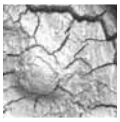
Revision of *Potamogeton* fossils from the Most Basin and their palaeoecological significance (Early Miocene, Czech Republic)

VASILIS TEODORIDIS



Only 37 incomplete endocarps and fragments of *Potamogeton wiesaensis* Kirchheimer from the Nástup-Tušimice Mine and cores of KU 115 and MR 59, and one incomplete leaf assigned as *Potamogeton praenatans* Knoll from the Bílina Mine (horizon No. 1) are described from the Most Basin. These samples studied here stratigraphically belong to the Holešice, Libkovice and Lom members of the Most Formation. According to the analysis of *Potamogeton* autecology and the floristic composition of the horizon No. 1, the fossil taxa can be interpreted as elements of an aquatic and reed vegetation. • Key words: leaves, endocarps, *Potamogeton*, palaeoecology, Early Miocene, Most Basin.

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Occurrences of Potamogetonaceae are extremely rare in the area of the Most Basin. This study focuses on a revision and modern evaluation of leaf and carpological material previously collected by Č. Bůžek (from 1961 to 1962) and others and its implication for the palaeoecological significance. E. Knobloch gave an overview about the Neogene and Early Quaternary *Potamogeton* fossils from Moravia and Slovakia including short comments on Czech specimens (Knobloch 1977, pp. 30, 31).

The family Potamogetanaceae contains perennial or rarely annual floating-leaved or submersed glabrous herbs growing in fresh or brackish waters, sometimes stranded by receding water levels (Haynes *et al.* 1998). The systematics of the Potamogetonaceae is contentious and usually two or three genera are determined; *Potamogeton* L., *Groenlandia* J. Gay and *Coleogeton* (Rchb.) Les & R.R. Haynes (Les & Haynes 1996), the latter newly reassigned as *Stuckenia* Börner (Haynes & Hellquist 2000); see Les & Haynes (1995), Haynes *et al.* (1998). The foliage of *Potamogeton* L. occurs as submersed or floating leaves in alternate to subopposite position. The floating leaves have a firmer texture, mostly petiolate, rarely subsessile, elliptic to ovate in outline, subulate to obtuse at apex and cuneate to rounded or cordate at base, leaf margins entire, venation parallelodromous to acrodromous with 1–51 veins. The submersed leaves are sessile or petiolate, linear to orbicular in outline, subulate to obtuse at apex and cuneate to perfoliate at base, leaf margins entire or serrate, rarely crimped, venation parallelodromous to acrodromous with 1–35 veins.

Fruits of *Potamogeton* are best considered as a drupe having a membranous exocarp, fleshy mesocarp and stony endocarp. *Potamogeton* fruits are born laterally on a fruiting spike usually in whorls of four, with from one to over 20 whorls per spike. Each fruit is sessile, attached at the base of the ventral (adaxial) margin and contains a single, pendulous, campylotropous ovule. The fruits are D-shaped to subovate in lateral view, bisymmetrical and strongly bilaterally flattened in the plane of symmetry. They are narrowly ovate in transverse section (Collinson 1982, p. 84); see Fig. 4F–H. The seed is equally lobed and curved around an internal process from the lateral and ventral faces of the fruit wall. A rounded depression is present on the external faces of the fruit in the position of this process. A germination valve occupies the entire dorsal margin and extends around the base of the fruit.

Geological settings

The Most Basin is located between the Doupovské hory Mts. and the České středohoří Mts. in northwestern Bohemia and genetically belongs to the tectonic system of the Eger Graben. The basin fill spans the time interval from the Oligocene to late Early Miocene. These sediments belong

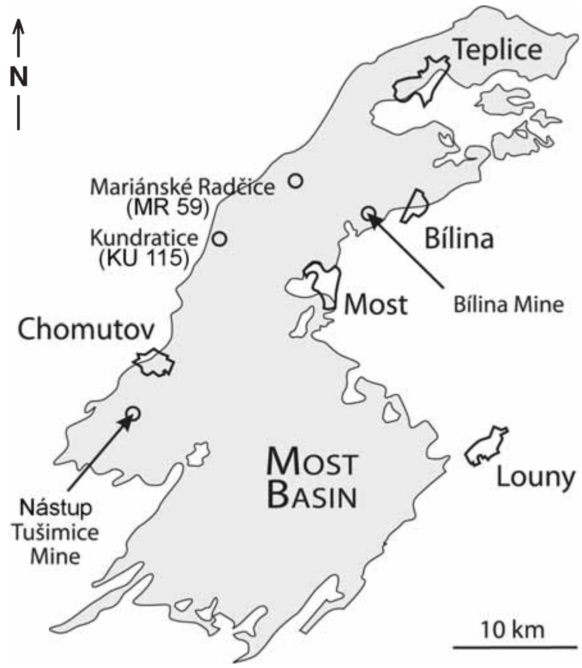

Figure 1. Geographical position of the studied localities and cores in the area of the Most Basin.

stratigraphically to the Střezov Formation and the Most Formation (*sensu* Domácí 1977). The volcanic rocks of the Střezov Formation consist of magmatic weathered lava flows related to volcanogenic deposits. These sediments are also mixed with weathered residua of older rocks from wider surroundings, and had been transported within a river system of the so-called "Hlavačov Gravel and Sand" (Váně 1985, Rajchl & Uličný 2005). This river system probably persisted during depositing of the first Duchcov Member of the Most Formation (*e.g.*, Teodoridis 2004), called previously and/or informally the Underlying Formation (*sensu* Elznic 1973). The overlying Holešice Member corresponds to a sedimentary setting of the Main Coal Seam that has been interrupted by irregularly distributed sandy-clayey bodies of the Žatec Delta (*e.g.*, Václ & Malkovský 1962, Rajchl & Uličný 2005) and the Bílina Delta (*e.g.*, Mach 2002). These delta bodies are situated in the SE part of the basin. The deposition of the Libkovice Member, *i.e.* the Overlying Formation *sensu* Elznic (1973), continued the sedimentary process in the Most Basin. These sediments, mostly clay or claystone spread over the mire covering the previous "coal" layers. A coal-forming vegetation re-appears in the uppermost part of the Most Formation and has delimited the range of the Lom Member *sensu* Domácí (1977), *i.e.* the Lom Formation of Elznic (1973). More details about the geological situation can be found in Malkovský *et al.* (1985), Mach (2002), Rajchl & Uličný (2005), Teodoridis & Kvaček (2006), *etc*.

The core MR 59 (Mariánské Radčice) offers the most abundant material (29 specimens) from two fossiliferous levels; a coal horizon (depth 48–50 m) and a light brown clayey horizon with plant fragments (depth 49.8–50 m) (Jirotka 1976, Kvaček & Bůžek 1982). These horizons belong to the coal seam of the Lom Member (Figs 1, 2).

The core KU 115 (Kundratice) has yielded only one endocarp from a coal-clayey horizon (depth 97.0–98.0 m) corresponding to the uppermost part of the Libkovice Member (Figs 1, 2). The endocarps from the Nástup-Tušimice Mine (7 specimens) are bound in a brown clayey horizon that contains also a rich fish fauna (Oberhelová 1983, p. 7) and belongs to the uppermost part of the Holešice Member (Kvaček 2006); Figs 1, 2. Similarly, the studied leaf material is bound to a sandy-clayey horizon (No. 1) from the Bílina Mine (Bůžek *et al.* 1992), corresponding to the lower part of the Libkovice Member (Figs 1, 2).

Material and methods

The fossil carpological material is compressed, carbonaceous and three-dimensionally preserved and was obtained from the cores by washing. It is housed in the palaeontological collection of the National Museum, Prague (NM – 37 specimens). The incomplete leaf (DB 1-55) is from horizon No. 1 (Bílina Mine) and is housed in the palaeontological collection of the Severočeské doly, a.s., Doly Bílina (DB). The comparative fossil leaf material from the locality Ležáky (Most Basin) originally assigned (erroneously) to *Potamogeton* (Hurník *in* Hurník & Knobloch 1966) is housed in the geological collection of the Regional Museum in Most (MM). Comparative extant material was obtained from the herbaria of the Charles University, Prague (PRC), National Museum, Průhonice (PR) and W. Szafer Institute of Botany, Polish Academy of Sciences, Krakow (KRA). The specimens were examined and detailed studies and observations made using a binocular microscope and a 15 kV Jeol JSM – 6380 LV scattered electron microscope (SEM) used at the Institute of Geology and Palaeontology, Faculty of Science, Charles University in Prague. One specimen of *Potamogeton wiesaensis* Kirchheimer (G 8537) from the Nástup-Tušimice Mine was studied for the structure of the testa. A mechanically isolated testa was washed in water and briefly macerated in Schulze solution, followed by rinsing in weak potassium hydroxide solution (KOH), then water, and embedded in glycerine directly on the microscope glass, after a few minutes covered with a cover slide and sealed with nail polish.

Currently accepted morphological terminology follows Stearn (2004) for leaves and Velichkevich & Lesiak (1996) for fossil endocarps. Symbols and abbreviations for distinguishing vegetation storeys in environmental reconstruction and climatic parameters are: E1 (herbs and vines), E2 (shrubs and lianas), E3 (trees under 25 m high) and E4 (trees over 25 m high).

Description

Potamogetonaceae Dumortier

***Potamogeton* L.**

***Potamogeton wiesaensis* Kirchheimer**
Figure 3A–P

1942 *Potamogeton*? n. sp., Kirchheimer, p. 443, fig. 18.
1957 *Potamogeton wiesaensis* Kirchheimer, p. 271, 354, pl. 13, fig. 61a–c.
1985 *Potamogeton* sp., Friis, p. 74, pl. 22, figs 15, 16 (Fasterholt flora, Middle Miocene).
2003 *Potamogeton wiesaensis* Kirchheimer. – Czaja, p. 95, pl. 19, figs 6, 7.
2003 *Potamogeton wiesaensis* Kirchheimer. – Teodoridis, p. 25, pl. 7, figs 3, 4, 10, non 9, pl. 8, figs 8, 9 .

Description. – Endocarps one-loculed with a strongly curved seed cavity, oval to rounded in outline (Fig. 3E, I), robust and thick-walled, often laterally compressed, 1.74–(2.61)–2.89 mm long and 1.25–(1.95)–2.3 mm broad, maximal thickness in transversal plane 1.02–(1.06)–1.12 mm; base rounded, basal wart rarely incomplete preserved (Fig. 3B), apex obtuse including indistinct fragmentary acute base of style (Fig. 3E, J), lateral sides markedly convex with distinct central depression, oval to rounded in outline (Fig. 3B), 0.44–(0.5)–0.63 mm long and 0.25–(0.34)–0.45 mm broad, rarely perforated in the middle (Fig. 3G), ventral side straight or concave (Fig. 3L), rarely convex (Fig. 3I), sometimes with distinct mouth of central depression (Fig. 4L); germination valve extending from base to apex (no "shoulder" in apical part), bordered by the distinct keel (Fig. 3H, K), upper surface more or less smooth. Anatomical structure of the germination valve is composed of two parts: outer multiseriate layer of tetragonal to polygonal sclereids, often compressed, 11.84–(19.47)–23.68 μm long and 11.84–(20.79)–27.63 μm broad (Fig 2Na) and inner uniseriate layer is built of elongated orthogonal sclereids, 23.68–(27.63)–34.21 μm long and 7.89–(9.87)–11.84 μm broad (Fig. 3Nb). Cracked endocarps show upper surface of seed testa (Fig. 3F). Seed campylotropous, cashew-shaped, rounded on both ends (Fig. 4O); micropyle indistinct, chalaza present at the rounded end (Fig. 4P). Seed testa reticulate, only outer thin layer of the regular, tetragonal, thin-walled cells preserved, 22.37–(45.3)–57.9 μm long and 11.84–(15.57)–21.1 μm broad (Fig. 3Nc, P).

Discussion. – Several species of *Potamogeton* L. appear in a period from the Late Oligocene to the Early Miocene in West and Central Europe. The delimitation of species based on the fruit morphology is problematic even in the case of complete endocarps but it is almost impossible when using their fragments. *Potamogeton nochtensis* Mai, *P. heinkei* Mai and *P. wiesaensis* Kirchheimer are known from Early Miocene localities in Middle Europe (Saxony, Lusatia; *e.g*., Czaja 2003; Mai 1999, 2000) and morphologically correspond to the studied material at first view. These taxa are more or less identical in shape and size but differ in other details. Mai (1987, p. 117, pl. 9, figs 5, 6, text-fig. 4a–d) described endocarps of *P. nochtensis* Mai and based this taxon on the holotype from the locality Nochten. However, it is necessary to point out that this taxon has been firstly described and typified by Holý (1976, p. 10, pl. 3, figs 1–10) as *P. nochtensis* Mai sp. nov. "(hoc loco)" from the locality Kristina including determination of holotype G 4295 (NM); see Gregor (1982, p. 127). The endocarps of *P. nochtensis* possess suddenly narrowing apices into the strong style and non-keeled germinal valves in the apical area, *i.e.* having a "shoulder" *sensu* Velichkevich & Lesiak (1996). The endocarps of this taxon are closely related to those of *Potamogeton minutus* Dorofeev (1963, p. 103, pl. 8, figs 7–16) based on the material from

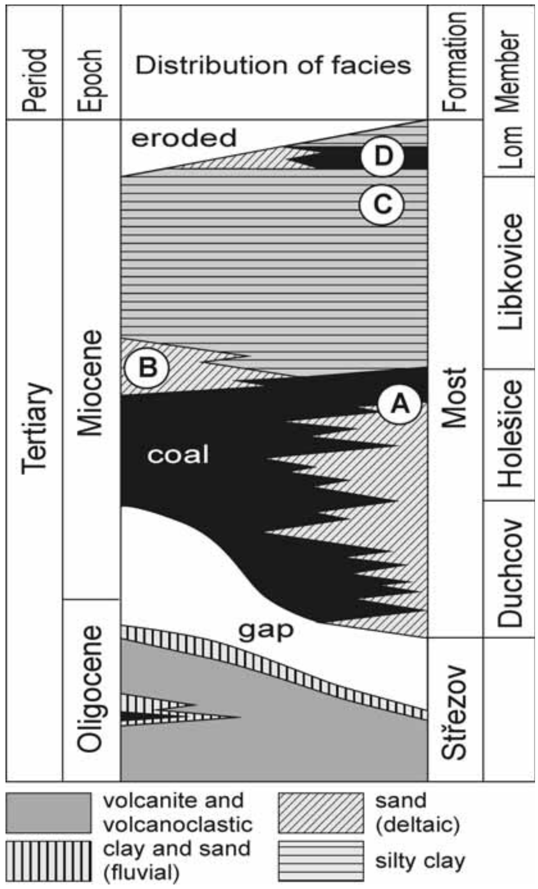

Figure 2. Stratigraphical position of the studied localitiea and cones in the Most Basin. Litostratigraphy modified after Mach (2002). Symbols: A – the Nástup-Tušimice Mine, B – the Bílina Mine (horizon 1), C – core KU 115 (Kundratice), D – core MR 59 (Mariánské Radčice).

the locality Tchernolutchej (Late Miocene, Siberia), but differs in the smaller size and distinctly keeled germination valves of the endocarps. Recently, further records of *P. minutus* were described from other European localities of the Middle and Late Miocene age, *e.g.*, Klettwitz (Mai 2000, p. 29). Comparable endocarps of *Potamogeton manykinii* Dorofeev (1977, p. 375, text-figs 5–8) with smaller "shoulders" are also known from the Early Miocene of Lusatia, *e.g.*, Hartau, Zittau, Spremberg (Mai 1999, p. 31) but they strongly differ in the dentate keel of the germination valves and a distinct S-shaped sinus on the ventral side. *Potamogeton heinkei* Mai was defined on the carpological material from the locality Hartau (Mai 1960, p. 78, pl. 4, figs 1–6). These endocarps occur in association with the above-mentioned *P. nochtensis* in the locality Kristina Mine, Hrádek upon Nisa (Holý 1974, 1976), and their delimitation is in some cases unclear. A clue could be the absence of the "shoulder", *i.e.* the fully developed keel of the germination valves in *P. heinkei*. Friis (1985) extended the morphological description of *P. heinkei* and gave information about the endocarp wall and inner germination valve structures, based on the material of the Fasterholt, Damgaard and Søby floras from Demark (Middle Miocene). She described also several endocarps as *Potamogeton* sp. from the Fasterholt flora. This material is well comparable to *P. heinkei* in general morphology, only slightly smaller, but differs strongly in the inner structure of the germination valve, which is, however, identical to the studied material from the Most Basin (Fig. 3N). Another similar species of *Potamogeton* – *P. wiesaensis* Kirchheimer is based on carpological material from the locality Wiesa (Kirchheimer 1957, p. 271, pl. 13, fig. 61a–c). These endocarps have usually been presented as bigger and more robust than those of *P. nochtensis* and *P. heinkei* but with the respect to length and breadth parameters, they show a mutual overlapping in the intervals of 1.5–2.1 mm (length) and 1.0–1.5 (breadth); see Holý (1974, 1976), Mai (1960, 1987), Czaja (2003), Teodoridis (2003). However, endocarps of *P. wiesaensis* are typical of markedly arched (convex) thick-walled lateral sides including deep or perforated central depressions and distinctly keeled germination valves. Similar endocarps but more slender with bigger central depressions on lateral sides were described from the Early Miocene of western Siberia as *Potamogeton dravertii* Dorofeev (1963, p. 25, fig. 6/1–5). Besides the above-mentioned taxa, there are some others occurring during the Late Oligocene-Early Miocene period that differ in size, *e.g.*, *P. tenuicarpus* C. et E.M. Reid (1910, p. 173, pl. 16, figs 53, 54) or in the presence of spiny keel of germination valve in *P. pygmaeoides* Mai (1987, p. 117, pl. 9, figs 7–9, text-fig. 5a–d) and *P. ornatus* Dorofeev (1963, p. 21, fig. 3/1–12).

The above-described carpological material from the cores KU 115, MR 59 and the Nástup-Tušimice Mine shows more or less uniform morphological pattern and corresponds to the presented definition of *Potamogeton wiesaensis* Kirchheimer. The endocarps vary in size contrary to the type material from the locality Wiesa. Bůžek & Holý (1964, p. 124, pl. 6, fig. 16, text-fig. 2/8) described three complete and two fragmentary specimens as *Potamogeton* sp. from the cores Hš 4 (Hošnice), Ot 27 (Otvice), Pe 21 (Pesvice) and VP 14 (Vysoká Pec). Unfortunately, this material is missing. The published figures and the detailed description show a totally different morphological pattern compared to the studied material. The published specimens are twice as big and differ in the rugulose to short spinulose upper surface. The assignment of this material to *Potamogeton* is uncertain and less probable. These facts corroborate the preliminary statement of Bůžek *in* Knobloch (1977, p. 31), who also excluded the affinity with *Potamogeton*. Bůžek *et al.* (1976, p. 110) described one endocarp as *Potamogeton* sp. from the locality Markvartice (Late Oligocene, České středohoří Mts.). The endocarp is completely different from

Figure 3. A–M – *Potamogeton wiesaensis* Kirchheimer. • A – complete endocarp with slightly concave ventral side and fragment of style, G 8343 (NM), Mariánské Radčice, core MR 48.0–49.3 m, scale bar 500 μm. • B – complete endocarp showing rounded central depression on its lateral side, basal wart (arrow) and distinctly convex lateral sides, G 8518 (NM), Mariánské Radčice, core MR 59/49.8–50.0 m, scale bar 500 μm. • C – incomplete endocarp with distinct germination valve, G 8519 (NM), Mariánské Radčice, core MR 59/49.8–50.0 m, scale bar 500 μm. • D – incomplete endocarp in dorsal view showing germination valve and its keel, G 8532 (NM), scale bar 500 μm. • E – cracked complete endocarp with fragment of style showing striated surface of seed (arrow), G 8521 (NM), Mariánské Radčice, core MR 48.0–49.3 m, scale bar 500 μm. • F – detail of Fig. 3E showing striated surface of seed in detail, scale bar 500 μm. • G – incomplete endocarp with perforated central depression on its lateral side, G 8525 (NM), Mariánské Radčice, core MR 59/49.8–50.0 m, scale bar 500 μm. • H – complete endocarp with distinctly keeled germination valve (arrow) and markedly convex on its lateral sides, G 8517 (NM), Mariánské Radčice, core MR 59/48.0–49.3 m, scale bar 500 μm. • I – complete endocarp of rounded outline, G 8338 (NM), Kundratice, core KU 115/97.0-98.0 m, scale bar 500 μm. • J – complete endocarp with fragment of style and distinct keeled germination valve, G 8534 (NM), Nástup-Tušimice Mine, scale bar 500 μm. • K – detail of Fig. 3J in dorsal view showing germination valve and its keel (arrow), G 8534 (NM), scale bar 500 μm. • L – incomplete endocarp with distinct concave ventral side and mouth of central depression (arrow), G 8522 (NM), Mariánské Radčice, core MR 48.0–49.3 m, scale bar 500 μm. • M – longitudinal cross-section of endocarp showing section of cashew-shaped seed cavity (a) and one rounded seed end (b), G 8553 (NM), Nástup-Tušimice Mine, scale bar 500 μm. • N – detail of Fig. 3M, inner structure of germination valve and seed testa: composed of outer several layers of elongated and polygonal sclereids (a), inner uniseriate layer built of elongated orthogonal sclereids (b), reticulate seed testa composed of one outer thin layer of regular, tetragonal, thin-walled cells (c), G 8536 (NM), Nástup-Tušimice Mine, scale bar 200 μm. • O, P – *Potamogeton wiesaensis* Kirchheimer, macerated seed testa G 8537 (MN), Nástup-Tušimice Mine. • O – testa of cashew-shaped seed, scale bar 500 μm. • P – detail of Fig. 3O, chalaza and reticulate pattern of seed testa composed of regular, tetragonal, thin-walled cells, scale bar 100 μm.


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all other species of *Potamogeton* in the Tertiary and should be recognized as a new species.

***Potamogeton praenatans* Knoll**
Figure 4A–C

1903 *Potamogeton praenatans* Knoll, p. 272, pl. 10, figs 1–4.
?1969 *Potamogeton martinianus* Sitár, p. 112, pl. 22, fig. 4, pl. 23, figs 3, 4, pl. 27, figs 1, 2, text-fig. 2.
?1991 *Potamogeton martinianus* Sitár. – Kovar-Eder & Krainer, p. 746, pl. 7, figs 4–6, 10, 11.

Description. – Incomplete leaf oblong in outline, 33.5 mm long and 16.2 mm broad, apex not preserved, base cuneate, narrowed into thick fragmentary petiole (5.74 mm broad in its upper part), margin entire; venation acrodromous with thicker midrib and 2 lateral pairs of thick primary veins (leaf 5-veined), interspaced at the distance of 0.15 mm (in central part of the leaf lamina) by thinner lower-order lateral veins, originated from the midrib (Fig. 4C), venation of higher orders not preserved.

Discussion. – The leaf is morphologically similar to *Potamogeton praenatans* Knoll described by Knoll (1903) from the locality Windisch-Pöllau near Gleisdorf (Austria, Pannonian). These fossils represent submersed and floating leaves. The studied leaf is interpreted as the submerse type due to its oblong outline and the character of the leaf base and petiole. Hurník *in* Hurník & Knobloch (1966) noticed occurrences of *Potamogeton* cf. *praenatans* Knoll from the locality Ležáky (Most Basin). However, these leaves (Fig. 4D, E) match better the recently defined morphospecies of *Smilacinites ungeri* Kvaček *in* Kvaček *et al.* (2004, p. 34, figs 20/1–4, 21/1–7) rather than *Potamogeton*. Both taxa differ mainly in the leaf shape and venation, which in *Smilacinites* is characterized by three orders of lateral veins and the typical oblique transversal connective veins (Fig. 4E). Kvaček & Bůžek (1982, p. 17) recorded the rare occurrence of "*Potamogeton*" leaves in the delta facies of the Bílina Mine. Generally leaves of *Potamogeton* are rare in the Tertiary settings. A submersed leaf of *Potamogeton bruckmanni* A. Br. is noted from the locality Öhningen (Switzerland) by Braun (Braun *in* Stizenberger 1851, p. 76) and figured by Heer (1855, p. 102, pl. 47, fig. 7). Knoll (1903) supposed its affinity to the family Alismataceae based on the venation (Knoll 1903, p. 271). Besides the mentioned species *P. praenatans*, Knoll (1903) also described other leaves from the locality Andritz near Graz (Austria, Pannonian) as *Potamogeton stiriacus* Knoll. The leaves can be interpreted as floating leaves and are more or less identical with *P. praenatans* except for the less distinct leaf midribs. Brabenec (1909, p. 64) described leaves and fruits of *P. geniculatus* A.Br. from the localities Břešťany (Early Miocene, Most Basin) and Kučlín (Late Eocene, České středohoří Mts.), leaves of *P. poacites* Ettingsh. from the locality Jehličná (Late Eocene, Sokolov Basin) and leaves of *P. schrotzburgensis* Heer from the locality Kundratice (Early Oligocene, České středohoří Mts.). Unfortunately, this material is missing. Similarly, Němejc (1967, pp. 16–18) mentioned leaves belonging probably to *Potamogeton* sp. from the Sarmatian localities Hontianské Vrbice, Nižní Skalník and Krásné upon Hornád (Slovakia). Knobloch (1969a) described one complete leaf as *Potamogeton* sp. from the locality Žilina near Nový Jičín (Karpatian, Northern Moravia). This sample is different from the above-described *P. praenatans* in having oval shape and high number of primaries (18). Knobloch (1969b) described another leaf material as *P. wieseri* Kov. from the Dukla Mine near Mistřín (Pannonian, Southern Moravia). Sitár (1969) described incomplete leaves as *Potamogeton martinianus* Sitár from the locality Martin (Sarmatian, Slovakia). This material shows considerable similarities in shape and venation pattern with the floating leaves of *P. praenatans*. Therefore, the epitethon "praenatans" should be given priority. Kovar-Eger & Krainer (1991) described further *Potamogeton* leaves from the locality Reith near Unterstorcha (Pannonian, Austria). They showed some similarity in leaf character with the leaf fragment from the Sarmatian flora of the Holy Cross Mts., Poland (Zastawniak 1980, p. 85).

Associated flora

In addition to the *Potamogeton* leaf, the horizon No. 1 (Fig. 2) yielded a rich flora with one horsetail, two ferns, two conifers and 40 angiosperm species (Table 1). The composition of this flora is consistent with the general cha-

Figure 4. A–C – *Potamogeton praenatans* Knoll. • A – submersed leaf, DB 1-55 (DB), Bílina Mine (horizon No. 1), scale bar 10 mm. • B – detail of leaf base and petiole, DB 1-55 (DB), Bílina Mine (horizon No. 1), scale bar 5 mm. • C – detailed venation of leaf lamina with originating of lower-order lateral vein from midrib (arrow), DB 1-55 (DB), Bílina Mine (horizon No. 1), scale bar 5 mm. • D, E – *Smilacinites ungeri* Kvaček. • D – leaf, G/Pa 355 (MM), Ležáky, scale bar 10 mm. • E – detailed venation of leaf lamina, G/Pa 355 (MM), Ležáky, scale bar 5 mm. • F – *Potamogeton polygonatus* Pour, Almquist 1911 (KRA), S Zwecia, Poland, fructification, scale bar 5 mm. • G, H – *Potamogeton polygonatus* Pour, Schepping 1889 (KRA), Lauchhamer, Germany, endocarps, scale bar 500 µm. • I, J – *Potamogeton nodosus* Poiret, Z. Kaplan 03/203 (PR), Sokoleč, Czech Republic. • I – habit, scale bar 10 mm.• J – detailed venation of leaf lamina with origination of lower-order lateral vein from midrib (arrow), scale bar 5 mm.


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Table 1. Floristic composition of the associated floras from the studied locality and cores in the Most Basin. • Abbreviations: C– cone, F – fruit, L – leaf, S – seed, Sp – spores, G – associated floras from the studied localities, H – No. 1, I – Nástup-Tušimice, J – KU 115, K – MR 59, O – organ.

Taxa	O	G			
		H	I	J	K
Acer angustilobum Heer	L	*			
Acer integerrimum (Viviani) Massalongo	L	*			
Acer tricuspidatum Bronn *sensu* Procházka & Bůžek	L, F	*		*	
Alnus gaudinii (Heer) Knobloch & Kvaček	L	*		*	
Alnus julianiformis (Sternb.) Z. Kvaček & Holý	L, F	*		*	
Azolla aff. *nana* Dorofeev	F				*
Azolla aff. *rossica* Dorofeev	F				*
Azolla aff. *ventricosa* P. Nikitin *sensu* Dorofeev	F				*
Berberis cf. *berberidifolia* (Heer) Palmarev & Petkova	L	*			
Berchemia multinervis (A.Br.) Heer	L	*			
Betula sp.	L	*			
Carex sp.	F			*	
Cercidiphyllum crenatum (Ung.) Brown	L, F	*			
Comptonia difformis (Sternb.) Berry	L	*			
Comptonia srodoniowae Friis	F			*	
Craigia bronnii (Ung.) Kvaček, Bůžek & Manchester/ *Dombeyopsis lobata* Ung.	F, L	*			
Daphnogene polymorpha (A.Br.) Ettingsh.	L	*		*	
Decodon gibbosus (E.M. Reid) E.M. Reid in Nikitin	L	*			
Diversiphyllum aesculapi (Heer) Bůžek	L	*			
Engelhardia macroptera (Brongn.) Ung.	F	*			
Equisetum parlatorii (Heer) Schimper	L	*			
Faxinus bilinica (Ung.) Kvaček & Hurník	L, F	*			
"*Ficus*" *truncata* Heer *sensu* Bůžek	L	*	*		
Glyptostrobus europaeus (Brongn.) Ung.	L, C, S	*		*	
"*Juglans*" *acuminata* A.Br. ex Ung.	L	*			
Koelreuteria reticulata (Ettingsh.) Edwards	F	*			
Laurophyllum pseudoprinceps Weyland & Kilpper	L			*	
Laurophyllum pseudovillense Knobloch & Z. Kvaček	L			*	
Leguminosites sp. div.	F	*			
Liquidambar europaea A.Br.	F	*			
Mahonia bilinica (Ung.) Kvaček & Bůžek	L	*			
Myrica integerrima Kräusel & Weyland	L	*			
Myrica lignitum (Ung.) Sap.	L			*	
Nyssa bilinica (Ung.) Kvaček	L, F	*	*		
Osmunda parschlugiana (Ung.) Andreanszky	L	*			
Paliurus tiliaefolius (Ung.) Bůžek	L, F	*			
"*Parrotia*" *pristina* (Ettingsh.) Stur *sensu* Bůžek	L	*			
Pinus engelhardtii Menzel	C			*	
Pinus sp.	L	*			
Pinus urani (Ung.) Schimper	C			*	
Poaceae vel Cyperaceae gen. et sp. indet.	L	*			
Podocarpium podocarpum (A. Br.) Herendeen	L	*			
Populus populina (Bron.) Knobloch	L	*			
Populus zaddachii Heer var. *brabenecii* Teodoridis	L	*			
Pronephrium stiriacum (Ung.) Knobloch & Kvaček	L	*			
Pungiphyllum cruciatum (A.Br.) Frankehäuser & Wilde	L	*			
Quasisequoia coutsiae (Heer) Kunzmann	L, C, S		*		
Quercus rhenana (Kräusel & Weyland) Knobloch & Kvaček	L	*			
Rubus merianii (Heer) Kolakovskij	L	*			
Salix haidingeri Ettingsh.	L, F	*			
Salvinia reusii Ettingsh.	L, Sp				*
Schisandra moravica (Mai) Gregor	S			*	
Smilax weberi Wessel	L	*			
Spirematospermum wetzleri (Heer) Chandler emend. Koch & Friedrich	S		*		
Stratiotes kaltennordheimensis (Zenker) Keilhack	S	*			
Symplocos sp.	F			*	
Taxodium dubium (Sternberg) Heer	C, L, S	*			
Ulmus pyramidalis Goepp.	L, F	*			
"*Viburnum*" *atlanticum* Ettingsh.	L	*			
Vitis teutonica A. Br.	S	*			
Zelkova zelkovifolia (Ung.) Bůžek & Kotlaba	L	*			

racter of the Bílina Delta floras (see for detail Bůžek *et al.* 1992, Kvaček *et al.* 2004, Teodoridis & Kvaček 2006). The associated floras of the core KU 115 included three conifers and 11 angiosperms and of the core MR 59 contained only four aquatic ferns (Table 1; Teodoridis 2005, Teodoridis & Kvaček 2006). Similarly, associated flora from the Nástup-Tušimice Mine included only coal forming elements (Table 1; Kvaček 2006, Teodoridis & Kvaček 2006).

Living relatives

According to the morphological analysis of the recent fruits, it is possible to associate *Potamogeton wiesaensis* Kirchheimer with the endocarps of the extant species *Potamogeton polygonatus* Pour (Fig. 4F–H) that correspond to later published opinions in agreement with Mai (1999). Knoll (1903) defined *Potamogeton natans* L. as the living relative of *Potamogeton praenatans* Knoll and *P. corolatus* Hornem (syn. *P. corolatus* Vahl.) as the extant descendent of *P. stiriacus* Knoll. Similarly, Sitár (1969) related the living *P. corolatus* Hornem. to the fossil *P. martinianus* Sitár. According to Kaplan (personal communication 2006), the leaf described herein matches better the extant *P. nodosus* Poir. (Fig. 4I, J) with smaller leaves than *P. natans*, *P. coloratus* and *P. polygonatus*.

Palaeoecological interpretation

The *Potamogeton* remains occurred in two genetically different environments. The first one is a deltaic environment (system of the Bílina Delta), which is documented by the leaf from the Bílina Mine (horizon No. 1). The second type is a basin environment characterized by coal and coal-clayey lithofacies including the studied fruits from the cores of MR 59/48–50 m, KU 115/97–98 m and the Nástup-Tušimice Mine. According to the autecology of the modern species of *Potamogeton* L., the fossils belong to the aquatic vegetation within coal-forming biotopes and also the reed vegetation associated within riparian settings. The aquatic vegetation corresponds to *Salvinia reussii* association *sensu* Kvaček & Bůžek (1982, p. 20), which includes together with *Potamogeton* other aquatic free-floating elements such as *Salvinia reussii* Ettingsh. (E1), *Azolla* sp. (E1), *Hemitrapa heissigii* Gregor (E1), *Stratiotes kaltennordheimen-*

sis (Zenker) Keilhack / *S. schaarschmidtii* Kvaček (E1), *Lemna cestmiri* Kvaček (E1), *Limnobiophyllum expansum* (Heer) Kvaček, (E1) *Hydrochariphyllum buzekii* Kvaček (E1) and *Elephantosotis dvorakii* Kvaček (E1). This vegetation can simply pass distal parts to reeds and then into coniferous swamp forest or mixed swamp forest association – Teodoridis (2004, pp. 134–136). The association of reeds contains other rooted "aquatic" elements, *i.e.* Poaceae vel Cyperaceae (E1), *Decodon gibbosus* (E2), *Sparganium* spp. (E1), *Proserpinaca reticulata* C et E.M. Reid (E1); and helophytes elements such as *Spirematospermum wetzleri* and *Zingiberoideophyllum liblarense* (E2), *Pronephrium stiriacum* (E2), *Calamus daemonorhops* (Unger) Chandler (E2) and *Sabal* sp. (E2). According to Kvaček (1998), the accumulation of *Salix haidingerii* Ettingsh., well known from delta deposits in Bílina and Hrabák (the Žatec Delta), can be interpreted as periodically flooded, pioneer, monotonous growths that also occurred in association with a rich aquatic vegetation of the horizons No. 21 and No. 47 (Kvaček 2003). The associated flora of the Nástup-Tušimice Mine shows elements that correspond to the association of coniferous swamp forest (*Glyptostrobus* association *sensu* Kvaček & Bůžek 1982). The associated flora of horizon No. 1 also contains typical elements of the mixed swamp forest (*Nyssa-Taxodium* association *sensu* Kvaček & Bůžek 1982) in combination with riparian and mesophytic elements (*Parrotia-Ulmus pyramidalis* association *sensu* Kvaček & Bůžek 1982).

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