocene sediments preserved reproductive organs (fruits, endocarps) of palms, already mentioned in "Introduction" (see also Erdei 2019). The late Oligocene floras included a relatively diverse array of palms as well (Hably and Erdei 2023), although in lower number as compared to the Early Miocene flora of Ipolytarnóc. This might be interpreted by the onset of the Mid-Miocene Climate Optimum for the Ipolytarnóc site if palms are considered as indicators of warm/tropical climates. Most of the modern species in the palm family flourish in tropical wet vegetation, which has often given the basis for the ecological interpretation of fossil palm occurrences as indicating warm and wet climates, although palms are not unequivocal indicators of wet tropical conditions (Brightly *et al.* 2024). According to Thomas and Boura (2015) palm stem may bear a climatic signal and may indicate wet or drier conditions, which may be tested in our case in the scope of a subsequent detailed study. Nevertheless, palm occurrences, even during the late Middle Miocene (late Serravallian/Sarmatian, reg. strat.) in Hungary (Andreánszky 1959, Erdei 1995) in plant associations constructed of species mostly suggesting temperate climatic requirements, support the fact that diverse ecology characterized ancient palms. A great diversity of palms have been described in the global fossil record, however stems, due to uncertainties in systematic identification, make up only a limited part of it (Harley 2006). The stem remain from Hungary (Ilona Valley) may contribute with more data to the fossil palm record and the palaeo-ecology of palms.

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*Acknowledgements* – This work was supported by the National Research, Development and Innovation Office (NKFI-K120123). The authors are grateful to Gábor Schmidt, the collector of the stem (*Palmoxylon* sp. 1, Ilona Valley), for offering it to the collection of the Mátra Museum and to Jakub Sakala (Charles University, Prague) for corrections and useful suggestions to the manuscript.

**Összefoglaló**: [Fosszilis pálma törzs maradványok Észak Magyarország alsó miocén rétegeiből.] Fosszilis pálma törzsmaradványok kerültek elő észak-magyarországi alsó miocén rétegekből, a Mátra hegységben a Parádfürdő melletti Ilona-völgyből és a Bátonyterenyéhez közeli Majkász-völgyből. A két törzsmaradvány eltérő mértékben kovásodott. Az ilona-völgyi maradvány, *Palmoxylon* sp. 1, a törzs tenyészőcsúcsához közeli részt képviseli, míg a majkász-völgyi *Palmoxylon* sp. 2. egy erősen összenyomott és erodálódott törzsmaradvány. A maradványokból készült vékonycsiszolatok tipikus, a pálmákra jellemző anatómiát, az alapszövetben szórtan elhelyezkedő fibro-vaszkuláris nyalábokat mutatnak. Mivel a maradványok hosszabb-rövidebb szállítódás után kerülhettek a beágyazódás helyére, az általuk képviselt őskörnyezet és társulásuk jellege bizonytalan. A pálmák előfordulása összhangban van más, a térség hasonló korú lelőhelyeinek, pl. Ipolytarnóc, flóra összetételével. A kutatást az NKFIH (K120123) támogatta.

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(submitted: 11.10.2024; accepted: 04.12.2024)