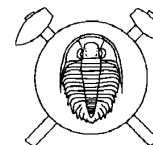


## Early Miocene freshwater and swamp ecosystems of the Most Basin (northern Bohemia) with particular reference to the Bílina Mine section



### Spodnomiocenní sladkovodní a bažinné ekosystémy mostecké pánve (severní Čechy) se zvláštním zřetelem k profilu dolu Bílina

(21 Figs, 4 Tables)

ZLATKO KVAČEK<sup>1</sup> – MADELAINE BÖHME<sup>2</sup> – ZDENĚK DVOŘÁK<sup>3</sup> – MAGDA KONZALOVÁ<sup>4</sup> – KAREL MACH<sup>1</sup> – JAKUB PROKOP<sup>4</sup> – MICHAL RAJCHL<sup>1</sup>

<sup>1</sup> Charles University, Faculty of Science, Institute of Geology and Palaeontology, Albertov 6, CZ-12843 Praha 2, Czech Republic. e-mail: kvacek@natur.cuni.cz, rajchl@natur.cuni.cz

<sup>2</sup> Universitätsinstitut und Staatssammlung für Paläontologie und historische Geologie München, Richard-Wagner-Str. 10, D-80333 München. e-mail: m.boehme@lrz.uni-muenchen.de

<sup>3</sup> North Bohemian Mines, j.s.c., Bílina Mines, ul. 5. května 213, 418 29 Bílina, Czech Republic, e-mail: Mach@mail.sdass.cz, Dvorak.Zdenek@mail.sdass.cz

<sup>4</sup> Charles University, Faculty of Science, Department of Zoology, Viničná 7, CZ-12844 Praha 2, Czech Republic. e-mail: jprokop@natur.cuni.cz

<sup>5</sup> Institute of Geology, Academy of Sciences of the Czech Republic, Rozvojová 135, CZ-16500 Praha 6, e-mail: konzalova@gli.cas.cz

Various stages of ecosystem development within the Early Miocene Most Formation, the coal-bearing fill of the Most Basin in northern Bohemia, are reviewed on the basis of recent sedimentological and palaeontological studies. Several types of environment with specific plant and animal assemblages have been recognized and evaluated – low moor coal-forming mire with low nutrient supply and the ground water level near or reaching the earth surface rarely reaching a raised bog regime, shallow ox-bow lakes with various water quality, mineral back swamp along streams and in deltas on clayey and silty fat soils with an irregular supply of nutrients and a high groundwater level, flooded delta plains, riverbanks and levees with light, well aerated sand- and clay-dominated substrate well supplied by nutrients and moisture, drier habitats beyond the influence of flooding, and a deeper lake surrounded by a drier sloping upland with acid soils. Fossil records of plants, insects and lower vertebrates have been treated in more detail with special reference to palaeoenvironmental properties. Characteristics of the following newly established taxa are included – Pisces: *Umbra longidorsalis* Böhme, sp. nov., Plantae: *Bilinasporites multilamellatus* Konzalová, gen. et sp. nov., *Nyssa bilinica* (Unger) Z. Kvaček, comb. nov., *Nyssa bilinica* forma *haidingeri* Z. Kvaček, f. nov., *Pseudotrappa buzekii* Z. Kvaček, gen. et sp. nov. and *Smilacinites ungeri* Z. Kvaček, gen. et sp. nov.

**Key words:** Environment & ecosystems; plants; insects; lower vertebrates; northern Bohemia; Early Miocene.

## Introduction

The North Bohemian Brown Coal Basin, i.e., the Most Basin in the present geological terminology, is the largest freshwater sedimentary body of Neogene age in the Czech Republic (see Havlena 1964). Its diversified deposits of mainly fluvial-lacustrine origin have yielded a wealth of plant and animal fossils since Sternberg's times during the last two centuries. Intensive long-term mining of lignite (Luxa 1997) provided ideal opportunities not only to collect fossil remains but also to follow the composition and changes of fossil assemblages due to various depositional settings and consequently environmental circumstances and interactions of individual fossil ecosystems. One of the excavated sections in the area of Bílina, known from the very beginning of palaeontological research in northern Bohemia (Bůžek et al. 1992, Knobloch – Kvaček 1995), has been subjected to a detailed geological and palaeontological field examination for several decades, mainly carried out by the staff of the Bílina Mine geological department. During the last 30 years, new data have accumulated to such an extent that it has become necessary to summarize knowledge concerning the plant record monographically (Kvaček et al. 2004). However, this book is intended mainly for broad-

er audience including hobby palaeontologists and amateur collectors, and is written in Czech. Moreover, the animal fossils, which are also abundant in the sedimentary fill of the Most Basin, will be covered by another monograph. Before this project was started we decided to strive for an integrated evaluation of at least some animal components that lived directly in freshwater and swamp environment of the basin, namely ichthyofauna and insects, together with the already well known vegetation types and pollen assemblages (Konzalová 1976, Boulter et al. 1993, Kvaček 1998).

Most new collections from the Bílina area have been gathered by Zdeněk Dvořák, late Čestmír Bůžek and their co-workers and friends. These collections are housed in the Bílina Mine Headquarters, Bílina (DB), in the Czech Geological Survey and the National Museum, Prague. Fossil material from various parts of the basin has been also rescued by other colleagues and is scattered in several public institutions (e.g., museums in Most, Teplice, Chomutov) and private collections. The published type and figured specimens described in several separate studies and also in this paper are largely housed in the National Museum, Prague (NM). Also earlier collections assembled since Sternberg's times and scattered in various repositories over Europe were re-studied at this oc-

casion. The following review is by far not complete, leaving apart rich mammal faunas, which are under the study of Oldřich Fejfar and his co-workers, and invertebrate faunas of gastropods and ostracodes (see Čtyroký – Witt 1998). We believe, however, that our account will offer a more complex insight into the geological history of the Most Basin and reveal more details of the life during the deposition of its fill.

The co-authors have participated on individual topics as follows: K. Mach and M. Rajchl – depositional history, Z. Kvaček – stratigraphy, plant macrofossils, vegetation, Z. Dvořák – a list of plant macrofossils, M. Konzalová – palynology, M. Böhme – lower vertebrates, and J. Prokop – insects.

### Palaeoenvironment and depositional history of the Most Basin, and of the Bílina Delta in particular

The Most Basin with its area of ca. 870.3 km<sup>2</sup> (Fig. 1) represents a minor sedimentary body in the global scale compared to other Neogene basins. Its category does not change even if we enlarge the area twice considering the fact that it is an erosive remnant of an originally larger basin. Thirty largest lakes of the world today occupy an area well exceeding 5000 km<sup>2</sup> each. Among lakes in Europe, the “North Bohemian Lake” would place seventh among present lakes in Scandinavia and northern Rus-

sia. Clay deposits of this lake, which buried peat layers, reached over 300 m in thickness, and the basin fill (i.e., the Most Formation) in the centre is about 500 m in complete thickness.

Palaeontological data suggest that the area of the Most Basin started to function as a sedimentary reservoir some time between 25 and 23 Ma at the Oligocene/Miocene boundary (Lotsch et al. 1994, Teodoridis 2002, Suhr 2003). At that time, the main-phase volcanic activity in the adjacent volcanic centres of the České Středohoří Mountains and Doupov Mountains almost ceased. The Krušné hory Mountains range did not exist and the whole basin subsided very slowly. Weathered products from older rocks from southern, southeastern and southwestern Bohemia yielded pebbles, sand, silt and clay material, which was transported by streams into the basin. These deposits accumulated in valleys along lower reaches of the streams on flood plains or directly on riverbeds, and formed a wide belt of fluvial sandy facies (Hlavačov Sand and Gravel) of the south–north direction coming from central Bohemia (Fig. 1), entering the basin near Žatec and leaving the basin probably near Chomutov (Mach in Kvaček et al. 2004) or across the České Středohoří Mountains (Suhr 2003). An equivalent deposit can be traced further north in Germany towards the “Ancient” North Sea, which was situated in wider surroundings of Leipzig during the Late Oligocene and Early Miocene (Lotsch et

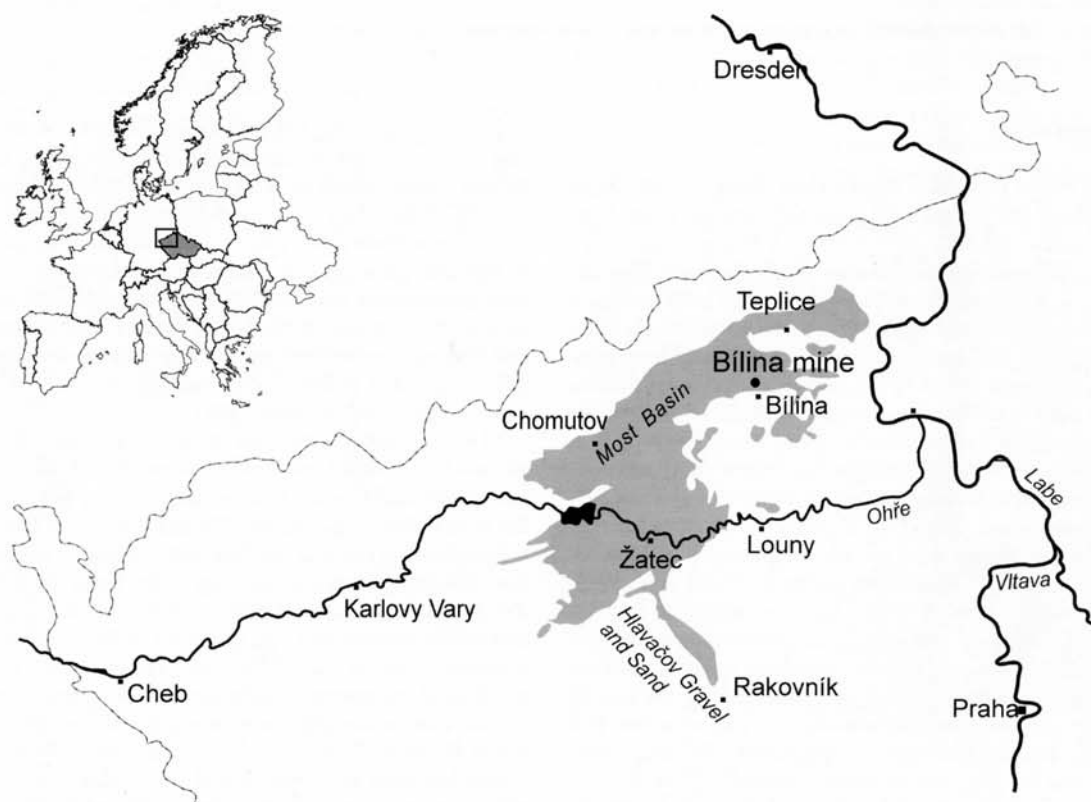


Fig. 1. Geographic position of the Most Basin and the Hlavačov Gravel and Sand belt in northern Bohemia.

al. 1974, Standke 2002). In other parts of the basin, these allochthonous fluvial sediments of limited extent passed into layers of sub-autochthonous weathering products transported from flat volcanic slopes or from erosion valleys cut into the Cretaceous, Carboniferous and Precambrian rocks.

During the Early Miocene, the subsidence of the basin caused an increase of the area flooded by rivers and a spreading of flatland with swamps and shallow lakes. This period is connected with two palaeontological localities, the Merkur-North Mine at Ahníkov and the limestone at Tuchořice. At first, only occasional flooding inundated wetlands, which got transformed into periodically or steadily inundated local mires, where plant biomass accumulated in the form of peat. Individual mires gradually fused into continuous wide belts along the main stream and its tributaries. This type of landscape was stable in the basin for a long time. From the south, a small stream entered the basin at Žatec, probably with a lower discharge than the today's Ohře River, and continued across the mire towards the north. It might have not reached the northern margin of the basin but deposited the transported sand and clay in the nearby peat deposits or in the streambed. Only during flooding events or higher levels of groundwater, the fluvial facies spread over several kilometres far into the basin forming whitish clay and sand-dominated interbeds in peat layers. This way, the basin filtered stream waters flowing towards the North Sea and enriched them in organic matter. As the area of the mire enlarged, luxurious vegetation spread over swamps and wetlands and increased the evaporation (which could have been three times higher from a plant cover than that from the open water level). The amount of water flowing from the basin towards the north was ever smaller. In times of the largest extent of the mire, the basin was able to evaporate most of the running waters. The mire corresponded for most of its life to the low-moor type. This means that the accumulation of plant biomass was in equilibrium with the increase in groundwater level caused by inflow of streams. Rare periods of temporarily increased precipitation supplied water for the northern Bohemian mire to reach the raised bog regime.

At the peak of its development, the mire was filled with a thick layer of peat, locally up to 200 m thick (Mach 1997, 2003). This layer of biomass was interrupted by interbeds of clay and sand that originated during longer periods of high water level in the basin. Besides detrital sand and clay deposited along rivercourses, in small deltas of temporary lakes and in swamps, also authigenic clay particles precipitated within the basin. Sulphate-reducing bacteria, which lived in organic matter under the water table in swamps and lakes, reduced the content of sulphates in water and transformed them into hydrogen sulphide. The reaction of hydrogen sulphide with Fe ions resulted in the formation of sulphides – pyrite and marcasite. The amount of these two minerals definitely controls the sulphur content in coal today. Organic matter of

the peat accumulated also other compounds or elements, namely metals.

In the wider environs of Žatec, where most streams discharged, sand-dominated deposits prevailed due to the lowering of the river gradient; therefore, the conditions for peat formation were limited and short-termed. Thicker layers of biomass could not accumulate in such unstable environment. At present, a similar model example of such deposits can be seen, e.g., in continental deltas of the Okavango River, Botswana, in South Africa (McCarthy et al. 1991).

Further orogenic processes together with climatic changes shifted the mouth of the main stream to the Bili-na area and caused a complete flooding of the basin, which progressively turned into a large lake. The process started in a smaller lake surrounded by mires, where thick beds of sand and clay were deposited in a small delta.

The delta body, called the “Bilina Delta” (see also Hurník 1959, Dvořák – Mach 1999, Mach 1997, Uličný et al. 2000), first originated in a narrow elongated lake about 1 km wide and 5 km long, the broadening of which allowed the delta to shift towards the NE. It formed at the mouth of a river that belonged to a large drainage system of NE, E, and SW Bohemia (Malkovský 1995) and drained into a fairly shallow, at most several metres deep lake surrounded by wide peat swamps over most of the Bilina Delta lifetime. The deposits of this relatively small system (ca. 5 km across) are excellently exposed in a complete thickness of ca. 150 m in the opencast Bilina Mine.

The architectural pattern of the Bilina Delta depositional system is characterized by shingle-like arrangement of wedge-shaped and lenticular bodies of the heterolithic deltaic deposits (individual deltaic bodies) and packages of lacustrine strata (Fig. 2). Thinly laminated clays with variable silt admixture represent the lacustrine deposits. Individual deltaic bodies, representing individual stages of the delta development, range from hundreds of metres to first kilometres in lateral extent and from ca. 10 m to several tens of metres in thickness (documented maximum was 50 m). Four fundamental architectural elements (facies associations) representing essential parts of the delta were distinguished in these bodies (Rajchl – Uličný 1999, Uličný et al. 2000).

1. *Fluvial and delta-plain heterolithic sheets* include homogeneous, strongly rooted palaeosols of a riparian forest, carbonaceous mudstones representing swamps of the delta plain, and stratified, commonly rooted sands to clays, interpreted as deposits of intertributary bays. Coarser facies (coarse-grained sand or granule) occur only in the form of thin lenses or sheets deposited as crevasse splays.
2. *Fluvial-channel fills* are mostly composed of coarse-grained sand or granule and are represented by (i) large-scale (50 m to several hundred metres wide, 3 to 5 m thick) multi-storey and multi-lateral channel fills interpreted as channel belts formed by lateral shifting of major fluvial channels of the feeder system,

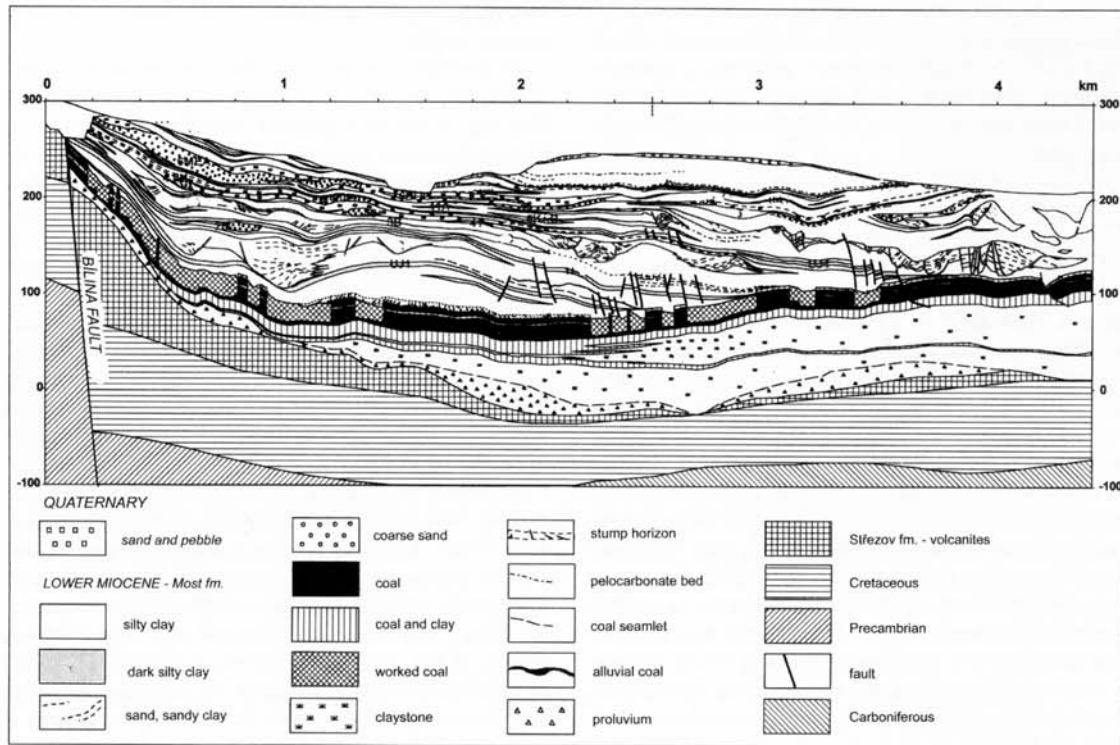


Fig. 2. Geological cross-section of the Bilina opencast mine. (Adapted from Mach 2003.)

and by (ii) isolated small-scale channel fills 5 to 20 m wide and 0.5 to 1.5 m thick, interpreted as individual distributaries which acted as feeder channels of individual mouth bars (below).

3. *Sand-dominated mouth-bar wedges* (Fig. 3) are generally composed of fine- to coarse-grained sand and are characterized by originally flat-lying, trough cross-bedded or ripple-bedded topsets, and planar or tangential foresets, commonly steeply dipping (up to  $30^\circ$ ), with usually inversely graded laminae. These sedimentary bodies are interpreted as friction-dominated mouth bars mostly typical by a steep mouth-bar front dominated by grain-flow deposition and characterized by Gilbert-type profile (Fig. 4a; sensu Postma 1990). Locally, the mouth bars have a shoal-water profile (sensu Postma 1990) with no foresets (Fig. 4b).
4. *Prodelta heterolithic sheets* (Fig. 3) commonly pass laterally up depositional dip into the mouth-bar sands and are characterized by ripple-bedded or flaser-laminated fine-grained sand in the proximal part (close to the bodies of the mouth bars) passing into laminated silty clay with increasing distance from the mouth bars. Based on the spatial continuity between the heteroliths and mouth-bar foresets, a major part of the heterolithic sheets is interpreted as bottomsets of the Gilbert-type mouth bars or their genetic equivalents in case of shoal-water mouth bars. The presence of current ripples and frequent changes of sand or clay layers could indicate deposition from turbidity currents.

Based on the above mentioned facies and architectures, the Bilina Delta is interpreted as a fluvial-dominated, mouth-bar-type delta, with distributaries terminated by friction-dominated mouth bars, mostly with the Gilbert-type profile (Fig. 4c; see Rajchl – Uličný 1999, Uličný et al. 2000) and a fan-like plan-view shape. The height of the foresets of the Gilbert-type mouth bars, plus the thickness of the topsets, formed in a few centimetres of water, shows that the depth of the receiving lake was up to 5 m at the delta front. The shoal-water mouth bars formed in water depths of ca. 1 m or less. A significant feature of the Bilina Delta is the grain-size distribution. The delta plain and prodelta were dominated by muddy lithologies, with a subordinate proportion of heterolithic facies (e.g., crevasse splay sands, or sand/mud laminites in the prodelta, traceable into mouth bar foresets), whereas the feeder channels and Gilbert-type mouth bars were dominated by sands. The small depth of the lake, and probably a very small difference in density between the waters of the fluvial feeder system and the freshwater lake are interpreted as having caused the high degree of segregation of grain sizes, as well as the formation of Gilbert-type foresets in a shallow setting that lacked topographic breaks, normally associated with steep, Gilbert-type delta fronts. Homopycnal, turbulent jets were probably the main type of effluent at the distributary mouths. Turbulent mixing and deceleration at the distributary mouth caused the instant deposition of coarse material on the foresets. However, turbidity underflows

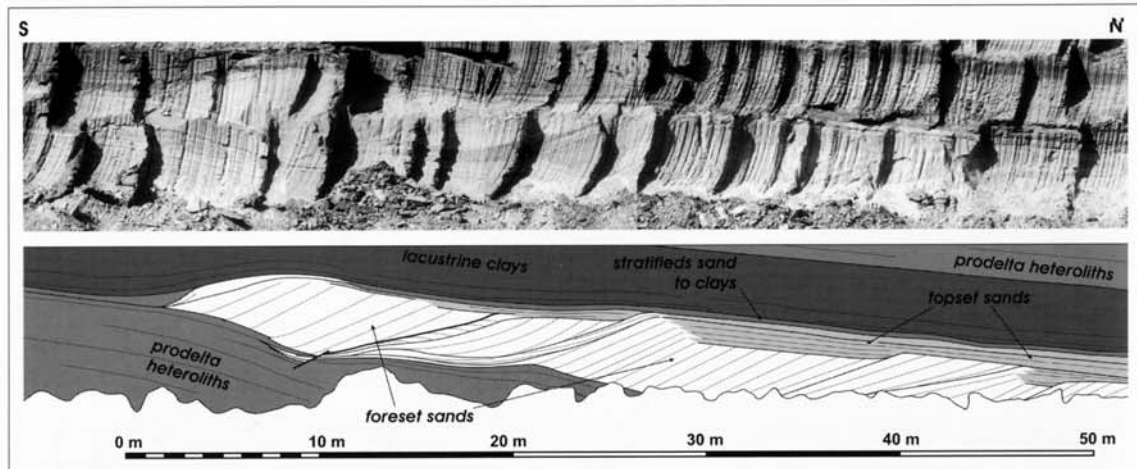


Fig. 3. Example of the mouth bar with the Gilbert-type profile.

could have formed during time intervals when the river carried a much higher proportion of suspended load.

Progressive flooding of the basin caused the clay facies to spread over the mire and to bury the peat layer all over its extent. During the existence of the Bilina Delta, several other small streams entered the basin from the north – from the today's Krušné hory Mountains area, and some other streams existed near the basin periphery in the Ústí nad Labem and Žatec areas. Northern streams transported lower amounts of sand but influenced the character of clay layers deposited in the lake by bringing trace amounts of mica. Later, the lake extended well beyond the present limits of the basin. The quartzose sandstone of the locality Černovice (Tschernowitz), the Hradiště Hill, now high above the basin on the Krušné hory Mts. may belong to this kind of deposits (Hurník 1960), although its position below the seam cannot be ruled out (Bůžek 1963, 1984).

At about 15 Ma, when the lake was already fairly filled, the deepening slowed down and shallow swamp and mire conditions were re-established in the environs of Lom in the central part of the basin. The Lom Seam, that arose from this temporary mire after the deposition of the overlying clays and sands, indicates this episode connected with the topmost part of the basin fill, now representing an incomplete erosive relict of a limited extent (Hurník 2001, fig. 42).

Geological and depositional settings of the deltas as well as models of the present landscape suggest five different types of environment vegetated by different, partly intermixed plant associations (Fig. 5):

1. Vegetation of drier habitats beyond the influence of flooding, well supplied by nutrients from the surrounding weathered substrate, but a lower supply of moisture.

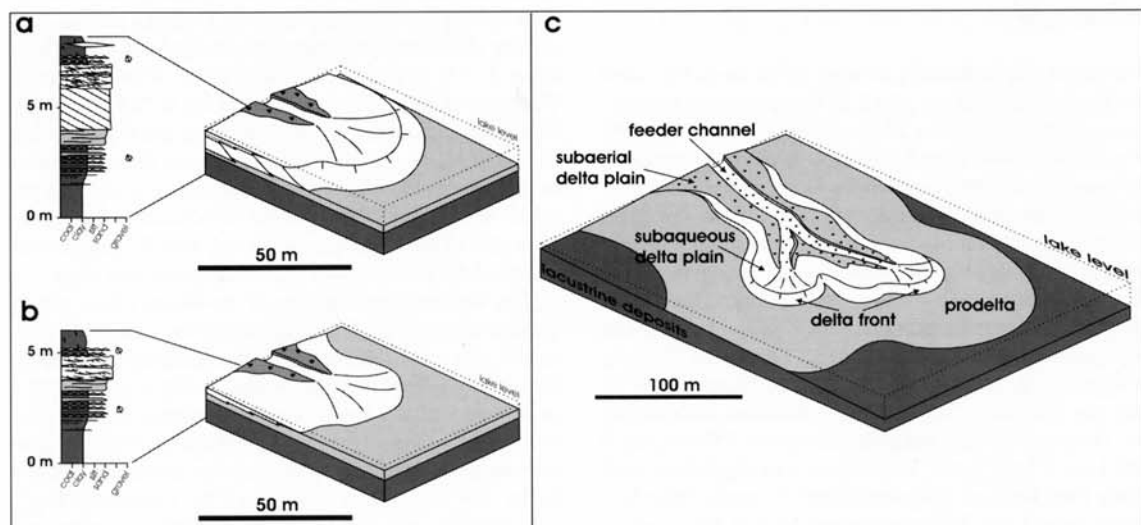


Fig. 4. Reconstruction of the Gilbert-type mouth bar (a) and the mouth bar with shoal-water profile (b) together with the hypothetical model of the Bilina Delta (c).

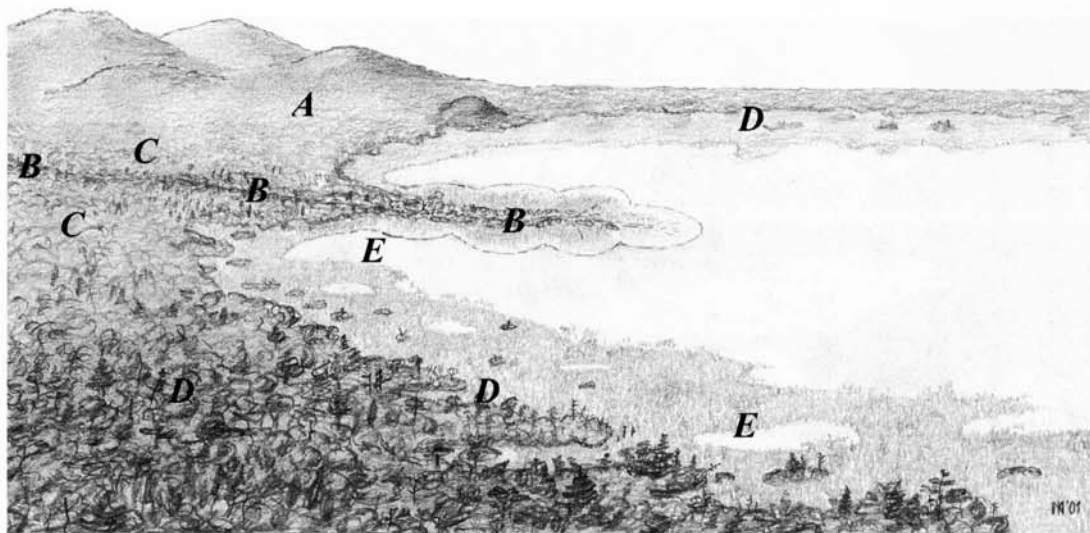


Fig. 5. Landscape during the deposition of deltas with various types of environment: A – drier habitats on slopes, B – riverbanks and levees, C – wetland and back swamps, D – coal-forming mire, E – open water table of lakes. (Adapted from Kvaček et al. 2004.)

2. Riparian vegetation of riverbanks and levees on light, well aerated sand- and clay-dominated substrate well supplied by nutrients and moisture.
3. Wetland vegetation in back swamps along streams and in deltas on clayey and silty fat soils with an irregular supply of nutrients and the groundwater level lying near or above the earth surface.
4. Mires with low nutrient supply, and also with groundwater level lying near or above the earth surface, with almost no nutrient supply in short-term periods of raised bog regime.
5. Aquatic vegetation free-floating in ox-bow lakes and swamps, or rooted in the mud of shallow waters.

### Stratigraphy

The recent comprehensive reviews of the basin fill called the Most Formation are based on intensive core exploration carried out over the whole basin (Elznic et al. 1986, Váně 1987, 1999, Hurník 2001). It is not the purpose of this paper to describe in detail the rather complicated geological structure of the main parts of the basin: the Žatec “Delta” (or alluvial plain) in the southwest, the Chomutov part with three split partial seams, the deepest central part between Most and Horní Litvínov, the Bilina Delta and the northeastern part near Ústí nad Labem. The deposition of the fill, i.e., the Most Formation (Fig. 6), is subdivided, in general according to Domáci (1977), into the Duchcov (“Underlying”) Member, overlain by the Holešice (“Main Seam”), Libkovic (“Overlying”) and Lom (“Lom Seam”) Members. The deposition took place from the Late Oligocene/Early Miocene boundary to the latest Early Miocene/earliest Middle Miocene according to palaeomagnetic dating (Malkovský 1995) and

palaeofloristic correlation (Kvaček et al. 2004). Rocks underlying the Main Seam were dated to mammal zone MN 3 of Early Burdigalian (–Early Eggenburgian) age – see Fejfar (1990), Fejfar – Kvaček (1993).

In general, the following environments were present during the deposition of the Most Formation. Early stages of the basin are characterized by flat land with stagnant-water lakes in the northwestern part filled with colluvia of neo-volcanics, lakes in the central part with clay deposition (Elznic 1964), and fluvial and deltaic facies near the mouth of the stream coming from central Bohemia (Hlavačov Sand and Gravel – Váně 1985, Teodoridis 2001, 2003b). In the next stage, vast swamps of the Holešice Member were intercalated with clay and sand beds reaching out from the deltas in the Žatec and Bilina areas. During a sudden subsidence of the basin, the landscape changed into a large lake about 1–7 m in depth, filled with clays of the Libkovic Member, which is also developed in the delta facies in the Bilina and Žatec areas. It should be noted that the sediments richest in fossils, the Břešťany Clay, were deposited within this very event. The renewed shallowing of the lake resulted in the accumulation of the Lom Seam in the uppermost part of the basin fill, which was also connected with a small delta in the central part of the basin near Osek.

The well-explored section of the Bilina Mine, which yielded most of the described assemblages and new elements, allows to describe the lithostratigraphic subdivision in more detail (see Bůžek et al. 1992, Kvaček 1998). In this part of the basin, the development of the Main Seam was unusually irregular (Hurník 1959). A thin seamlet splits from the top of the Main Seam and extends to the clay above; it is called the Clay Superseam Horizon (CSH) – see also Bůžek et al. (1992). Further upwards, alluvial sandy clay deposits of the Bilina Delta are

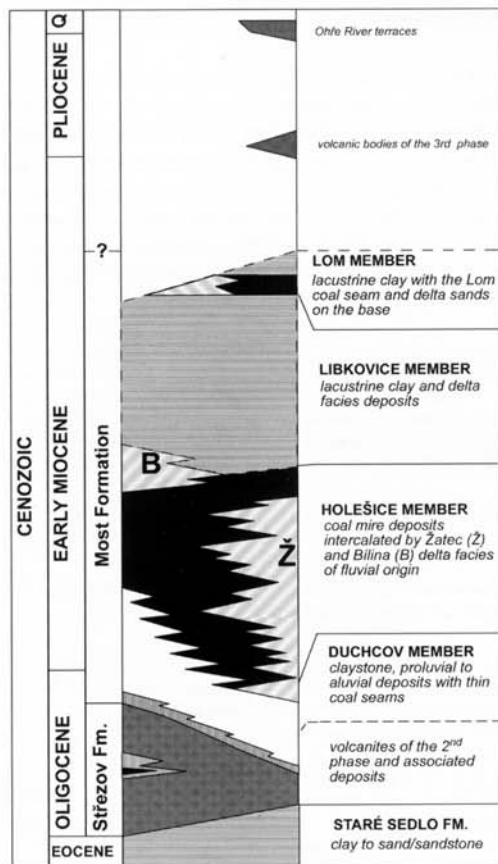


Fig. 6. Lithostratigraphic column of the Most Basin. (Adapted from Mach 2003.)

called the Delta Sand Horizon (DSH). This horizon yielded most of the plant remains, but much fewer insects and no fish due to its highly oxidized environment. It is considered a lateral equivalent of the coal seam in its lower part (i.e., Holešice Member) and of the lacustrine facies of the Libkovice Member in its uppermost part. The Bilina section revealed the exact position of the Břešřany Clay considered the most famous fossiliferous horizon of this area, which is a lateral continuation of the Lake Clay Horizon (LCH) of the Libkovice Member.

#### Lower vertebrate fauna

The lower vertebrate fauna (fishes, amphibians, reptiles) of the Most Basin is one of the most diverse regional assemblages of the Eurasian Lower Miocene. More than 50 species have been found – 11 fishes, 16 amphibians, >19 reptiles (see Table 1). This is because the Most Basin as a part of the Central European Rift System (Ziegler 1990) exhibits various types of peat and fluvio-lacustrine deposits belonging to different ecosystems such as swamps, deltas, shallow and deeper lakes.

Lower vertebrates from the swamp ecosystem are best documented at the famous site of Ahníkov, the Merkur-

North Mine. More than 30 species have been recorded to date, with the highest amphibian diversity ever found world-wide in Tertiary deposits. The current studies by J. Klembara, Bratislava, and M. Böhme, Munich, will surely increase the number of taxa. Taphonomical studies on the few fish remains reveal their allochthonous origin: they were buried as dead bodies either by predation or after flooding. This indicates a wetland ecosystem in very shallow ponds without a large permanent open water surface. The absence of salamanders with rheophilous larval stages (*Salamandra*, *Chioglossa*) suggests stagnant water conditions. The dominance of heliophobic species preferring shady and damp spawning and living habitats indicates low diurnal variability in air humidity, a dense vegetation cover, and a high and stable groundwater level.

Shallow lake ecosystems are characterized by non-laminated bituminous clays and marls rich in ostracodes and aquatic gastropods. Such sediments have been recorded, e.g., from the Duchcov Member near the base of the main seam (Skyřice, Hrabák Mine; Böhme 1996). Fishes and amphibians are abundant in this facies throughout the basin (Table 1) but are preserved in disarticulated state suggesting high wave energy, bioturbation and possible presence of scavengers. Characteristic fishes are minnows *Palaeoleuciscus chartaceus* and *Palaeotinca egeriana*, and the mudminnow *Umbra*. Amphibians are represented by two aquatic frog genera *Palaeobatrachus* and *Eopelobates*; the latter being mainly documented by tadpoles (Špinar 1972). Disarticulated fish remains are also common in the Libkovice Member where they were recovered mainly from cores (Obrhelová 1990).

Unlike sediments from shallow lakes, those from deeper lakes lack benthonic organisms and bioturbation, and often show a distinct, very fine lamination. Vertebrates are preserved as complete, articulated skeletons (e.g., Břešřany, Bilina Mine – Horizon 30). This indicates a deeper stratified lake with anoxic bottom waters. In some cases vertebrate skeletons are preserved in sideritic nodules, indicating rapid diagenesis under anoxic conditions (e.g., in the underground Paul Mine, underground Eugen Mine, in the Libkovice Member near Teplice, and in the Bilina and Československé armády mines). Deeper lake ecosystems are bound to the Holešice and Libkovice Members. Their vertebrate fauna is characterized by diverse fishes (minnows, mudminnow, pike) and aquatic turtles and the absence of terrestrial vertebrates (the only mammal found is a beaver from Břešřany – Liebus 1935). Some additional species from the Břešřany taphocoenosis may be parautochthonous, like birds (Laube 1901, 1909), rare loaches (*Cobitis*, *Nemachilus*) and the rare giant salamander *Andrias* (Liebus 1929a, b).

The first attempt at suggesting local biostratigraphy based on fishes was made by Obrhelová (in Obrhelová – Obrhel 1987). She pointed out that the minnow *Palaeotinca egeriana* and the mudminnow *Umbra* (including *Umbra longidorsalis* described herein) are re-

stricted to the Duchcov and Holešice Members, whereas *Palaeotincta obruncata*, "*Aspius*" *laubei*, "*Barbus*" *bohemicus*, "*Chalcalburnus*" *steindachneri*, the loaches *Cobitis ioannis*, and *Nemachilus tener*, and the pike *Esox* sp. characterize the Libkovic Member. Vertebrates are unknown from the uppermost Lom Member. These results are confirmed here by the study of new material from Horizon 30 of the Bílina Mine (Holešice Member), but it is stressed here that especially the species assigned to "*Aspius*", "*Barbus*" and "*Chalcalburnus*" need a re-vision.

### Fossil insects

The Early Miocene (Eggenburgian/Ottangian) insect fauna of the Most Basin, particularly the Bílina Mine, provides a sensitive view into insect diversity of Neogene freshwater ecosystems and their surroundings during the sedimentation of the Most Formation. A systematic composition of almost 300 specimens within 31 families of 11 insect orders (Prokop 2003a) enabled to study significant evolutionary trends in comparison with their modern relatives (see Table 2).

Table 1. Lower vertebrates (fishes, amphibians, reptiles) of the Most Formation (Lower Miocene, Burdigalian).

Member	Locality	Taxa	Reference
Duchcov	Skyfice, underground Prokopi Mine	Teleostei, Cyprinidae: <i>Palaeoleuciscus chartaceus</i> , <i>Palaeotincta egeriana</i> , Cyprinidae indet., Umbridae: <i>Umbra</i> sp.; Anura, Palaeobatrachidae: <i>Palaeobatrachus diluvianus</i> ; rich in epibenthos (ostracodes, gastropods)	Laube 1903, Obrhelová 1970, 1990, Špinar 1972, Böhme 1996
	Skyfice, opencast Marianna Mine, below the Main Seam	Teleostei, Cyprinidae: <i>Palaeoleuciscus chartaceus</i> , <i>Palaeotincta egeriana</i>	Obrhelová 1970, 1990
	opencast Hrabák Mine, below the Main Seam	Teleostei, Cyprinidae: <i>Palaeoleuciscus chartaceus</i> , <i>Palaeotincta egeriana</i> ; Anura, Pelobatidae: <i>Eopelobates bayeri</i> , <i>E. cf. anthracinus</i> ; rich in epibenthos (ostracodes, gastropods)	Obrhelová 1970, 1990, Špinar 1972
Holešice	Ahníkov, opencast Merkur-North Mine	Teleostei, Cyprinidae: <i>Palaeoleuciscus</i> sp., Umbridae: <i>Umbra</i> sp.; Allocaudata, Albanerpetontidae: <i>Albanerpeton</i> sp.; Urodela, Batrachosauroididae: Batrachosauroididae indet., Cryptobranchidae: <i>Andrias</i> sp.; Salamandridae: <i>Chelotriton</i> 3 sp., <i>Mertensiella</i> sp. nov., <i>Triturus</i> sp.; Anura, Palaeobatrachidae: <i>Palaeobatrachus</i> sp., cf. <i>Pliobatrachus</i> sp., Discoglossidae: <i>Latonia ragei</i> , Pelodytinae: <i>Pelodytes</i> sp., Pelobatinae: <i>Eopelobates</i> sp., Ranidae: <i>Rana (ridibunda)</i> sp.; Gekkota, Gekkonidae: Gekkonidae indet.; Iguania, Chameleoniae: <i>Chameleo caroliquarti</i> ; Scincomorpha, Lacertidae: <i>Lacerta</i> sp.; Anguimorpha, Anguinae: <i>Ophisaurus</i> sp.; Crocodylia, Alligatoridae: <i>Diplocynodon</i> sp.; Serpentes, Boidae: <i>Baveriboa</i> sp., Colubrinae: <i>Coluber caspioides</i> , <i>C. suevicus</i> , <i>C. dolmicensis</i> , cf. <i>Elaphe</i> sp., Colubrinae gen. indet., Natricinae: <i>Natrix merkurensis</i> , <i>N. sansaniensis</i> , Colubridae gen. indet., Elapidae: Elapidae gen. indet., Viperidae: <i>Vipera</i> sp.; Testudines: diverse (not studied)	Fejfar – Schleich 1994, Ivanov 2002, Böhme 2003
	opencast Bílina Mine, Horizon 30	Teleostei, Cyprinidae: <i>Palaeoleuciscus chartaceus</i> , <i>Palaeotincta obruncata</i> , Umbridae: <i>Umbra longidorsalis</i> Böhme, sp. nov., Anura, Ranidae: <i>Rana</i> sp.	this paper
	Želénky	Teleostei, Cyprinidae: <i>Palaeoleuciscus chartaceus</i> , <i>Palaeotincta egeriana</i>	Obrhelová 1990
	opencast Nástup Mine, 1 m below to 0.1 m above the top of the Main Seam	Teleostei, Cyprinidae: <i>Palaeoleuciscus chartaceus</i> , <i>Palaeotincta</i> sp., Umbridae: <i>Umbra</i> sp.	Obrhelová 1990
	opencast Merkur Mine, 1 m below the top of the Main Seam	Teleostei, Cyprinidae: <i>Palaeoleuciscus chartaceus</i> , <i>Palaeotincta</i> sp., Umbridae: <i>Umbra</i> sp.	Obrhelová 1990
	Pruněřov, core Pn-140, depth 46 m	Teleostei, Cyprinidae: <i>Palaeoleuciscus chartaceus</i> , <i>Palaeotincta</i> sp.	Obrhelová 1990
	Tušimice (Tuschnitz), underground Josef-Oswald Mine, 6 km ENE of Kadaň	Crocodylia, Alligatoridae: <i>Diplocynodon</i> sp.	Stur 1873, Laube 1901
	Želeč (Seltsch), 3 km S of Měcholupy (Michelob)	Testudines, Emydidae: <i>Ptychogaster</i> sp.; Crocodylia, Alligatoridae: <i>Diplocynodon</i> sp.	Laube 1901



Table 1. (continued)

	Blov (Flahä, Flahe), 6 km SSE of Kadaň	Crocodylia, Alligatoridae: <i>Diplocynodon</i> sp.	Stur 1873, Laube 1901
Libkovice	Břešťany (Preschen)	Teleostei, Cyprinidae: " <i>Aspius</i> " <i>laubei</i> , " <i>Barbus</i> " <i>bohemicus</i> , " <i>Chalcalburnus</i> " <i>steindachneri</i> , <i>Palaeoleuciscus chartaceus</i> , <i>Palaeotınca obtruncata</i> , Cobitidae: <i>Cobitis ioannis</i> , <i>Nemachilus tener</i> , Esocidae: <i>Esox</i> sp.; Urodela, Cryptobranchidae: <i>Andrias scheuchzeri</i> ; Testudines, Trionychidae: <i>Trionyx</i> sp., Chelydridae: <i>Chelydropsis</i> sp., Emydidae: <i>Ptychogaster laubei</i>	Laube 1897, 1900, 1901, Liebus 1929 a, b, 1930, 1936, Obrhelová 1967, 1970
	opencast Bílina Mine, uppermost parts	Testudines, Trionychidae: <i>Trionyx</i> sp.	this paper
	Černovice	Teleostei, Cyprinidae: <i>Palaeotınca obtruncata</i>	Obrhelová 1970
	opencast Československé Armády Mine near Ervěnice, 2 m above the Main Seam	Teleostei, Cyprinidae: <i>Palaeotınca obtruncata</i> , " <i>Barbus</i> " <i>bohemicus</i> , cf. " <i>Chalcalburnus</i> " sp.	Obrhelová 1990, this paper
	Teplíce, nodules of micritic siderite ironstone	Teleostei, Cyprinidae: <i>Palaeotınca obtruncata</i> , " <i>Aspius</i> " <i>laubei</i>	Obrhelová 1970, 1990
	underground Eugen Mine, depth 11 m; 450 m S of Lom (Bruch) near Osek	Testudines, Trionychidae: <i>Trionyx</i> sp.	Laube 1896
	underground Paul Mine, depth 26.5 m; 3.2 km NW of underground Eugen Mine	Teleostei, Cyprinidae: <i>Palaeoleuciscus chartaceus</i> , Testudines, Trio- nychidae: <i>Trionyx</i> sp.	Laube 1896, Böhme 1996
	Osek, core Os-9/39, depth 143.5 m	Teleostei, Cyprinidae: <i>Palaeoleuciscus chartaceus</i> , " <i>Aspius</i> " <i>laubei</i> , cf. " <i>Chalcalburnus</i> " sp., <i>Palaeotınca obtruncata</i>	Obrhelová 1990
	Mariánské Radčice, core MR-58, depth 134 m	Teleostei, Cyprinidae: <i>Palaeoleuciscus chartaceus</i>	Obrhelová 1990
	Mariánské Radčice, core MR-59, depth 59.8 m	Teleostei, Cyprinidae: <i>Palaeoleuciscus chartaceus</i> , Esocidae: <i>Esox</i> sp.	Obrhelová 1990
	Mariánské Radčice, core MR-59, depth 114 m	Teleostei, Cyprinidae: " <i>Chalcalburnus</i> " <i>steindachneri</i>	Obrhelová 1990
	Mariánské Radčice, core MR-59, depths 125.5 and 142.5 m	Teleostei, Cyprinidae: " <i>Aspius</i> " <i>laubei</i>	Obrhelová 1990
	Horní Litvínov, core LiH-13, depth 57–58 m	Teleostei, Cyprinidae: " <i>Aspius</i> " <i>laubei</i>	Obrhelová 1990
	Růžodol, core RL-3, depth 31–32 m	Teleostei, Cyprinidae: <i>Palaeotınca obtruncata</i> , cf. " <i>Chalcalburnus</i> " sp.	Obrhelová 1990
	Lom, core Lom-16, depth 61–62 m	Teleostei, Cyprinidae: <i>Palaeotınca obtruncata</i> , " <i>Aspius</i> " <i>laubei</i>	Obrhelová 1990
	opencast Nástup Mine near Pruněfov	Teleostei, Cyprinidae: <i>Palaeoleuciscus chartaceus</i> , <i>Palaeotınca</i> sp., " <i>Aspius</i> " <i>laubei</i> , " <i>Chalcalburnus</i> " <i>steindachneri</i> , " <i>Barbus</i> " sp.	Obrhelová 1990

The fossil specimens were kept in a dry state, not treated by any special conservation methods. Almost all fossils were compressed with the exception of some three-dimensionally preserved strongly sclerotized elytra (Coleoptera: Hydrophilidae). Insect specimens are classified mostly to the order or family levels, less often to genera and species, according to the state of preservation. The classification of insect families follows in general CSIRO (1991), and the fossil record was checked by the website updated by Carpenter (1992), Ross – Jarzembowski (1993), Labandeira (1994) and Jarzembowski (2000).

Besides the records from the Bílina Mine, fossil insects have been found at two other localities within the Most Basin. The sclerotized aquatic beetle elytra of Dytiscidae (Coleoptera) rarely occurs in the freshwater limestone of Tuchořice (see Fig. 7.8), and an isolated elytron of Hydrophilidae (Coleoptera) was found at the top of the Main Seam of the Merkur Mine.

The three examined insect taphocoenoses within the Bílina Mine reflect dynamic changes of depositional environment by variable relative abundances of aquatic and terrestrial insect members in successive upper coal seam

Table 2. A list of principal insect families occurring at the Bilina Mine.

(The list is arranged according to the natural system of main groups. Abbreviations for the fossiliferous horizons: CSH – Clay Superseam Horizon, DSH – Delta Sand Horizon, LCH – Lake Clay Horizon.)

Order	Family	Horizon	Reference
Odonata	Aeshnidae	CSH, DSH	Prokop – Nel 2000a
	Gomphaeschnidae	CSH	Prokop – Nel 2002
Plecoptera	Perlidae	CSH	Prokop – Nel 2002
Isoptera	Hodotermitidae	DSH, LCH	Prokop – Nel 1999
Ensifera	Tettigonidae	DSH	unpubl.
Auchenorrhyncha	Cicadidae	CSH	Prokop – Boulard 2000
Heteroptera	Belostomatidae	CSH, DSH	Prokop – Nel 2000b
	Alydidae	CSH	unpubl.
	Pentatomidae	CSH	unpubl.
	Coreidae	CSH, DSH	Prokop 1997
Coleoptera	Cupeidae	CSH	Prokop 1997
	Carabidae	CSH	unpubl.
	Dytiscidae	CSH, DSH	Prokop 1997
	Hydrophilidae	CSH, DSH	Prokop 1997
	Elateridae	CSH	unpubl.
	Buprestidae	CSH, DSH	Prokop – Bílý 1999
	Trogositidae	CSH	unpubl.
	Curculionidae	CSH	unpubl.
	Scarabaeidae	CSH	unpubl.
	Tenebrionidae	CSH	unpubl.
	Cerambycidae	CSH	unpubl.
Diptera	Chrysomelidae	CSH	unpubl.
	Tipulidae	CSH	unpubl.
	Bibionidae	CSH, LCH	Prokop 1997
	Syrphidae	CSH	Prokop 1997
Trichoptera	Phryganeidae	CSH, DSH	unpubl.
Lepidoptera	Notodontidae	CSH	unpubl.
Hymenoptera	Ichneumonidae	CSH	unpubl.
	Vespidae	CSH	Prokop – Nel 2003
	Formicidae	CSH, DSH, LCH	Prokop 1997
	Apidae	CSH, LCH	Prokop – Nel 2003

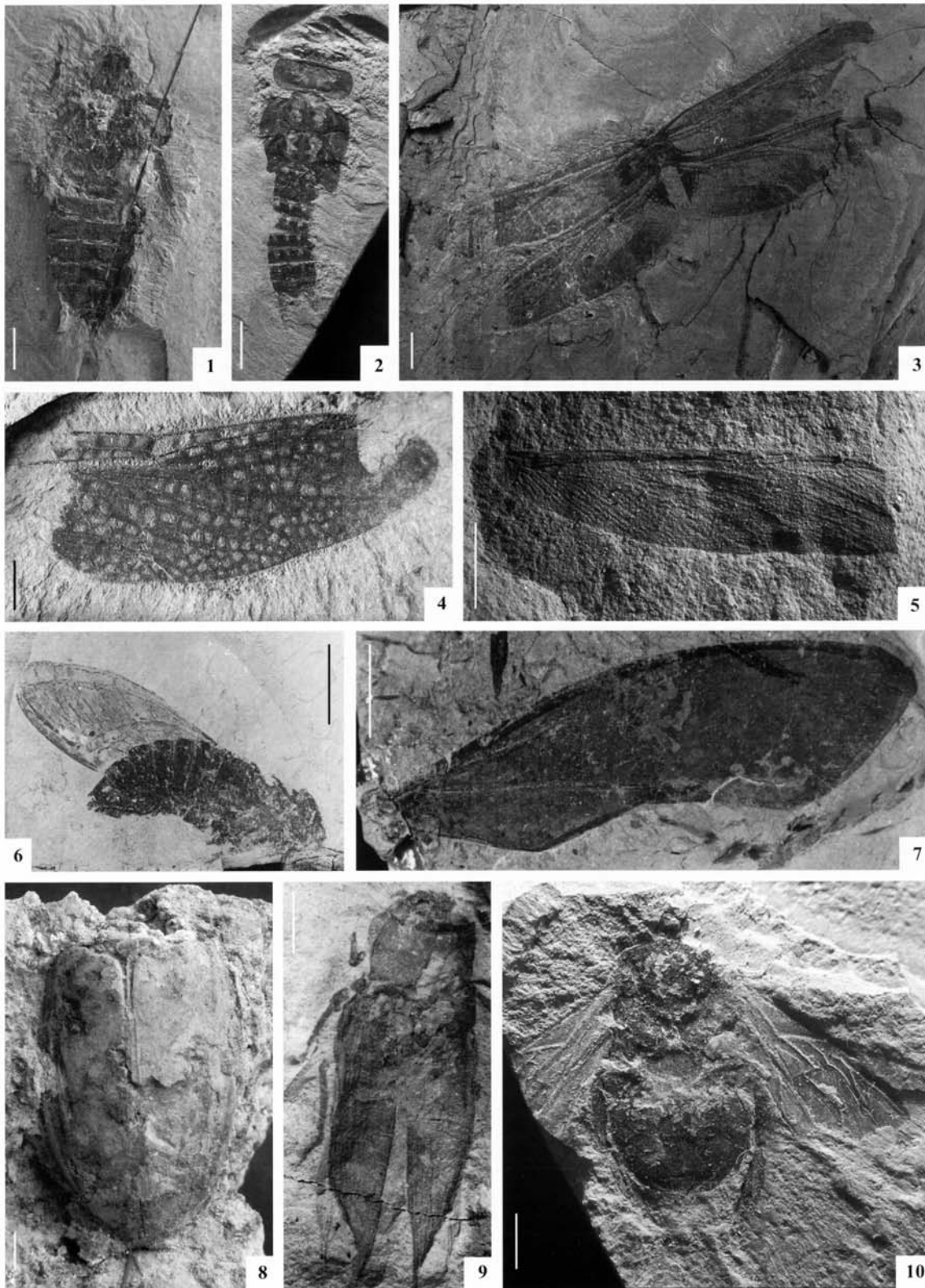
horizons (see Prokop 2003b). The local palaeoenvironmental conditions such as the distance from the shoreline or water depth after Wilson (1988) are interpreted on the basis of insects and accompanying fossil fish and plant assemblages. In spite of the fact that the relative abundances of fossil assemblages do not correspond well to the composition in living fauna, as was demonstrated on Willcox Playa by Smith (1999), some palaeoenvironmental or palaeoecological conclusions can be drawn based on significant insect species together with palaeo-

botanical reconstructions of vegetation. The comparison of relative abundances and insect diversity at palaeontological sites together with the actualistic approach may help to better understand insect preservation and environmental aspects. Moreover, these quantitative data bring additional information on the depositional environment such as the shoreline distance *sensu* Wilson (1982).

The richest lowermost Clay Superseam Horizon (CSH) is often represented by complete specimens or disarticulated fragments of insects such as wings, legs or other more

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Fig. 7. 1 – cf. Gomphidae (larvae), DB ZD0065, Bilina Mine, Horizon 30 (scale bar 3 mm). 2 – *Perla* cf. *burmeisteriana* Classen, DB ZD0185, Bilina Mine, Horizon 30 (scale bar 3 mm). 3 – *Merlax bohemicus* Prokop et Nel, 2000; NM P 419, Bilina Mine, Horizon 30 (scale bar 10 mm). 4 – *Gomphaeschna miocenica* Prokop et Nel, 2002, DB ZD0184, Bilina Mine, Horizon 30 (scale bar 3 mm). 5 – *Ulmeriella* sp., DB JP0259, Bilina Mine, Horizon 11 (scale bar 3 mm). 6 – *Tibicina sakalai* Prokop et Boulard, 2000, DB JP9711, Bilina Mine, Horizon 30 (scale bar 10 mm). 7 – *Lethocerus* sp., DB ZD9712, Bilina Mine, Horizon 30 (scale bar 10 mm). 8 – Dytiscidae gen. et sp. indet., s.n., Charles University coll., Tuchořice freshwater limestones. 9 – *Dicerca bilinica* Prokop et Bílý, 1999, DB ZD9704, Bilina Mine, Horizon 30 (scale bar 3 mm). 10 – *Apis* sp. indet., DB ZD001, Bilina Mine, Horizon 30 (scale bar 3 mm).



sclerotized parts. Generally, insects from this horizon are dominated by aquatic or terrestrial species on one side and facultative accumulations of disarticulated ant remains (Hymenoptera: Formicidae). With regard to the insect taphonomy of the Clay Superseam Horizon documented by the abundance of complete specimens, this may indicate subsequent *in situ* post-mortem decay with no water current. However, these conditions were sometimes changed as indicated by beds with abundant strongly disarticulated specimens (largely ants) representing sudden episodes with water movement. This dual character can be explained by occasional flooding of oligotrophic environment with developing connected mire, as supported by plant record from its periphery, e.g., carbonized fruits of *Engelhardia macroptera* (Sakala 2000). Less complete insect fossils of mainly aquatic specimens like water beetles (Coleoptera: Dytiscidae, Hydrophilidae) and caddisflies cases (Trichoptera: Phryganeidae) together with several terrestrial elements such as termites (Isoptera: Hodotermitidae – Fig. 7.5) and jewel beetles (Coleoptera: Buprestidae – Fig. 7.9) represent the middle Delta Sand Horizon (DSH). This palaeoenvironment is interpreted as a nearshore zone of a shallow pond or an oxbow lake. The uppermost Lake Clay Horizon (LCH) is typically an offshore zone of a deepening lake sedimentation represented strictly by disarticulated insect specimens dominated by terrestrial specimens like ants (Hymenoptera: Formicidae), flies (Diptera: Bibionidae) and others.

The present systematic study revealed new members attributed to seven insect orders. Particular attention was paid to dragonflies (Odonata) described mainly on the basis of wing venation, which is also commonly used in modern taxonomy. A new genus and two new species have recently been established from the Clay Superseam Horizon (*Merlax bohemicus* Prokop et Nel, 2000 – Fig. 7.3; *Gomphaeschna miocenica* Prokop et Nel, 2002 – Fig. 7.4). These discoveries have significantly extended the diversity of the European Tertiary dragonfly fauna and its palaeogeographic distribution (Prokop – Nel 2000a, 2002). Aquatic immature stages of dragonflies (Odonata: Anisoptera) from the Clay Superseam Horizon of the Bilina Mine are presented in the systematic part for the first time (Fig. 7.1). Several insect species from the Bilina Mine are linked to other Oligo-Miocene localities as demonstrated by the abundant fossil genus *Ulmeriella* sp. (Isoptera – Fig. 7.5) after Prokop – Nel (1999), which is known from the Late Oligocene to Late Pliocene deposits of Europe, North America and Japan. This fact assumed their existence before the Late Oligocene break-up of continents of the Bering Strait and a contemporaneous existence in a refuge of, e.g., Central America, Africa etc. However, no evidence exists in previous fossil record and even their biological strains were probably different from those of the modern family representatives (Nel – Paicheler 1993). Another specimen is significant from palaeoecological point of view: an immature stonefly (*Perla* cf. *burmeisteriana* Claassen, 1936

– Fig. 7.2) described from the Clay Superseam Horizon is probably an allochthonous element transported into the basin during occasional flooding (Prokop 2002). Other two species *Tibicina sakalai* Prokop et Boulard, 2000 (Auchenorrhyncha – Fig. 7.6) and *Dicerca bilinica* Prokop et Bily, 1999 (Coleoptera) with an unknown genus of moth (Lepidoptera: Notodontidae) document the extraordinary preservation of the Bilina Mine material that allowed to study fine body structures. The discovery of several hemelytra of *Lethocerus* sp. (Heteroptera: Belostomatidae – Fig. 7.7) enabled their study and comparison with modern relatives based on the structure of the forewing venation (Prokop – Nel 2000b). The presence of highly specialized insects such as anthophilous taxa, e.g., bees or vespids, has also been recorded from this locality. The comparative study of specimens of *Apis* sp. (Fig. 7.10) from the Bilina Mine based on wing biometrics together with other described

Table 3. Plant-insect interactions recorded at the Bilina Mine (from Prokop 2003a).

Plant taxon	Horizon	ZDI Nos. coll. Bilina Mine	Continuous marginal trace	Interrupted marginal trace	Non-marginal trace	Window or skeleton feeding	Gall	Leaf Mine
? <i>Alnus</i>	36	28	+					
<i>Alnus gaudinii</i>	36	6		+				+
<i>Alnus julianiformis</i>	1	7			+			
<i>Alnus julianiformis</i>	24	25		+	??			
<i>Alnus julianiformis</i>	30	19	+	+				
<i>Berchemia multinervis</i>	57	13	+	+				
<i>Berchemia multinervis</i>	57	31	+					
<i>Betula</i> sp.	1	15		+			??	
<i>Carya</i> cf. <i>costata</i>	57	11	+		+			
<i>Carya</i> sp.	36	28						+
<i>Carya</i> sp.	41	18						+
<i>Carya</i> sp.	41	21					+	+
<i>Carya</i> sp.	57	20						+
<i>Cercidiphyllum crenatum</i>	1	12	+					
<i>Ficus multinervis</i> = <i>Decodon gibbosus</i>	2	2			+			+
<i>Ficus multinervis</i> = <i>Decodon gibbosus</i>	48	34	+	+				
<i>Fraxinus bilinica</i>	1	9		+				
<i>Fraxinus bilinica</i>	3	4					+	+
<i>Fraxinus bilinica</i>	5	3			+			+
<i>Fraxinus bilinica</i>	24	14						+
<i>Fraxinus bilinica</i>	24	23						+
<i>Nyssa bilinica</i>	1	9		+				
<i>Nyssa bilinica</i>	17	10	+					
<i>Paliurus tiliaefolius</i>	36	35		+				
<i>Populus zaddachii</i>	48	1	+					+
<i>Populus zaddachii</i>	48	17						+
Sapindaceae	57	29						+
<i>Sapindus falctifolius</i>	57	20			+			

fossil species has proved their relationships with the species described from the Upper Miocene of Austria and France (Prokop – Nel 2003). All these fossils are similar in their wing venation and size range to the extant *Apis dorsata* Fabricius, 1798 now living in India and southeast Asia. This fact supports the hypothesis of Nel et al. (1999) concerning the existence of Western Palaeartic species related to *A. dorsata* during the Miocene.

The presence of trace fossils of insects and particularly the plant-insect interactions such as galls or mines or various traces on foliage have been recorded in several fossiliferous horizons at the Bílina Mine (see Table 3). Other ichnofossils like wood borings produced by the feeding activities of beetle larvae were described from the Bílina Mine by Mikuláš – Dvořák (1999).

Despite the overall low diversity and scarce quantitative data on insect taphocenoses, it is possible to explain especially local changes in depositional environment regarding taphonomy and actualistic strains of certain insect species present. In conclusion, several taxa can be considered of prime significance for taxonomy and phylogeny as well as for the extension of paleogeographic distribution and first appearance records.

#### Flora and vegetation as documented by macrofossils

The Early Miocene flora of the Most Basin belongs to the richest of this age in Europe. Its main part falls to the middle part of the Early Miocene (lower Burdigalian, Eggenburgian, lower Orleanian), as indicated by the mammal faunas of MN 3 zone from Ahníkov – Merkur-North Mine (MN 3a) and the limestone of Tuchořice (MN 3b) – see p. 6. The composition of plant assemblages is not uniform throughout the basin due to local environmental conditions and the evolution in time. Various palaeobotanical (leaf anatomical, palaeocarpological, palynological and palaeoxylotomical) and coal petrological methods were applied to resolve the changes in floral composition and vegetational development in the basin area and its periphery.

In the flora itself, almost 200 plant species based on mega- and mesofossils have been recognized and recorded to date (see Table 4). The broad-leaved woody flora is diversified much more than ferns, fern allies and conifers, the latter three groups being far less represented both in the number of species and in the abundance of individual elements. In the case of herbs, particularly of monocots, the resolution of megafossil leaf remains is low, and more detailed studies of mesofossils should be carried out, especially of carbonized fruits and seeds, to fill this gap in our knowledge. Besides, the whole area of the basin is not evenly explored, so the attached floral list cannot be considered to be definitive. Significant parts of sedimentary fill, especially of the Libkovice and Lom Members, are not exposed, and the existing data from cores promise that higher levels of the basin fill may yield many more additional palaeontological objects on condition that these strata are accessible.

In general, the flora of the Most Formation was dominated by deciduous broad-leaved elements (Betulaceae, Salicaceae, Hamamelidaceae, Aceraceae, Rhamnaceae etc.), including beech, at the beginning of deposition in the Žatec area (Teodoridis 2001, 2003b). Its composition (except for the lack of *Pseudolarix*) corresponds to the spectrum of the Hlavačov gravel and sand deposits of the inflowing stream, which was correlated with the Late Oligocene Thierbach flora in Saxony (Lotsch et al. 1994). The noteworthy elements include *Chaneya oehningensis*, *Koelreuteria reticulata*, *Populus zaddachii* var. *brabenecii*, *Fagus saxonica* and *Carya ventricosa*. On the southeastern flank of the basin at Tuchořice, the limestone of thermal spring origin yielded a unique flora with date palm and other thermophilous plants (*Toddalia* cf. *turovensis*, cf. *Tectocarya*) besides deciduous broad-leaved trees (*Acer tricuspdatum*, *Celtis lacunosa*, *Ulmus*, *Zelkova* etc.). A different thermophilic assemblage with *Platanus neptuni* and *Trigonobalanopsis rhamnoides* has been recovered from the claystone underlying the Main Seam in the Bílina area (Jeníkov, core Je 96). Bituminous shale in the Marianna Mine at Skyřice has yielded a facultative halophilic water plant assemblage with *Limnocarpus* associated with deciduous forest elements (Kvaček – Bůžek 1983, Bůžek 1989).

Two depositional centres, called the Žatec and Bílina deltas, were two major sources of plant fossils and represent lateral equivalents of lignite deposits of the Holešice Member, and partly of the Libkovice Member. The floras of both areas are very similar to each other, the former having more frequent ferns (*Woodwardia*, *Pro-nephrium* – Bůžek 1971, Teodoridis 2003a), the latter including more thermophilic elements, particularly sabaloid and calamoid palms (Bůžek et al. 1992). Both areas are unusually rich in aquatic plants (*Salvinia*, *Stratiotes* etc.). Many woody elements are common to both deltas. Noteworthy are “*Juglans*” *acuminata*, *Carya serrifolia*, *C. denticulata*, *Comptonia difformis*, *Parrotia pristina*, *Podocarpium podocarpum*, *Celtis japeti*, *Fraxinus bilinica*, *Koelreuteria reticulata*, *Acer angustilobum*, *Nyssa bilinica*, *Salix haidingeri*, *Craigia bronniei*, *Alnus gaudinii*, *Mahonia bilinica*, *Pungiphyllum cruciatum*, “*Ficus*” *truncata*, *Paliurus tiliifolius*, *Diversiphyllum aesculapi* and *Phyllites kvacekii* (the latter recorded also in the Miocene of Kazakhstan). *Phyllites nemejci* is endemic to the Žatec–Pětipsy area. *Ostrya* has also been documented only in this area, and macrofossils of *Pinus* are very scarce. One common form of alder foliage (*Alnus* sp. sensu Bůžek 1971) recalls that from the southern periphery of the basin, *Alnus* cf. *rostaniana* (Kvaček – Hurník 2000), which has not been reported from the Bílina Delta. The flora of the uppermost part of the Holešice Member and the lowermost part of the Libkovice Member is best known from the section of the Bílina Mine, described in detail below. The aquatic elements are much richer and in some cases endemic for northern Bohemia (*Elephantosotis dvorakii*, *Hydrochariphyllum buzekii*, *Lemna buzekii*). The index fossil *Schenkiella credneri*

(syn. "*Trapa*" *credneri*) occurs for the first time here, and suggests a direct correlation with the Brandis flora (3rd Lusatian Coal Seam) in Saxony. Other differences from the Žatec area are expressed by rich occurrences of *Alnus julianiformis*, *Alnus menzelii* and palms of the *Sabal* and *Calamus* type. The flora of the lacustrine clay of the Libkovice Member is different, probably due to environmental setting. A mixture of deciduous (Ulmaceae, Betulaceae, *Comptonia*, *Parrotia*, *Podocarpium*) and evergreen elements (*Myrica lignitum*, Lauraceae, *Trigonobalanopsis*) together with frequent pine fossils is typical of the Břešťany Clay correlated with the Libkovice Member. Higher levels of the Libkovice Member, mostly accessible in boreholes, have yielded very thermophilic assemblages characterized by Lauraceae (including *Laurus abchasica*), Theaceae (*Gordonia*), *Cedrelospermum*, *Platanus neptuni*, and *Quercus kubinyii*. Although the carpological record is not available from these levels, the leaf flora corresponds to a mastixoid assemblage (e.g., similar to that from the Cypris Shale in western Bohemia). Additional young elements, such as *Myrica undulatissima* and *Hemitrapa heissigii*, have been recovered from the highest member including the Lom Seam, i.e., the Lom Member, suggesting a correlation with the oldest levels of the Middle Miocene (e.g., in the Bavarian Molasse).

Study of depositional settings and statistical evaluation of plant assemblages over several tens of localities (Boulter et al. 1993) allowed to distinguish five main environments characterized by different vegetation types: mires with peat-forming swamp forests, mineral back-swamp forests, aquatic vegetation, riparian forests of inundated habitats and riparian and slope forests of drier habitats.

For the basin area, the most important unit is the peat-forming mire covered by a swamp forest. Compared with other brown coal basins in Europe, the mire was of a typical low-moor type, rarely reaching the raised bog stage because of the constantly deepening floor and sufficient supply of plant cover by groundwater (Schneider 1992). Two types of vegetation alternated within the mire. The swamp forest of the main coal seam was dominated by giant, widely spaced taxodioid – sequoiod trees (*Glyptostrobus*, *Quasisequoia*) with an admixture of broad-leaved arboreal swamp elements (e.g., *Quercus rhenana*, *Nyssa*, *Laurophyllum saxonicum*) and undergrowth of shrubs and lianas (*Myrica integerrima*, *Salix varians*, *Calamus*, *Sabal*, *Lygodium*). In open marshes, herbaceous wetland vegetation prevailed with many aquatics (*Salvinia*, *Azolla*, *Stratiotes*) and helophytes (*Pronephrium*, *Blechnum*, *Spirematospermum*, *Typha*, *Sparganium*, Cyperaceae). The swamp was well inundated, exceptionally reaching sub-climax stages with *Sciadopitys* (only a single pollen record). This is contrary to the Neogene mires of west Europe (e.g., Rhineland), where this conifer, endemic to Japan today, formed thick layers in coal seams (*Marco-duria*-type of roots) in association with true *Sequoia*.

The lignite of the main seam corresponds to the ortho-phase in quality and is characterized by alternation of xylitic and detritic coal beds. The seam occasionally

reaches the thickness of about 50 m. A slightly different peat-forming plant community developed in the Lom Seam in the uppermost part of the basin fill. A large part of the documented macrofossils belong to herbaceous aquatics – *Decodon*, *Hemitrapa*, and grass-like foliage. Less common are remnants of woody plants – Betulaceae, *Salix*, *Myrica* and *Glyptostrobus*. Lignite of the Lom Seam is of much lower quality due to the high content of mineral substance.

Mires of much smaller extent and duration were formed at the very beginning of the basin fill (basal and lower seamlets) and also within the delta plains and back swamps. The deltaic back-swamp forests produced much thinner seamlets within sandy clay deposits. The dominant trees were *Taxodium* and *Nyssa* with many broad-leaved deciduous arboreal elements – *Alnus*, *Cercidiphyllum*, *Acer tricuspidatum*, *Craigia bronni* and the undergrowth of *Rubus* and *Spirematospermum*. Within wetland flats, some raised positions (like "hammocks" in Florida) were inhabited by other hardwoods – *Fraxinus*, *Ulmus* and *Paliurus*. Uniform stands of swamp oak *Quercus rhenana* were traced by accumulations of its foliage and fruits starting with the clay facies deep under the Main Seam base in the central part of the basin and continuing to sediments overlying the Main Seam. Similar stands of live oak (*Quercus virginiana*) close to swamps pose a present-day parallel in Florida, although this oak is phylogenetically not closely related.

A detailed palaeofloristic analysis of the Bílina Delta and adjacent sites of porcellanite at Bílina and Zabušany was provided by Bůžek et al. (1992), Sakala (2000) and Kvaček – Hurník (2000). During the last 20 years, most of the fossiliferous horizons in this area disappeared due to mining. The section of the Bílina Mine allowed to study a succession from the mire vegetation to the back-swamp forest and various types of riparian forests on fertile soils.

The peat mire vegetation can be documented by macrofossils occurring in the uppermost part of the seam (Horizon 31 and equivalents) in leafy coal beds ("Blätterkohle"). Besides the predominating taxodioid conifers (*Glyptostrobus*, *Quasisequoia*, *Taxodium*), woody components of coal-forming vegetation were also represented by broad-leaved elements, such as *Laurophyllum saxonicum*, *Quercus rhenana*, *Nyssa bilinica*, *Alnus menzelii*, *A. julianiformis*, *Ulmus pyramidalis*, *Salix varians*, and *Sabal*. Herbaceous vegetation similar to the "Everglades" type included *Salvinia*, *Blechnum*, *Stratiotes*, Cyperaceae, Zingiberaceae (*Spirematospermum*) and calamoid palms.

The mineral swamp vegetation from the periphery of peat mire (Clay Superseam Horizon – Horizon 30) has recently been re-evaluated (Sakala 2000). The swamp was covered by similar woody plants as listed above, with several additional trees: *Craigia* (also documented by pollen and flower buds in the coal facies elsewhere in the basin), *Cercidiphyllum* (also with male flowers), *Diospyros*, cf. *Rhus*, and *Fraxinus*. The undergrowth was also richer, and included *Osmunda*, *Woodwardia*, *Berchemia*,

*Decodon*, *Paliurus*, *Rosa* and *Rubus*. Aquatic vegetation was dominated by *Salvinia*. An aquatic aroid *Pistia*, today confined to pantropical-subtropical areas, has been documented among mesofossils in Horizon 30. This parautochthonous assemblage matches in many respects those of the pelitic porcellanite of Želénky (Kvaček – Hurník 2000). Very rare remains of *Betula*, *Engelhardia*, *Zelkova*, *Apocynospermum*, cf. *Crataegus*, and *Leguminosites* are allochthonous traces of vegetation thriving on drier habitats outside the swamp.

The Delta Sand Horizon brought a wealth of plant macrofossils concentrated in many fossiliferous horizons (Bůžek et al. 1992), which document different kinds of riparian forests on fertile soils as characterized above and intermittent noteworthy assemblages of aquatic vegetation (Bůžek 1989, Kvaček 1998, 2003, this paper). The delta regime marked a major turnover in ecosystem development of the Bílina area. New kinds of habitats and substrate allowed the expansion of different, mostly broad-leaved deciduous forests over the delta plains. The upper horizons include elements of drier slope vegetation, like *Pinus*, *Tilia*, *Comptonia*, which are shared with the mixed plant assemblage of the famous Břešťany Clay.

Within delta plains, extensive and diversified aquatic vegetation developed. It was dominated by *Salvinia*, which formed free-floating carpet-like covers on free water level. Many unusual herbs have been preserved in this environment – *Limnobiophyllum*, *Hydrochariphyllum*, *Elephantosotis*, Nymphaeaceae, besides the common aquatics, such as *Decodon*, *Stratiotes*, *Potamogeton* and monocotyledons of the growth form of sedges and grasses (*Typha*, Cyperaceae etc.). The communities connected with peat layers thrived in more acid environment than those in pools and ox-bow lakes within the delta plains and were less diversified, with typical *Stratiotes*, *Limnobiophyllum* and *Spirematospermum* (Kvaček 2003). An extraordinary mixture of aquatic plants was found in the deltaic deposits of Horizon 47 at the Bílina Mine. Accumulations of carpet-like *Salvinia* fossils alternated with impressions of *Azolla*, *Lemna* and *Elephantosotis*, a novelty among dicot aquatics, and a large monocot *Smilacinites* described in this paper. Elsewhere in the Bílina section, clay lenses contained fossil Nymphaeaceae.

The riparian forests were very dense and variously differentiated depending on the water supply and habitat. Riparian forests of flooded parts of the fluvial flats were more monotonous than those of drier habitats. *Alnus*, *Salix*, *Populus*, *Ulmus*, *Liquidambar*, *Paliurus* and *Fraxinus* dominated the riparian forests of flooded habitats, also vegetated by solitary palms of the *Sabal* type. The forest borders were overgrown by dense curtains of Vitaceae (*Vitis*, *Ampelopsis*) and other lianas (*Berchemia*, *Smilax*). The riparian forest on levees and drier sites on fertile soils along the southern stream was probably three-storied and more diversified. The highest tree storey included Juglandaceae, mainly *Carya*, *Fraxinus* and *Platanus neptuni* and interspersed *Taxodium*. The lower tree storey consisted of *Zelkova*, *Parrotia*, *Liquidambar*,

*Koelreuteria*, various maples, such as *Acer integerrimum* and *A. angustilobum*, *Tilia*, Leguminosae (including *Podocarpium*), “*Ficus*” *truncata* (probably *Reveesia*) and some others from the flooded areas. The diversified shrub undergrowth was composed of *Berberis*, *Mahonia*, *Rosa*, *Pyracantha* and perhaps also enigmatic *Pungiphyllum* and *Phyllites kvacekii*. Evergreen Theaceae (*Ternstroemites* – *Eurya*) and Lauraceae (*Daphnogene*) might have entered the lower woody storeys as well. The composition of riparian forests on fertile soils slightly varied depending on the stratigraphical levels, as mentioned in the characteristics of the flora and palaeoclimate development. They retained prevalently deciduous character.

The expansion of the lake over the mire of the Main Seam and withdrawal of the Bílina Delta caused an episodic return of swamp conditions in the Břešťany Clay. Besides *Taxodium* – *Nyssa* forest elements with *Glyptostrobus*, *Quasisequoia*, *Acer*, *Alnus*, *Paliurus*, also rare extinct plants (e.g., *Chaneya*, *Buzekia*) were intermixed with newly immigrated mostly thermophilic forest elements of oligotrophic acid soils (e.g., *Pinus*, *Comptonia*, *Myrica lignitum*, *Trigonobalanopsis*, *Laurophyllum pseudoprinceps*). Sites of this not yet fully understood assemblage are no more available because they were completely removed several years ago by mining activities (Kvaček et al. 2004).

Along the periphery of the Krušné hory Mountains, the fluvial mica facies was connected with evergreen riparian forests composed mainly of pines, *Alnus*, Myricaceae, Lauraceae, *Engelhardia*, *Symplocos*, Ericaceae (*Vaccinioides*) and Theaceae (*Gordonia*, *Eurya*). Thanks to the sieved mesofossils, seeds and fruits, also rare plants such as *Meliosma*, *Magnolia* and *Staphylea*, were recognized to thrive along short streams entering the basin from its northwestern periphery. Lianas were also present, represented by, e.g., *Schisandra*, *Actinidia* and *Toddalia*. The flora of the quartzose sandstone at Hradiště (Purberg) at Černovice (Engelhardt 1877) most probably belongs to the same level, although the locality is beyond the area of the lignite seam on the slope of the Krušné hory Mountains (see p. 5). It may also belong to stratigraphic levels underlying the seam (Bůžek 1963, 1986, Váně 1987).

Higher in the section within the Libkvice Member, the composition of the forests is only fragmentarily known. A deciduous oak *Quercus kubinyii* appeared later in this type of subtropical, mostly broad-leaved evergreen forest vegetation with additional *Trigonobalanopsis*, *Platanus neptuni* dominating the highest tree storey, and various Lauraceae, Theaceae, *Engelhardia* and *Cedrelospermum* in the lower tree and shrub storeys. Another thermophilic element is the winding fern of *Lygodium*. Although the fruit and seed assemblages are not available from these levels, the leaf assemblage corresponds to the “Late Mastixioid” assemblages (*sensu* Mai 1995) known, e.g., from the Cypris Shale in western Bohemia, Wackersdorf and Wiesa in Germany, Oberdorf in Styria and elsewhere in Europe (Mai 1995, Kovar-Eder et al. 2001).

The overall physiognomy of different vegetation units did not change much during the deposition of the Most

Formation. Only weak warming trends can be noticed throughout the section of the basin fill. One site close to the base of the Holešice Member – the limestone at Tuchořice – includes typical tropical–subtropical thermophilic elements (Mastixiaceae, palms including *Phoenix*) besides deciduous trees (*Acer*, *Celtis*, Ulmaceae). Microclimatic conditions of thermal springs might have caused this “palm oasis”, which developed before the deposition of the Main Seam. The CLAMP analysis of the purely deciduous riparian forests of the Hlavačov Gravel and Sand suggested only 8 °C and of those of the Holešice Member in the Žatec Delta only 10 °C mean annual temperature (Teodoridis 2003b). However, the co-existence approach gives higher temperature of 15.7–16.6 °C (A. Bruch, personal communication). In the upper part of the Holešice Member in the Bilina Delta, tropical–subtropical elements reappeared in larger quantity (palms, *Pistia*, *Toddalia*). Climatic conditions

of that period were surely more equable and frostless, with the coldest months mean above zero. Today, similar environmental conditions exist in lowlands of central and northern Florida. The mesophytic forests of the Libkovice Member undoubtedly reflect warming trends and indicate that the climatic conditions were humid to per-humid even outside inundated areas, with high amount of precipitation. Sub-humid sclerophyllous elements like sclerophyllous oaks of the *Quercus mediterranea*-type have never been documented in the Most Basin. Slight signs of these elements can be seen in the Cypris Shale flora, while they were much more pronounced in southern Europe (e.g., Island of Evia, Greece – Kvaček 2002). This humidity gradient along the north–south transect across Europe in the Early Miocene was probably due to the seasonality rather than due to the total amount of annual precipitation in southern Europe.

Table 4. A list of plant species based on macrofossils and mesofossils occurring in the Most Formation.

(The list is arranged according to the natural system of main groups and in the alphabetical order of the families/genera/species. Abbreviations for occurrences: DM – Duchcov Member, HM – Holešice Member in coal-clay/porcellanite facies, LB – Libkovice Member in clay facies excl. Břešťany, LoM – Lom Member in coal facies, žd – Žatec Delta, bd – Bilina Delta, bc – Břešťany Clay, tl – Tuchořice limestone, hq – Hradiště quartzite, mf – mica sand facies in the Krušné hory Mts.)

Taxon	Occurrence	Organ	Common synonyms
<b>PTERIDOPHYTES</b>			
<b>Lycopodiopsida</b>			
Selaginellaceae			
<i>Selaginella saxonica</i>	HM, bd, mf	macrospores	
<b>Equisetopsida</b>			
Equisetaceae			
<i>Equisetum braunii</i>	bd	stems	
<i>Equisetum parlatorii</i>	bd	rhizomes	
<b>Filicopsida</b>			
Aspleniaceae			
<i>Asplenium</i> sp.	bd	foliage	
Blechnaceae			
<i>Blechnum dentatum</i>	HM, žd, bd, bc	foliage	
<i>Woodwardia muensteriana</i>	HM, žd, bd	foliage	<i>Woodwardia roessneriana</i>
Dennstaedtiaceae			
<i>Pteridium oehningense</i>	bd	foliage	
Osmundaceae			
<i>Osmunda parschlugiana</i>	HM, žd, bd, bc	foliage	
Azollaceae			
<i>Azolla nana</i>	HM, LM	macrospores	
<i>Azolla rossica</i>	HM, LM	macrospores	
<i>Azolla ventricosa</i>	HM, bd, LM	plants, macrospores	
Salviniaceae			
<i>Salvinia cerebrata</i>	HM, bd, mf	macrospores	
<i>Salvinia reussii</i>	HM, žd, bd, bc, LM in žd	plants, foliage	
Schizaeaceae			
<i>Lygodium kaulfusii</i>	HM, LM	foliage	<i>L. gaudinii</i>
Thelypteridaceae			
<i>Pronephrium stiriicum</i>	HM, žd, bd, bc	foliage	<i>Lastraea stiriaca</i>
<b>GYMNOSPERMS</b>			
<b>Pinopsida</b>			
Taxodiaceae			
<i>Glyptostrobus europaeus</i>	tl, HM, žd, bd, bc, mf, LM, LoM	foliage shoots, seed cones, seeds	
<i>Quasisequoia couttsiae</i>	HM, bc, LM	foliage shoots, seed cones, seeds	<i>Sequoia couttsiae</i> , <i>Athrotaxis c.</i> , <i>Sequoiadendron c.</i>
<i>Taxodium dubium</i>	HM, žd, bd, bc, LM	foliage shoots, seed cones, pollen cones, seeds	
Taxodiaceae gen.	HM, bd	wood	<i>Taxodioxyton</i>



Table 4. (continued)

Cupressaceae			
<i>Tetraclinis salicornioides</i>	bd, LM	foliage	<i>Libocedrus salicornioides</i>
Pinaceae			
<i>Pinus engelhardtii</i>	bd, bc, hq, LM	seed cones, pollen cones, seeds	<i>P. oviformis</i>
<i>Pinus ornata</i>	bc, hq	seed cones	
<i>Pinus rigios</i>	bd, bc, hq, mf, LM	foliage	
<i>Pinus urani</i>	hq, mf	seed cones	<i>P. laricio</i>
<i>Pinus</i> sp.	žd, bd, bc, hq, LM	foliage, pollen cones, seeds	
ANGIOSPERMS			
Dicotyledonae			
Aceraceae			
<i>Acer angustilobum</i>	HM, žd, bd, bc, LM in žd	foliage, fruits	<i>A. dasycarpoides</i>
<i>Acer intergerrimum</i>	? DM, HM, žd, bd, bc	foliage	<i>A. nervatum</i>
<i>Acer integrilobum</i>	bd	foliage	
<i>Acer pseudomonspessulanum</i>	žd	foliage	<i>A. decipiens</i>
<i>Acer tricuspidatum</i>	HM, žd, bd, bc, LM	foliage, fruits, flowers	<i>A. trilobatum</i>
Actinidiaceae			
<i>Actinidia faveolata</i>	HM, žd	seeds	
Anacardiaceae			
<i>Rhus noeggerathii</i>	bd	foliage	
Apocynaceae			
<i>Apocynospermum striatum</i>	HM	seeds	
Aquifoliaceae			
<i>Ilex</i> sp.	bd	fruits	
Aristolochiaceae			
<i>Aristolochia</i> sp.	bd	foliage	
Berberidaceae			
<i>Berberis berberidifolia</i>	bd, bc	foliage	<i>Ilex berberidifolia</i>
<i>Mahonia bilinica</i>	žd, bd, bc	foliage	<i>Quercus bilinica</i>
<i>Mahonia</i> sp.	bd	foliage	
Betulaceae			
<i>Alnus gaudinii</i>	HM, žd, bd, bc, LM	foliage	<i>Rhamnus gaudinii</i> , <i>Fagus ettingshausenii</i>
<i>Alnus gracilis</i>	bd, bc	infructescences of <i>A. julianiformis</i>	
<i>Alnus julianiformis</i>	? tl, HM, žd, bd, bc, hq, LM	foliage	<i>A. feroniae</i>
<i>Alnus kefersteinii</i>	HM, bd, bc	infructescences of <i>A. gaudinii</i>	
<i>Alnus menzelii</i>	HM, bd, bc	foliage, infructescences	<i>Betula</i> cf. <i>macrophylla</i>
<i>Alnus</i> cf. <i>rostaniana</i>	HM, žd	foliage, infructescences	
cf. <i>Alnus</i> sp.	LM	foliage	NFu 29 sensu Litke 1966
<i>Betula</i> sp.	HM, žd, bd, bc	foliage, fruits, bracts	
<i>Carpinus grandis</i>	HM, žd, bd, bc, LM in žd	foliage, fruits, involucre	
<i>Ostrya atlantidis</i>	žd	foliage, involucre	
Celtidaceae			
<i>Celtis japeti</i>	žd, bd	foliage	
<i>Celtis lacunosa</i>	tl, HM	endocarps	
Cercidiphyllaceae			
<i>Cercidiphyllum crenatum</i>	HM, žd, bd, bc, LM in žd	foliage, fruits, seeds, male inflorescences	<i>Grewia crenata</i> , <i>C. helveticum</i> (fruits)
Cornaceae			
cf. <i>Tectocarya</i> sp.	tl	endocarp	
Ebenaceae			
<i>Diospyros brachysepala</i>	žd, bd	foliage, fruit calices	
Ericaceae			
cf. <i>Kalmia saxonica</i>	LM	foliage	cf. Rosaceae gen.
<i>Vaccinioides lusatica</i>	mf	foliage	cf. Vacciniaceae gen.
Fabaceae (Leguminosae)			
<i>Buzekia tertiaria</i>	bd	fruits	<i>Pterocarpus tertiarius</i>
<i>Leguminosites tobischii</i>	HM, žd, bd, bc	fruits	"Acacia" <i>beneschii</i>
<i>Leguminosites</i> sp. div.	? DM, žd, bd, bc	foliage	cf. <i>Colutea</i>
<i>Podocarpium podocarpum</i>	žd, bd, bc, LM in žd	foliage, fruits, seeds	<i>Podogonium</i> , <i>Gleditsia knorrii</i> , <i>G. lyelliana</i>
<i>Wisteria</i> aff. <i>falax</i>	žd, bd	foliage	
Fagaceae			
<i>Fagus deucalionis</i>	HM in žd	fruits of <i>Fagus saxonica</i>	
<i>Fagus saxonica</i>	HM, LM in žd	foliage	
<i>Quercus kubinyii</i>	LM	foliage	<i>Castanea kubinyii</i>
<i>Quercus rhenana</i>	DM, HM, bd, bc, LM	foliage	<i>Ficus lanceolata</i> , <i>Q. lusatica</i>
<i>Trigonobalanopsis rhamnoides</i>	DM, bc, LM	foliage	<i>Castanopsis toscana</i>

Table 4. (continued)

Haloragidaceae			
<i>Proserpinaca reticulata</i>	HM, ?mf	fruits	
Hamamelidaceae			
<i>Liquidambar europaea</i>	HM, žd, bd, bc, LM in žd	foliage	
<i>Liquidambar magniloculata</i>	HM, žd, bd, bc	infructescences	
<i>Parrotia pristina</i>	HM, žd, bd, bc, LM in žd	foliage, infructescences	<i>P. fagifolia</i>
Juglandaceae			
<i>Carya costata</i>	tl, bd, bc	fruits (molds) of <i>Carya denticulata</i>	" <i>Juglans</i> " <i>dilatata</i>
<i>Carya denticulata</i>	HM, žd, bd, bc	foliage	<i>Carya</i> cf. <i>serrifolia</i> ,
<i>Carya serrifolia</i>	žd, bd, bc	foliage	<i>Quercus serrifolia</i>
<i>Carya ventricosa</i>	HM in žd	fruits of <i>Carya denticulata</i>	<i>Carya bohemica</i>
<i>Engelhardia macroptera</i>	HM, bd, bc	fruits of <i>Engelhardia orsbergensis</i>	
<i>Engelhardia orsbergensis</i>	? DM, HM, bd, bc	foliage	
Juglandaceae gen.	žd, bd, LM in žd	foliage	<i>Cyclocarya</i> sp.
Lauraceae			
<i>Daphnogene polymorpha</i>	DM, žd, bd, bc, hq, LM	foliage	<i>Cinnamomum polymorphum</i> , <i>D. bilinica</i>
<i>Laurocarpum</i> sp.	HM, bd	fruits, cupules	
<i>Laurophyllum markvarticense</i>	LM	foliage	
<i>Laurophyllum nechranicense</i>	žd, LM	foliage	
<i>Laurophyllum pseudoprinceps</i>	žd, bd, bc, LM	foliage	<i>Laurophyllum princeps</i>
<i>Laurophyllum pseudovillense</i>	LM	foliage	
<i>Laurophyllum saxonicum</i>	HM, bc	foliage	<i>L. nemejcii</i>
<i>Laurophyllum</i> sp.	žd, bd	foliage	
<i>Laurus abchasica</i>	LM	foliage	<i>Laurophyllum abchasicum</i>
Lythraceae			
<i>Decodon gibbosus</i>	HM, žd, bd, bc, LoM	twig with fruits, seeds and foliage	" <i>Ficus</i> " <i>multinervis</i> , <i>Apocynophyllum helveticum</i> (detached foliage)
Magnoliaceae			
<i>Magnolia burseraceae</i>	HM, mf	seeds	
<i>Magnolia kristinae</i>	bd	foliage	
Myricaceae			
<i>Comptonia difformis</i>	HM, žd, bd, bc, mf, hq, LM	foliage	<i>C. acutiloba</i> , <i>Myrica acutiloba</i>
<i>Comptonia srodniowae</i>	mf, LM	fruits and endocarps of <i>C. difformis</i>	
<i>Myrica ceriferiformis</i>	HM, mf	fruits of <i>M. lignitum</i>	<i>M. suppanii</i> (endocarps)
<i>Myrica ceriferiformoides</i>	HM, mf	fruits of <i>M. integerrima</i>	<i>M. suppanii</i> (endocarps)
<i>Myrica integerrima</i>	HM, LM	foliage	<i>Dryandroides lounensis</i>
<i>Myrica lignitum</i>	bc, hq, LM	foliage	<i>Dryandroides lignitum</i>
<i>Myrica undulatissima</i>	LoM	dispersed cuticles	
? Nelumbonaceae – Nymphaeaceae			
" <i>Nelumbium</i> " cf. <i>buchii</i>	bd, ?LoM	foliage, rhizomes	
Nyssaceae			
<i>Nyssa gmelinii</i>	?LoM	dispersed cuticles	" <i>Quercus</i> " <i>gmelinii</i> , <i>Nyssa</i> cf. <i>haidingeri</i>
<i>Nyssa haidingeri</i>	HM, žd, bd, bc, ?hq	foliage, male inflorescences	<i>Persea speciosa</i> , <i>Laurus haidingeri</i> , cf. " <i>Cephalanthus</i> sp." (inflorescence)
<i>Nyssa ornithobroma</i>	HM, žd, bd, bc, hq, ?mf	fruits, endocarps	<i>N. disseminata</i>
Oleaceae			
<i>Fraxinus bilinica</i>	HM, žd, bd, bc	foliage	<i>F. ungeri</i> , <i>Juglans bilinica</i> , <i>J. juglandiformis</i>
<i>Fraxinus macroptera</i>	?žd, bd, bc	fruits of <i>F. bilinica</i>	
Platanaceae			
<i>Platanus neptuni</i>	DM, bd, LM	foliage	
Rhamnaceae			
<i>Berchemia multinervis</i>	HM, žd, bd, bc	foliage	
<i>Paliurus tiliaefolius</i>	HM, žd, bd, bc, LM in žd	foliage	<i>Ziziphus tiliaefolius</i>
<i>Paliurus favonii</i>	HM, žd, bd, bc	fruits of <i>P. tiliaefolius</i>	
Rosaceae			
<i>Crataegus</i> sp.	žd, bd	foliage	
<i>Pyracantha acuticarpa</i>	bd, mc	endocarps	<i>Pyracantha</i> sp.
<i>Rosa europaea</i>	HM, žd, bd, bc, LM in žd	foliage, fruits	<i>R. lignitum</i>
<i>Rubus merianii</i>	HM, žd, bd, bc	foliage, fruits, fruitlets, thorns	<i>Rhus merianii</i>
<i>Rubus vrsovicensis</i>	HM, žd	foliage	<i>Rhus elegans</i> , cf. <i>Corylus insignis</i>
<i>Sorbus</i> sp.	bd	foliage	

Table 4. (continued)

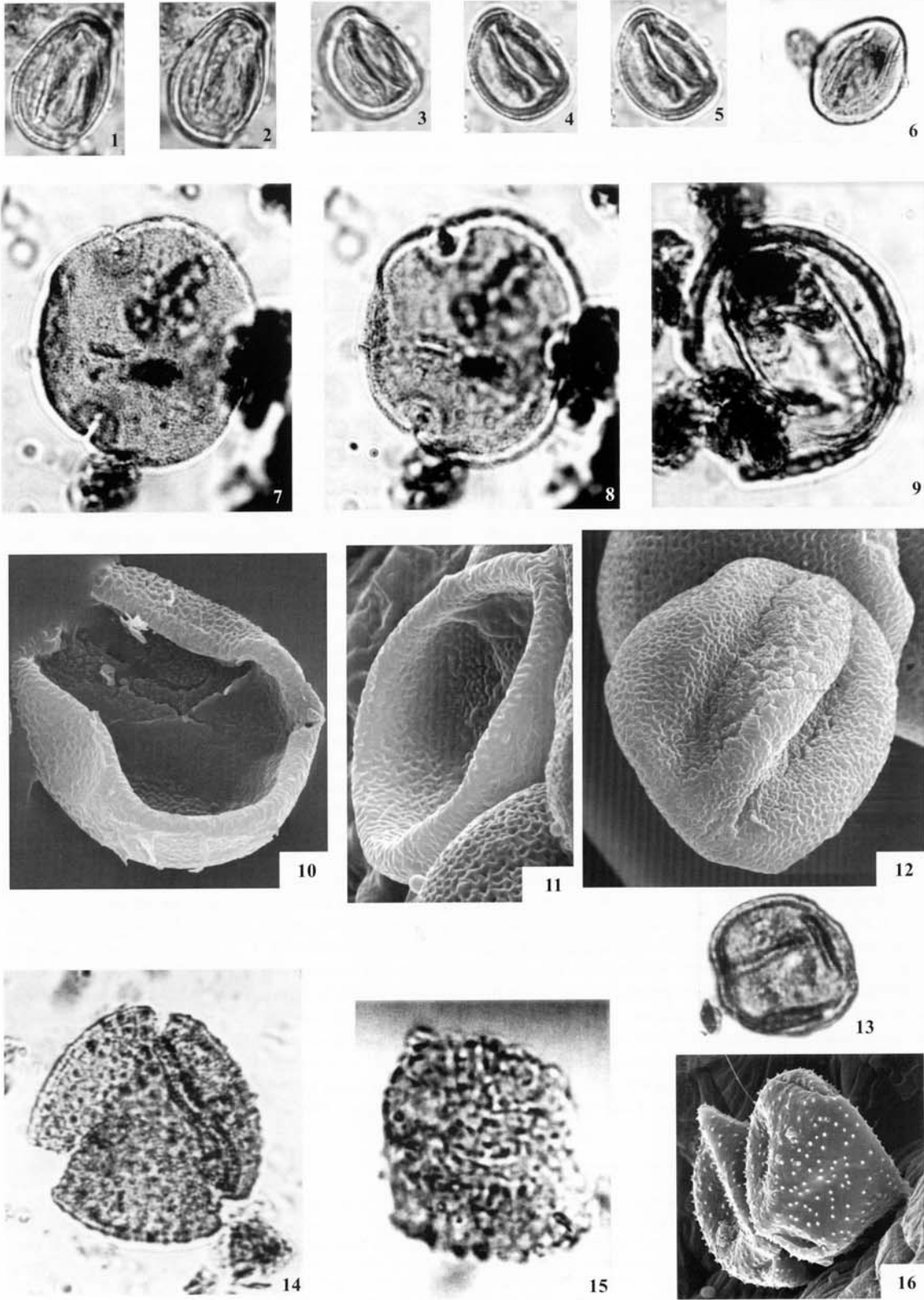
Rutaceae			
<i>Toddalia maii</i> <i>Toddalia</i> cf. <i>turovensis</i> <i>Zanthoxylum</i> sp.	HM, mf tl mf, tl	seeds seeds seeds	
Sabiaceae			
<i>Meliosma</i> sp.	mf	endocarps	
Salicaceae			
<i>Populus zaddachii</i> var. <i>brabenečii</i> <i>Populus populina</i> <i>Salix haidingeri</i>  <i>Salix varians</i>	HM, žd, bd HM, žd, bd, bc, LM in žd HM, žd, bd, bc  HM, žd, bd, LoM	foliage, fruits, male catkins foliage foliage twig with catkins, detached foliage and fruits foliage	<i>P. heerii</i> <i>P. latior</i> <i>Salix lavateri</i> , <i>S. angusta</i>  <i>Salix macrophylla</i>
Sapindaceae			
<i>Koelreuteria reticulata</i> "Sapindus" <i>falcifolius</i>	HM, žd, bd, žd, bd, bc	fruits foliage of <i>Koelreuteria reticulata</i>	<i>Koelreuteria macroptera</i>
Schisandraceae			
<i>Schisandra</i> sp.	mf	seeds	
?Scrophulariaceae			
<i>Elephantosotis dvorakii</i>	bd	plants, foliage	
Simaroubaceae			
<i>Ailanthus confucii</i> <i>Ailanthus</i> sp. <i>Chaneya oehningensis</i>	bd bd HM, žd, bd, bc	fruits foliage fruits	<i>Porana oehningensis</i> , cf. <i>Abelia</i>
Staphyleaceae			
<i>Staphylea</i> sp.	mf	endocarps	
Symplocaceae			
<i>Symplocos</i> sp. div.	mf, LM	foliage, endocarps	
Theaceae			
<i>Eurya stigmosa</i> <i>Gordonia hradekensis</i> <i>Ternstroemia</i> sp. <i>Ternstroemites</i> sp. Theaceae gen.	HM, mf mf, LM HM žd, bd, bc bd	seeds foliage seed foliage foliage	<i>Polyspora</i> sp.  "Viburnum" <i>atlanticum</i>
Tiliaceae			
<i>Craigia brononii</i>  <i>Dombeyopsis lobata</i> <i>Tilia brabenečii</i>	HM, žd, bd, bc, LM in žd  HM, žd, bd, bc bd, bc	fruits of <i>Dombeyopsis lobata</i> , flower buds  foliage foliage, fruits	<i>Pteleaearpum brononii</i> , <i>Ulmus brononii</i> , cf. <i>Tilia</i> sp. (flower buds) <i>Ficus tiliaefolia</i> <i>T. lignitum</i>
Trapaceae			
<i>Hemitrapa heissigii</i>	? bd, LoM	fruits	<i>Trapa silesiaca</i>
Ulmaceae			
<i>Cedrelospemum aquense</i> <i>Ulmoxylon marchesonii</i> <i>Ulmus pyramidalis</i> <i>Zelkova zelkovifolia</i>	LM bd ? DM, tl, HM, žd, bd, bc, LM in žd tl, HM, žd, bd, bc, LM in žd	fruits wood foliage, fruits foliage, fruits	<i>Embothrites borealis</i>  <i>U. longifolia</i> <i>Z. ungeri</i>
Viscaceae			
<i>Viscum</i> sp.	bd	foliage	
Vitaceae			
cf. <i>Ampelopsis ludwigii</i> cf. <i>Ampelopsis</i> sp. <i>Parthenocissus</i> sp. <i>Vitis stricta</i> <i>Vitis teutonica</i>	HM žd, bd mf HM, žd, bd, bc HM	seeds foliage seeds foliage seeds	
Familia incerta			
<i>Diversiphyllum aesculapi</i> "Ficus" <i>lobkowitzii</i> "Ficus" <i>truncata</i> "Juglans" <i>acuminata</i> <i>Phyllites kvacekii</i> <i>Phyllites nemejčí</i> <i>Pseudotrapa buzekii</i> <i>Pungiphyllum cruciatum</i> cf. "Rhus" <i>pyrrhae</i> <i>Saportaspermum</i> sp. <i>Schenkiella credneri</i> <i>Spondiaearpum mettenii</i>	žd, bd, bc žd HM, žd, bd, bc HM, žd, žd, bd žd žd, bd žd, bd žd žd, bd bd, bc	foliage foliage foliage foliage foliage foliage foliage foliage seeds fruits endocarps	<i>Sassafras aesculapi</i>  cf. <i>Cedrela</i>  <i>Trapa</i> sp. "Quercus" <i>cruciatum</i>  "Embothrium" <i>salicinum</i> <i>Trapa credneri</i> <i>S. turbinatum</i> , <i>Carpolithes hafniensis</i>

Table 4. (continued)

Monocotyledonae			
Araceae			
<i>Epipremnites cristatus</i>	HM	seeds	<i>Epipremnum cristatum</i>
<i>Lemna cestmirii</i>	bd	foliage	
<i>Limnospermum pistiforme</i>	bd	seeds of <i>Limnobiophyllum expansum</i>	
<i>Limnobiophyllum expansum</i>	HM, bd	plants, foliage	
<i>Pistia sibirica</i>	bd	seeds	
Arecaceae			
<i>Calamus noszkyii</i>	HM	foliage	<i>S. major</i>
<i>Calamus daemonorops</i>	HM, bd	thorny bark, thorns	
<i>Livistona macrophylla</i>	tl	foliage	
<i>Phoenix bohemica</i>	tl	endocarps	
<i>Sabal lamanonis</i>	HM, bd, bc	foliage	
Cyperaceae			
<i>Carex</i> sp.	tl, HM	fruits	<i>Cladiocarya chomutovensis</i>
<i>Caricoidea jugata</i>	DM, HM, bd	fruits	
<i>Cladiocarya trebovensis</i>	HM	fruits	
<i>Cladiocarya</i> sp.	HM	fruits	
Cyperaceae gen.	HM	fruits	
Hydrocharitaceae			
<i>Hydrochariphyllum buzekii</i>	HM, bd	foliage	<i>Podocarpus miocenica</i>
<i>Hydrochariphyllum miocenicum</i>	HM	foliage	
<i>Stratiotes schaarschmidtii</i>	bd	plants, foliage	
<i>Stratiotes kaltennordheimensis</i>	HM, žd, bd, mf	seeds	
Poaceae			
? <i>Arundo</i> sp.	HM	foliage, stems	
Poaceae gen.	žd, bd, bc	foliage, stems	
Potamogetonaceae			
<i>Potamogeton</i> cf. <i>praenatans</i>	bd	foliage	
<i>Potamogeton</i> sp.	mf, LoM	fruits	
Rubiaceae			
<i>Limnocarpus</i> sp.	DM	fruits	
Smilacaceae			
<i>Smilax weberi</i>	tl, HM, žd, bd, bc	foliage	<i>S. convallium</i> , <i>S. grandifolia</i>
Sparganiaceae			
<i>Sparganium</i> cf. <i>elongatum</i>	žd, bd	fruits	
<i>Sparganium</i> sp. div.	HM	fruits	
Typhaceae			
<i>Typha latissima</i>	HM, žd, bd	foliage	
<i>Typha</i> sp.	HM in žd	seeds	
Zingiberaceae			
<i>Spirematospermum wetzleri</i>	HM, žd, bd	seeds and fruits of <i>Zingiberoidophyllum liblarensis</i>	"Musa" <i>bilinica</i>
Zingiberaceae gen.	bd	rhizomes, sheaths	
<i>Zingiberoidophyllum liblarensis</i>	HM, bd	foliage	
Familia incerta			
<i>Carpolithes fejfarii</i>	tl, ? bd	? seeds	cf. <i>Coriaria</i> sp. Poaceae vel Cyperaceae, cf. <i>Phormium affine</i> <i>Poa</i> sp., <i>Phragmites</i> , <i>Panicum</i> , <i>Uniola</i> , <i>Arthrostilidium</i> sp. div.
<i>Cyperacites</i> sp.	HM, žd, bd	plants, foliage	
Monocotyledonae gen.	DM, HM, LM, žd, bd, bc	foliage	
<i>Smilacinites ungeri</i>	bd	plants, foliage	
FUNGI			
Fungi gen.	throughout the basin	perithecia, other fungal bodies	
Pyrenomycetinae	throughout the basin	perithecia	
<i>Roselinites areolatus</i>	throughout the basin	perithecia	
<i>Trematosphaerites lignitum</i>	throughout the basin	perithecia	



Fig. 8. 1, 2 – *Platanus*-pollen, *ipelensis* – type, former Concordia Mine, Želénky (Schelenken in German).  $\times 1000$ . 3–5 – *Platanus*-pollen, *ipelensis* – type, former Concordia Mine, another specimen.  $\times 1000$ . 6 – *Platanus*-pollen, *ipelensis* – type, Bilina Mine, Upper Seam.  $\times 1000$ . 7, 8 – Tiliaceae, *Intratriplopollenites microreticulatus* Mai, one specimen at two focus levels, Bilina Mine, Upper Seam.  $\times 1000$ . 9 – cf. Palmae (Arecaceae) vel Araceae – cf. *Arecipites* sp. vel *Monocolpopollenites* sp. A., Bilina Mine, Upper Seam.  $\times 1000$ . 10–12 – Palmae (Arecaceae), three specimens of modern *Chamaerops* – pollen. SEM.  $\times 1500$ . 13 – Water and rim herbaceous plant pollen – cf. Alismataceae, Ranunculaceae – *Punctoriatipollis ludwigi* W. Kr., Vršany,  $\times 1300$ . 14 – Caprifoliaceae, *Loniceraipollis interospinosus* Zhou – type (36.8  $\mu\text{m}$ ), Bylany – Havraň (core Hn 38, depth 69.2–69.7 m),  $\times 1300$ . 15 – Palmae, Calamoidae – *Dicolpopollis kockeli* Pfl., Bilina Mine, Upper Seam.  $\times 2100$ . 16 – Modern pollen of Caprifoliaceae – *Lonicera periclymenum* L., two connected pollen with typical spinulae on the surface. SEM.  $\times 1000$ .



### Micropalaeobotanical (palynological) research

A general palynological characteristic of the Most Basin has been given previously (Konzalová 1976) and is not repeated here. During current studies of the pollen flora in the Most Basin and the Neogene sediments of the West Bohemian deposits including the surroundings of Plzeň (Němejc et al. 2003), new morphological features of some pollen and spores have recently been ascertained that allow better understanding of their affinities. The morphological study was focused on detailed analysis of the exine habitus, i.e., tectum, tectal ornamentation and exitus composition, and detailed comparisons with the selected modern genera and/or species. Most of them belong to flowering plants, particularly the representatives of palms (Arecaceae) and the honeysuckle family (Caprifoliaceae).

In the monocot family of Arecaceae (Fig. 8.9, 8.15), the presence of which was confirmed in the Most Basin by the detailed study of modern representatives, differences in the morphology of exitus have been ascertained in pollen collected from the same living plant specimen. Among typical monosulcate pollen of extant *Chamaerops* (Figs 8.10, 8.11) also trisulcate-like pollen have been recognized (Fig. 8.12). These observations and identifications offer broader diagnostic features useful for the study of fossil monocotyledon pollen derived from palms and also allow to delimit some of the analogous quasi-tricolpate pollen (at the first-sight observation) in the pollen spectra. This evidence is important for the interpretation of the palaeoenvironment, particularly for palaeoclimatic considerations, because palms are generally known as sensitive indicators of the cold month mean and annual mean temperature.

The second group subjected to a detailed morphological study comprises selected taxa of the family Caprifoliaceae, whose representatives occur as rare entomophilous elements in the pollen spectra. They were found earlier in the Most Basin (Konzalová 1973, 1976) and recently in the western Bohemian Tertiary. Within the present study, the specimen from the Most area is more precisely assigned to the generic and species level (Fig. 8.14). The recorded specimens have been studied and reviewed by direct comparison with living plant taxa (e.g., Fig. 8.16) and on the basis of literature data.

Both the above groups of angiosperms can be designated as significant components of the Miocene vegetation of the Most Basin with a specific climatic signal (elements of subtropical/warm temperate and temperate floras). By their occurrences, they are also connected with deposits from the western part of the Ohře Rift basins. Their representatives

were recently recovered also from younger Neogene relics near Plzeň in western Bohemia (Konzalová in prep.).

Other rare angiosperm elements have been recognized in the western part of the Ohře Rift. They belong to the family Fabaceae, so far not found in the pollen spectra of the Most Basin. Nevertheless, their occurrence cannot be ruled out there with regard to the presence of the corresponding macrofossils (*Podocarpium*).

The newly found and observed dicot elements are rare but valuable also for their time range and palaeogeographic occurrences. They are traceable from the Oligocene (Caprifoliaceae, Fabaceae) in all Euroasiatic floras and, moreover, involve information linked with migration paths from the East Asian centres, where they are very common to abundant.

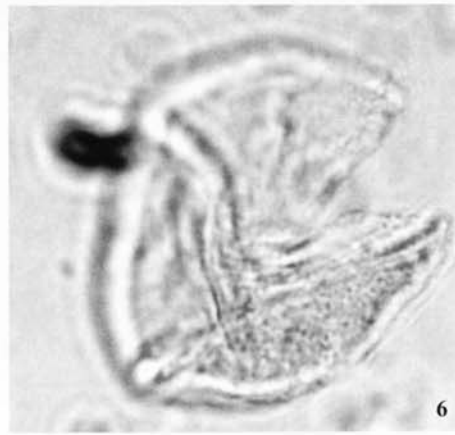
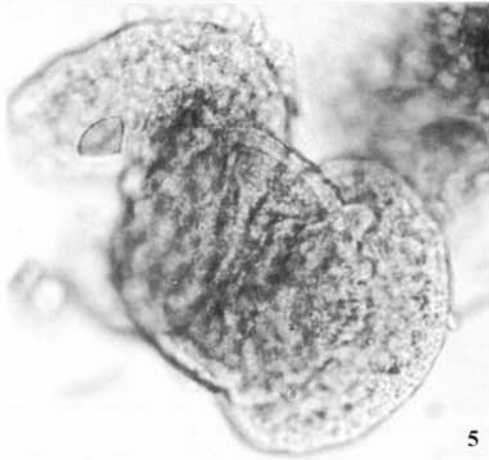
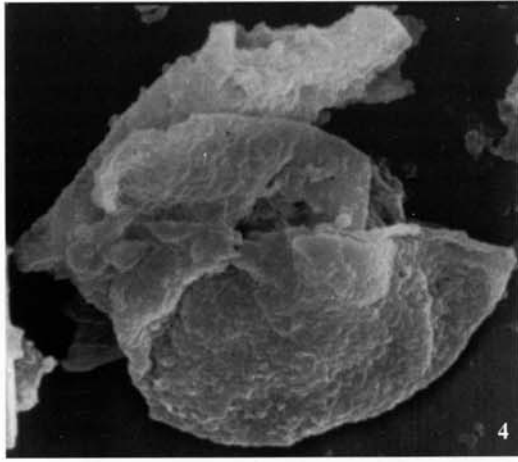
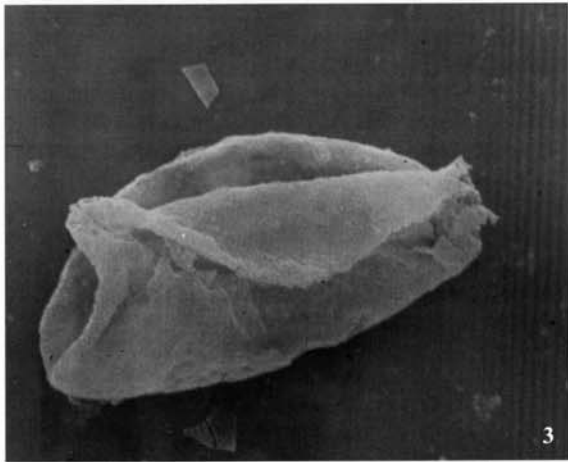
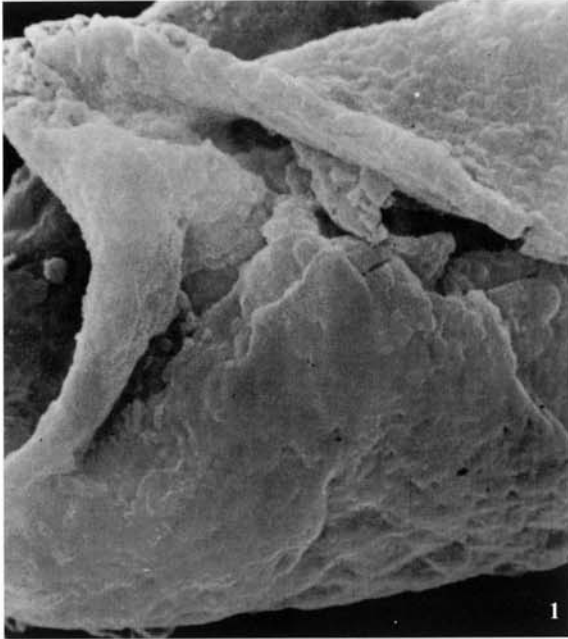
In connection with these dicotyledons, other Asiatic woody plants are noteworthy: *Platanus* pollen of the *ipelensis* type (Fig. 8.1–8.6), occurring together with *Cercidiphyllum* (Konzalová 1972, Kvaček – Konzalová 1996) and the other mentioned plants.

Noteworthy are the records of aquatic and rim plant pollen – cf. Alismataceae, Ranunculaceae–*Punctiorati-pollis ludwigi* W. Kr. (Fig. 8.13), Sparganiaceae (Konzalová 1976, 2002), Potamogetonaceae, Gramineae, Cyperaceae, recorded at several levels of the Main Seam in the Bílina Mine, along with algal spores *Ovoidites*, Zygnemataceae, rarely *Botryococcus* and other algae. Higher frequencies of aquatic components have been recorded in the Upper Seam at Bílina in a sample from the upper part of the section as well as in the clays of the former Concordia Mine at Želénky (Konzalová 1976) and the Nové Sedlo nad Bílinou – Kyjice locality.

Conifers, namely swamp cypresses, locally represented by abundant inaperturate pollen of the Taxodiaceae–Cupressaceae, characterize the coal-bearing facies of the Holešice Member and contribute fundamentally to its genesis. Several morphotaxa have been recognized within this group and most of them display a continuous range in the Most Formation and the rift fill package in general. This group involves even rare taxa and specimens of very low frequency. Among others, such as *Sciadopitys* (Fig. 10.6) and *Cunninghamia* (Fig. 11.8, 11.9), pollen of the *Sequoia* type can be mentioned (Fig. 9.1–9.3). The pollen with *Sequoia*-like papilla are produced by several living genera of conifers: *Cryptomeria*, *Sequoia*, *Sequoiadendron* and *Metasequoia* (Stuchlík 2002). *Sequoiapollenites* cf. *major* W. Kr. (vel *S. largus* W. Kr.), comparable with the above mentioned living genera, has newly been recorded within the Tušimice – Merkur Mine area, in a typical cupressa-

⇒

Fig. 9. 1–3 – Taxodiaceae, *Sequoiapollenites* cf. *major* W. Kr., Tušimice, Merkur Mine, (Lower Miocene, MN 3 zone). SEM, 1 – Detail of papilla,  $\times 6000$ . 2 – Another specimen, LM,  $\times 1400$ . 3 – Exine shown in Fig. 1 in overall view,  $\times 1350$  (size of the pollen 35  $\mu\text{m}$ ). 4 – *Inaperturopollenites concedipites* (Wodeh.) W. Kr., close to *Glyptostrobus* (striate part of endexine not preserved, sculpturing of equatorial and proximal exine surface similar to pollen of *Glyptostrobus* sensu Zetter in Van der Burgh and Zetter 1998). Tušimice, Merkur Mine, SEM,  $\times 2100$ . 5 – Pinaceae, morphotype of *Podocarpus* habitus (more probable than Podocarpaceae) – *Podocarpidites nageiaformis* (Zakl.) W. Kr. Bílina Mine, Upper Seam,  $\times 1200$ . 6 – *Inaperturopollenites* cf. *insulipapillatus* (Trev.) W. Kr. Bílina Mine, Upper Seam.  $\times 1600$ .



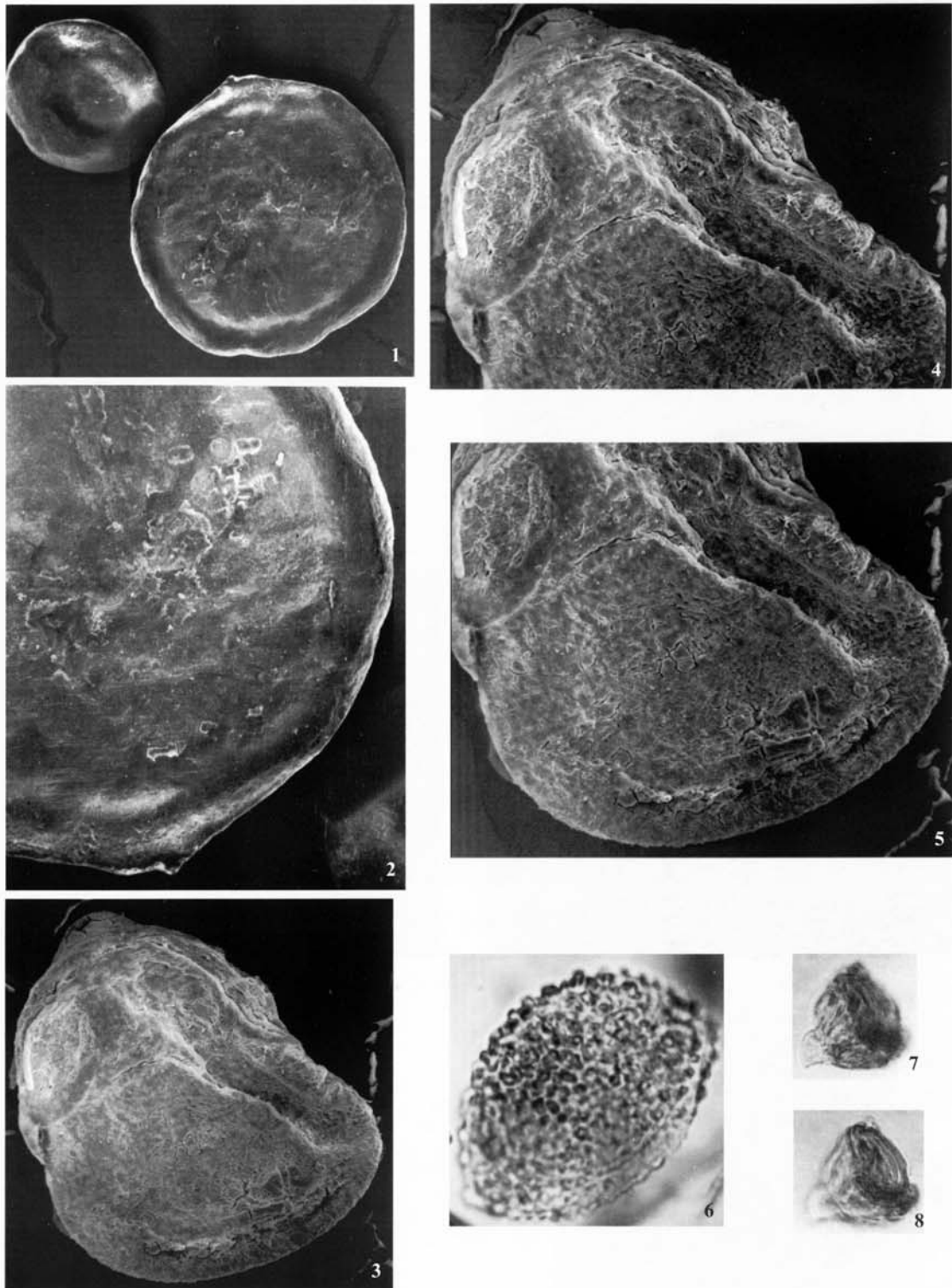
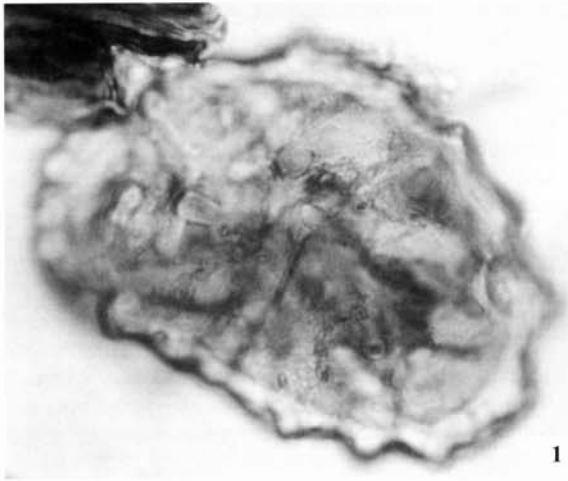
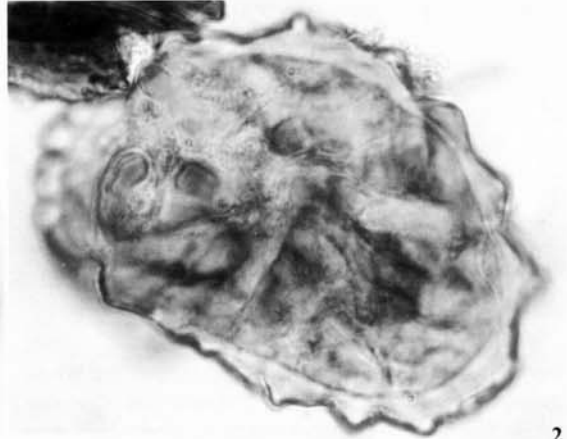


Fig. 10. 1–5 – Hydropteridales, *Azolla* macrospores, Čermniky, SEM. 1 – Macrospore (probably two macrospores of different size) without perispore,  $\times 200$ . 2 – A detail of the preceding micrograph. Trilete scar invisible or slightly demarcated at the right half of the spore, observable at higher magnification,  $\times 450$ . 3–5 – Macrospore with perispore and floating apparatus attached to proximal face. 3 – General view,  $\times 200$ . 4 – Floating apparatus in detail,  $\times 300$ . 5 – Surface of the distal part in detail,  $\times 300$ . 6 – *Sciadopitys* – *Sciadopityspollenites serratus* (R. Pot. et Ven.) Raatz ex Potonič, Vršany (core Vrš 3, depth 8.0–9.0 m),  $\times 1370$ . 7, 8 – Small-sized ribbed spore probably of Bryophytes, Musci. Vršany (core Vrš 23, depth 78.5 m),  $\times 1000$ .

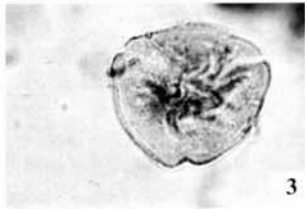




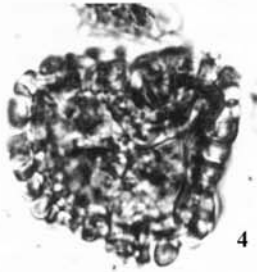
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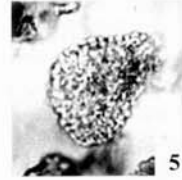
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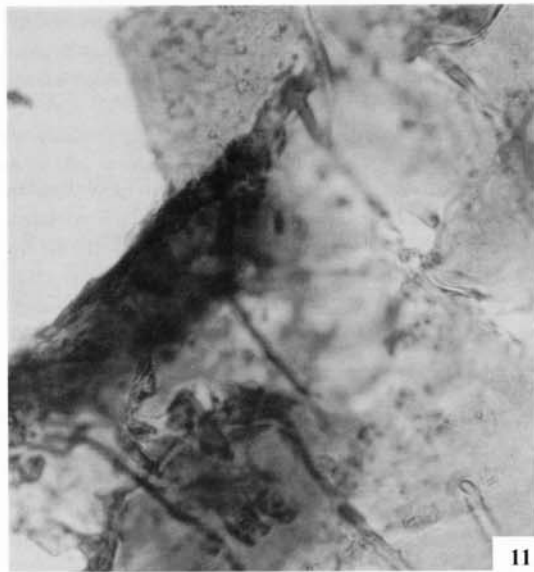
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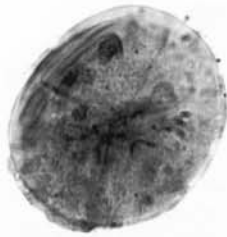


Fig. 12. Megaspore of Salvinaceae – Azollaceae. Spore without perispore, surface of spore finely pitted. Kyjice – Nové Sedlo nad Biliinou (core NSB 18, depth 70.5 m),  $\times 400$ .

ceous/taxodioid assemblage in 0.5 percent of the whole spectrum (Konzalová 2002a, b). The spectrum characterizes the site dated to the mammalian Neogene MN 3 zone (after Fejfar in Bůžek et al. 1989). In their morphology, *Sequoia* pollen are of medium-sized to large dimensions (Krutzschn 1971, p. 226). (The rugulate–verrucate sculpture has been observed in SEM only – Fig. 9.1, 9.3.) *Sequoiapollenites* does not belong to the regularly appearing elements in the assemblages from the Bilina Mine, neither as a pollen morpho-genus, nor as its modern counterpart. It occurs sporadically only in the pollen record, like *Sciadopitys* and *Tsuga*. Another occurrence of *Sequoiapollenites* has been recorded at the locality of Slatinice (core SL-125, depth 9.0–9.9 m, Konzalová 1973, Pl. 9, fig. 2), which displays slight differences in exine surface ornamentation and has been compared with *Cryptomeria* (*sensu* Kremp and other authors, see Krutzschn 1971, Stuchlik 2002).

Other inaperturate pollen, very common in the Most Basin, are the pollen of a swamp cypress forest, e.g., *Inaperturopollenites concedipites* (Wodehouse) W. Kr. close to living *Taxodium* and *Glyptostrobus* (Fig. 9.4) and many other inaperturate types (e.g., Fig. 9.6).

Besides the angiosperm and gymnosperm pollen elements, new components of the fern flora have been recognized. They are represented by semi-macrospores and most probably belong to the hydrophyte ferns or lycopods. They are new for the Most Basin and are preliminarily designated as *Bilinasporites multilamellatus* Konzalová, gen. et sp. nov. (Fig. 17.1–17.3).

Other macrospores are also present in the pteridophyte flora of the Most Basin. They lack perispores and occur rarely relative to the macrospores provided with the perispore. Their walls are smooth or finely foveolate to aspidate with a simple trilete scar, the arms of which reach to one third to one fourth of the spore radius. The spores are large, more than 100  $\mu\text{m}$  in size, provided with a wall about 5–6  $\mu\text{m}$  thick (in LM). They lack the perispore but

occur in association with aquatic ferns (Fig. 10.1–10.2) of *Salvinia* and *Azolla* (Collinson 1991) with attached perispore and, in the case of *Azolla*, with float apparatuses (Fig. 10.3–10.5). In transmitted light, similar specimens (Fig. 12) are translucent and belong to the macrospores of hydrophytes. Also this type may illustrate the macrospore itself, most probably a smooth macrospore of *Azolla* or finely pitted macrospore of *Salvinia*.

The macrospores recorded in the coal facies at Bilina and the surrounding area display size differences (see Fig. 10.1) that probably represent the growth and maturity stages.

Musci belong to the very rare elements of the coal facies. Their spores occur sporadically and are mostly limited to the *Stereisporites* type (Sphagnaceae and related families). The plant bodies and characteristic cells of Sphagnaceae have not been preserved, only one small phylloid of the bryophytic type has been found in SEM. It is cuneiform, composed of tiny elongated cells, tapering to the top. Another record of Musci is represented by a small-sized trilete spore, 18  $\mu\text{m}$  in diameter, sparsely ornamented with narrow (about 1–2  $\mu\text{m}$ ) ribs, similar to the small cicatricose spore (Fig. 10.7–10.8). The trilete scar seems to reach to the equator and is elevated over the body of spores. Small auriculae-like outgrowths are present at the equator, on the outer part of the trilete scar. Spores remind a tiny replica of the schizeaceous spores in their morphology.

Terrestrial fern spores of the Polypodiaceae type with perispore (associated with *Pinus* pollen and the specimens of thermophilous monocots) are shown in Figs 11.1–11.2.

The study of microfossils and organic components from the coal seam of the Most Basin, particularly from the Bilina area, led to the acquisition of more accurate morphological data of fossil exines and in some cases to a closer recognition of their mother plants and vegetation type. A comparison with related modern taxa and SEM observations yielded new data significant for the relationship of dispersed fossil specimens and their occurrences. These implicitly contributed to the assessment of their climatological signals, ecological and edaphic requirements and growth forms, such as elements of the canopy, forest undergrowth, aquatic vegetation, presence outside or within swamp forests.

### Systematic palaeontology

The following chapter includes descriptions of important novelties of the fauna and flora recently recognized in the Most Basin. This part adds some new elements not yet defined and documented to complement the inventory of the groups treated in the previous part.



Fig. 11. 1–11. Spores, pollen and animal remains. Upper Seam, Bilina Mine unless stated otherwise. 1, 2 – Polypodiaceae, Davalliaceae – *Verrucatosporites* sp. (aff. *V. semihistiopteroides* W. Kr. with transition to *V. clatriformis* (Mürr. et Pf. ex Th. et Pf.) W. Kr.) one specimen at two focus levels.  $\times 1200$ . 3 – Juglandaceae, cf. *Engelhardtia*-pollen vel inc. sedis.  $\times 1100$ . 4 – Aquifoliaceae, *Ilex* – *Ilexpollenites iliacus* (R. Pot.) Thiery. ex Potonié, former Concordia Mine, Želénky.  $\times 1000$ . 5 – Palmae, Calamoidae – *Dicolpopollis kockeli* Pfl.  $\times 1000$ . 6 – Juglandaceae, *Engelhardtia* – pollen. Vršany (core Vrš 23, depth 41.2–41.6 m coal seam).  $\times 1100$ . 7 – Palmae (Arecaceae), *Sabal* – type, *Sabalpollenites* cf. *retareolatus* (Pf.) Nagy.  $\times 1000$ . 8, 9 – Taxodiaceae, *Cunninghamia* – *Cunninghamiapollenites janinae* Stuchlik et Konzalová, former Concordia Mine, Želénky.  $\times 1100$ . 10, 11 – Animal remains, probably insect cuticles, in LM.  $\times 1000$ .

Animalia  
 Pisces  
 Family Umbridae  
 Genus *Umbra* Walbaum, 1792

***Umbra longidorsalis* Böhme, sp. nov.**

Figs 13–16

**Holotype:** No. DB “18.3.1995”, a complete skeleton illustrated in Fig. 13 (collections of the Bilina Mines).

**Paratypes:** Nos. DB “4.7.1995” illustrated in Fig. 14 and DB “1996” illustrated in Figs 15–16, incomplete skeletons, lacking the anterior half (collections of the Bilina Mines).

**Locus typicus:** Opencast Bilina Mine, Most Basin (northern Bohemia, Czech Republic).

**Stratum typicum:** Horizon 30 of the Holešice Member (Most Formation); Lower Miocene, Middle Burdigalian, ca. 19 to 18 Ma.

**Etymology:** from Latin “*longidorsalis*” – long dorsal fin.

**Occurrence:** Known from the type locality only.

**Diagnosis:** A new species of *Umbra*, differing from all modern and fossil species in its larger dorsal fin (20 dorsal fin spines), completely fused hypurale 4 and 5, and a lower number of vertebrae (ca. 30 vertebrae).

**Description and Discussion:** The description of the material is limited by poor fossilisation of the bones (Figs 13, 14) and the partial preservation of the paratypes. The preserved length of the holotype is 113 mm (total length ca. 135 mm). The large dorsal fin comprises 20 fin rays and begins opposite to the pelvic fin. The anal fin is short and includes 6 or 7 fin rays (Fig. 15). Their anterior insertion is below the 12<sup>th</sup> praearal centre. Ca. 30 vertebrae are present in the axial skeleton, of which about 15 are caudal. The number of vertebrae, especially the precaudals, in modern and fossil umbrids is generally higher: 37–38 (18–19 precaudals) in *Novumbra hubbsi*, 38–39 (20 precaudals) in the extinct *Novumbra oregonensis*, 40–41 (19–20 precaudals) in *Dallia pectoralis*, 34–39 (19–23 caudals) in the extinct *Proumbra irthyshensis*, 36–38 (20–21 precaudals) in *Umbra limi*, 36 (20 precaudals) in *U. krameri*, 34 (18–19 precaudals) in *U. pygmaea*, and 33–34 (15–16 precaudals) in the extinct *U. prochazkai* (Cavender 1969, Obrhelová 1978, Sytchevskaya 1980, Wilson – Veilleux 1982). The extinct

*U. oderiensis* has been reported to have 15 caudal vertebrae but the total number of vertebrae is unknown (Obrhelová 1978). Hypurale 1 to 3 are equal in size; hypurale 4 and 5 are completely fused (“1996”) like in some individuals of *Dallia pectoralis* (Wilson – Veilleux 1982, fig. 13). In living species of *Umbra*, this fusion is less pronounced (Wilson – Veilleux 1982), while both fossil northern Bohemian species show

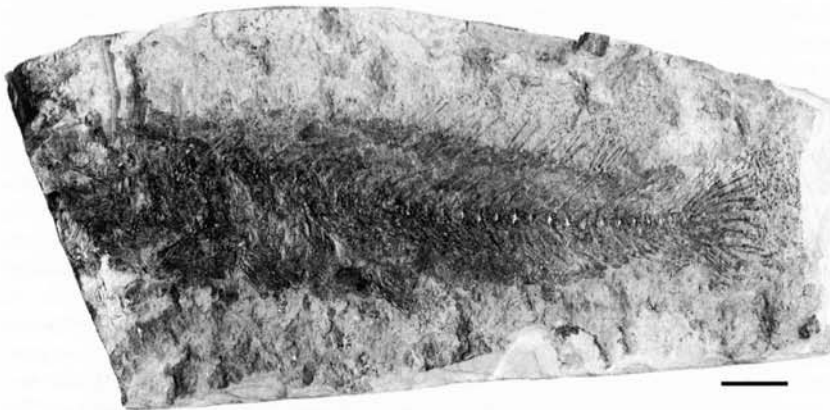


Fig. 13. *Umbra longidorsalis* Böhme, sp. nov. Holotype, DB “18. 3. 1995”. Bilina Mine, Horizon 30 (scale bar 10 mm).

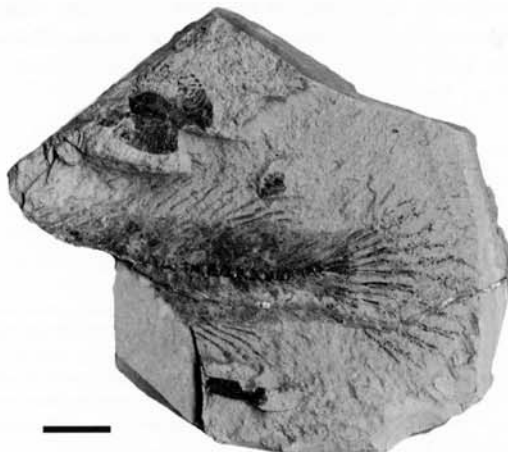


Fig. 14. *Umbra longidorsalis* Böhme, sp. nov. Paratype, DB “4. 7. 1995”. Bilina Mine, Horizon 30 (scale bar 10 mm).

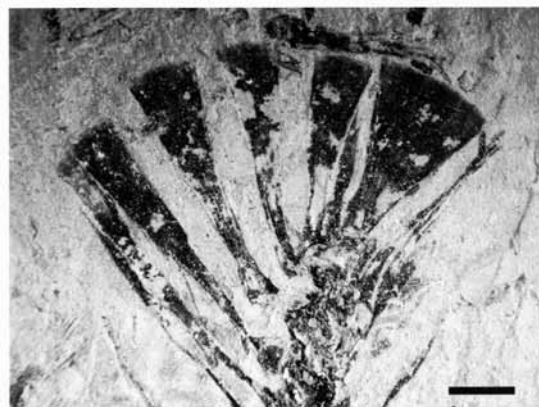


Fig. 15. *Umbra longidorsalis* Böhme, sp. nov. Paratype, DB “1996”, caudal fin. Bilina Mine, Horizon 30 (scale bar 2 mm).

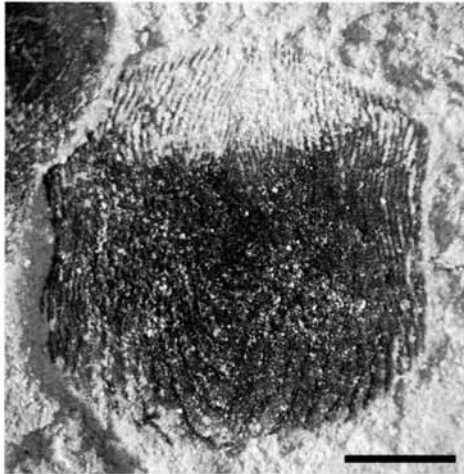


Fig. 16. *Umbra longidorsalis* Böhme, sp. nov. Paratype, DB "1996", scale. Bilina Mine, Horizon 30 (scale bar 1 mm).

separated hypurale 4 and 5 (Obrhelová 1978, fig. 13). The caudal fin comprises 12 principle rays and 3 procurrent rays dorsally (the number of ventrally procurrent rays is unknown). The range of 11 to 13 principal rays is typical of the genus *Umbra*, while *Novumbra* has 18–19, *Dallia* 20–22, and *Proumbra* 13–14 principal rays in the caudal fin (Sytchevskaya 1980, Wilson – Veilleux 1982).

In contrast to *Novumbra hubbsi* and *Dallia pectoralis*, the scales show a typical *Umbra*-like pattern lacking radii (Wilson – Veilleux 1982).

The probably contemporary *Umbra oderiensis* (Miocene to Late Oligocene of the lignite Odeř Mine near Ostrov nad Ohří, Sokolov Basin, western Bohemia), known only from incomplete specimens, differs from the new species by fewer dorsal fin spines (18), the separation of hypurale 4 and 5, and a slender body (Obrhelová 1978).

#### Insecta

Order Odonata

Suborder Anisoptera

Superfamily Aeshnoidea

Family ?Gomphidae Rambur, 1842

#### cf. Gomphidae gen. et sp. indet.

(larvae)

Fig. 7.1

**Material:** DB ZD0065 Imprint and counter-imprint of incomplete larva in dorsal view, head with distal part of labium (mask) preserved, legs and external wing rudiments preserved, abdomen with distinct anal pyramid preserved, Doly Bilina coll., Czech Republic.  
**Occurrence:** Bilina Mine, Clay Superseam Horizon, Most Basin, North Bohemia, Early Miocene, Czech Republic

**Description:** Body stout, elongate, 22 mm long and 7.5 mm wide; head triangular (4 mm long and 4 mm wide) with oval compound eyes in lateral position and distinctive post-ocular lobes; apical part of labium long, present anterior of head, labial palps with a broad apex,

movable hook of palpal lobes narrow and large, about 2.5 mm long. Legs slender, metathoracic shortly pilose on femoras, front tarsi two-jointed. External wing cases extending parallel backwards to cover the three basal abdominal segments. Abdomen broad (broader than head), 14.5 mm long and 7.5 mm wide with an anal pyramid, 3 spine-like appendages visible at tip; a slightly shorter epiproct is present between paired ventrolateral para-procts, about 2.5 mm long, dorsal hooks clearly present on 5 and 6 abdominal segments.

**Discussion:** Based on the key of Westfall (1987), our specimen clearly belongs to the Anisoptera because of the combination of the following characters: body relatively stout, head narrower than thorax and abdomen, prementum probably flat and palpal lobes without palpal setae, anus surrounded by three short, stiff pointed valves forming the anal pyramid at the tip of abdomen. Further significant character of two-jointed tarsi on prothoracic and mesothoracic legs is a unique apomorphy of Gomphidae. However, this character is not obvious due to the state of preservation; it is very probably present on the preserved protarsi. Next indirect characters of non-presence of a pair of latero-dorsal tufts of long black bristles on abdominal segments, a sharp spur at the base of the movable hook of the palpal lobe, triangular lobes not projecting upwards on most or all abdominal segments, and epiproct not bifid at the top support this attribution and rather exclude the other families Aeshnidae, Neopetalidae and Petaluridae within the Anisoptera families with flat mask. Because of lack of other structures like, e.g., antennae, the specimen is classified in open nomenclature with presumable position to Gomphidae.

The specimen probably represents an autochthonous aquatic element, living in a paleolake and indicating calm or slow-running water. This is supported by relative completeness of fine body tissue in respect of taphonomy. The modern larvae of Gomphidae are predominantly stream-dwellers and burrowers (Westfall 1987).

The family Gomphidae is known to occur since the Late Jurassic (see Carpenter 1992, Nel – Paicheler 1994). However, the identification of immature stages needs a better state of preservation for a detailed comparison of Tertiary fossils with their modern relatives.

#### Plantae

Pteridophyta

Family uncertain

#### Genus *Bilinasporites* Konzalová, gen. nov.

**Diagnosis:** Trilete spores with double-walled sporoderm and tree acrolamellae at the apex. Size of the spores around 200 µm, the acrolamellae 10–20 µm wide and ca. 20 µm high, spore wall more than 4 µm thick. Spores without perispore, acrolamellae thin and smooth, frazzled at the end. It differs from *Arcellisporites* and from spores with body ornamentation in the entire absence of outgrowths.

**Typus:** *Bilinasporites multilamellatus* Konzalová, sp. nov.

**Etymology:** From the name of the town of Bilina and the designation of the morpho-genus for spores – *Sporites* (masculine).

***Bilinasporites multilamellatus* Konzalová, sp. nov.**

Fig. 17.1–3

**Holotype** designated here: Fig. 17.1–3 (collections of the Institute of Geology, Academy of Sciences of the Czech Republic, Prague – Preparation 40/1, cross table 20.1: 99. 2 of LM Opton Axiomat).

**Locus typicus:** Opencast Bilina Mine, Most Basin (northern Bohemia, Czech Republic).

**Stratum typicum:** Upper Seam (upper part of the seam) of the Holešice Member (Most Formation); Lower Miocene, Middle Burdigalian, ca. 19 to 18 Ma.

**Etymology:** From Latin *multi* – many and *lamella* – lamella.

**Occurrence:** Only at the type locality, three specimens observed, of different type of preservation.

**Diagnosis:** As for the genus. Wall of the spore 4.5 µm thick, lamellae thin, shorter than the diameter of spore. Trilete scar at the apex hidden by acrolamellae. The spore body spherical or slightly prolonged in the direction to the acrolamellae. Surface smooth to ornamented by very tiny granulae, irregularly coalescing.

**Discussion:** Compared to other macrospores *Bilinasporites multilamellatus* displays smaller size and its proximal lamellae are not of definable structure or ornamentation. These may be rests of imperfectly developed or only partly preserved outgrowths. The affinities to the natural system cannot be stated on the basis of available literature yet.

Magnoliophyta  
Family Nysaceae

**Genus *Nyssa* Gronov*****Nyssa bilinica* (Unger) Z. Kvaček, comb. nov.**

Fig. 18

**forma *bilinica***

Fig. 18.1, 3, 4

1866 *Laurus bilinica* Unger, Denkschr. K. Acad. Wiss. math.-nat. Cl. 25: 72, Pl. 22, fig. 19 (Holotype), basionym (Břežánky – Priesen).

1866 *Apocynophyllum cinanchum* Unger, p. 14, Pl. 4, fig. 18 (Břežánky – Priesen).

1866 *Coccoloba bilinica* Ettingshausen, p. 164, Pl. 30, fig. 1 (Břežánky – Priesen).

1866 *Coccoloba acutangula* Ettingshausen, p. 165, Pl. 30, fig. 2 (Břežánky – Priesen).

1866 *Quercus nerifolia* auct. (non A. Braun); Ettingshausen, p. 54 (Břežánky – Priesen).

1868 *Persea speciosa* auct. (non Heer); Ettingshausen, p. 197, Pl. 32, Figs 15–16 (Břežánky – Priesen).

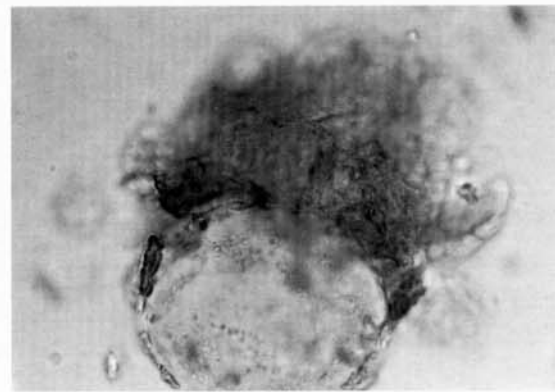
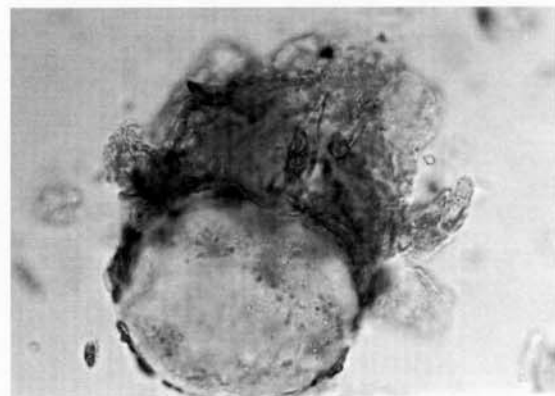
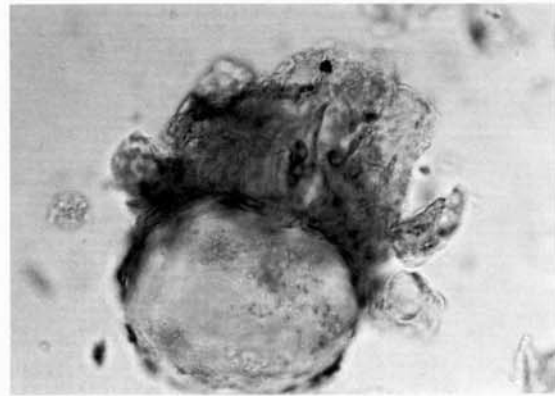
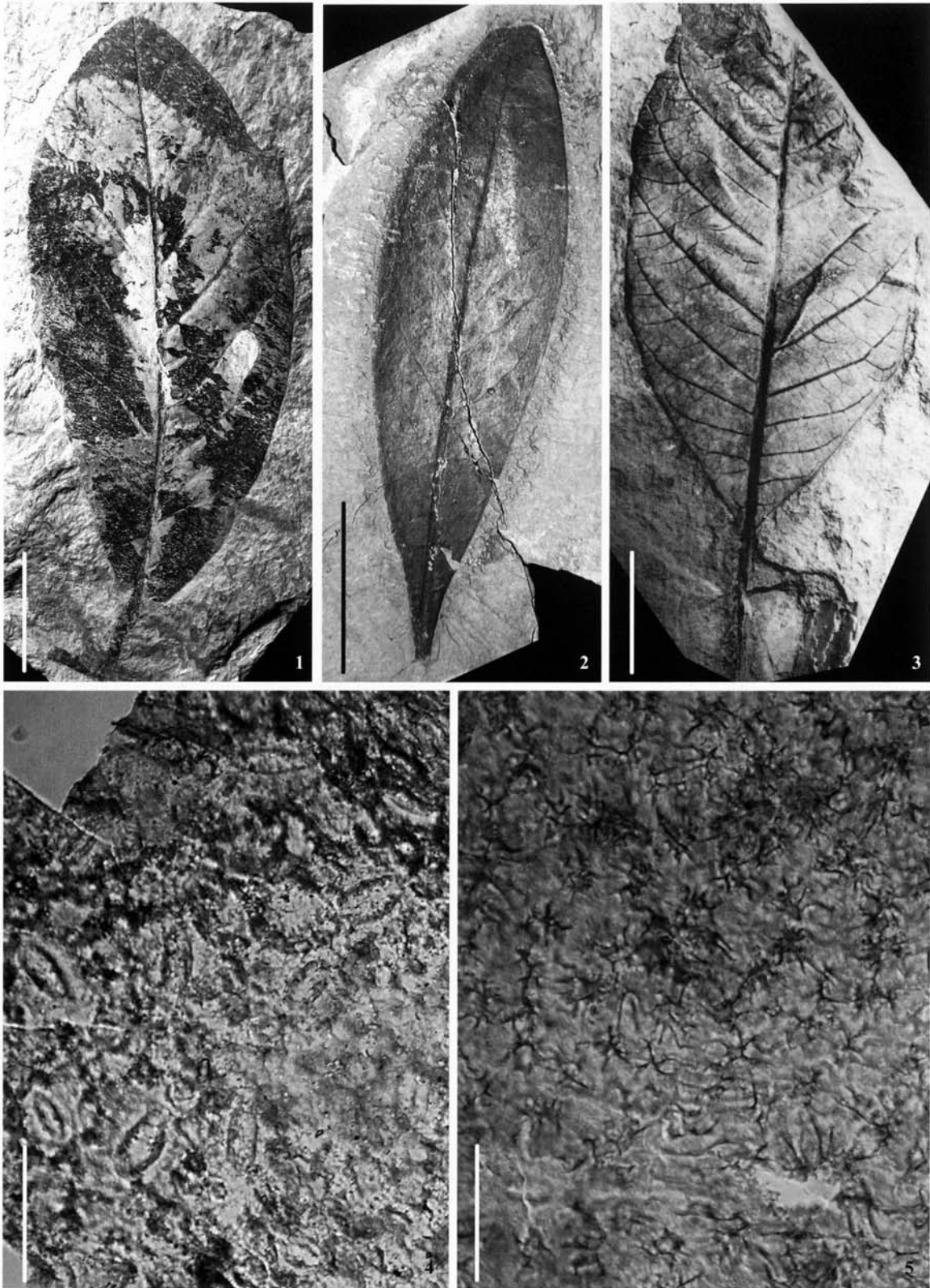


Fig. 17. 1–3 – *Bilinasporites multilamellatus* gen. et sp. nov. Holotype, macrospore, Bilina Mine, Upper Seam. 1 – lower focus level. 2 – middle focus level. 3 – higher focus level,  $\times 150$ .

Fig. 18. 1–5 – *Nyssa bilinica* (Ung.) Z. Kvaček, comb. nov. 1 – a large leaf with one indistinct tooth on the margin, DB MG(30)278. Bilina Mine, Horizon 30 (scale bar 20 mm). 2 – forma *haidingeri* Z. Kvaček, f. nov. Holotype, NM G 8881. Bilina Mine, Horizon 30 (scale bar 15 mm). 3 – holotype of *Nyssa bilinica* (Ung.) Z. Kvaček, comb. nov. BP 64.313.1. Břežánky, orig. Unger 1866, pl. 22, fig. 19 (scale bar 20 mm). 4 – abaxial cuticle of large leaf with spatulate gland, DB MG(30)503/1. Bilina Mine, Horizon 30 (scale bar 50 µm). 5 – forma *haidingeri* Z. Kvaček, f. nov., abaxial cuticle of the holotype. Bilina Mine, Horizon 30 (scale bar 50 µm).



- 1868 *Apocynophyllum cinanchum* Unger; Ettingshausen, p. 217, Pl. 36, Fig. 16 (Břežánky – Priesen).  
 1869 *Bombax oblongifolium* Ettingshausen, p. 12, Pl. 42, Figs 8–9 (Břežánky – Priesen).  
 1869 *Bombax salmaliæfolium* Ettingshausen, p. 12, Pl. 42, Figs 10–11 (Břežánky – Priesen).  
 1877 *Laurus heliadum* auct. (non Unger); Engelhardt, p. 383, Pl. 4, Fig. 6 (Tschernowitz – Černovice).  
 1881 *Persea speciosa* auct. (non Heer); Engelhardt, p. 5, Pl. 1, Fig. 22 (Liebotitz – Libědice).  
 1881 *Cinchonidium bohemicum* Engelhardt, p. 6, Pl. 1, Fig. 5b (Liebotitz – Libědice).  
 1881 *Persea speciosa* auct. (non Heer); Velenovský, p. 32, partim, Pl. 6, Fig. 6 (non Fig. 7) (Vršovice at Louny).  
 1881 *Cinchona* sp. sensu Velenovský, p. 98, partim, Pl. 6, Fig. 17 (non Fig. 18) (Vršovice at Louny).  
 1891 *Bombax oblongifolium* Ettingshausen; Engelhardt p. 178, Pl. 13, Figs 14–16 (Ladowitz – Ledvice).  
 1891 *Apeibopsis (?) descloesii* auct. (non Gaudin); Engelhardt, p. 179, Pl. 10, Fig. 19 (Schellenken – Želénky).  
 1891 *Juglans acuminata* auct. (non A. Braun); Engelhardt, p. 192, Pl. 15, Fig. 7 (Schellenken – Želénky).  
 1972 *Nyssa haidingeri* (Ettingshausen) Z. Kvaček & Bůžek, p. 373, partim, Pl. 1, Figs 1–2, 5, Pl. 2, Figs 1–2, Pl. 3, Figs 1, 3, Pl. 4, Figs 1–5, Text-fig. 1 (Břežánky – Priesen, Čermníky, Bílina Mine).  
 1992 *Nyssa haidingeri* (Ettingshausen) Z. Kvaček & Bůžek; Bůžek et al., p. 125, Pl. 3, Fig. 8, Text-fig. 4.6 (Bílina Mine).  
 2000 *Nyssa haidingeri* (Ettingshausen) Z. Kvaček & Bůžek; Kvaček – Hurmík, p. 18, Pl. 8, Fig. 1, Text-fig. 1.3, 3.18. (Vršovice at Louny, Schellenken – Želénky).  
 2000 *Nyssa haidingeri* (Ettingshausen) Z. Kvaček & Bůžek; Sakala, p. 71, Pl. 11, Figs 1–2 (Bílina Mine).

**Holotype designated here:** Specimen BP 64.313. 1 figured by Unger (1866, Pl. 22, Fig. 19) as *Laurus bilinica* Unger and by Ettingshausen (1868, Pl. 42, Fig. 11) as *Bombax salmaliæfolium* Ettingshausen – reproduced in this paper, Fig. 18.3 (collections of the Hungarian Natural History Museum, Budapest).

**Locus typicus:** Břežánky, Most Basin (northern Bohemia, Czech Republic).

**Stratum typicum:** Břežánky Clay of the Libkovic Member (Most Formation); Lower Miocene, Middle Burdigalian, ca. 19 to 18 Ma.

**Etymology:** From Latin *bilinicus* – adjective for the town of Bílina.

**Occurrence:** Most Basin – Braňany, Břežánky, Čermníky, Černovice, Dobříčice, Dolany, Libědice, Světec, Svinčice, Vršovice, Zabušany, Želénky, opencast mines J. Šverma Holešice, Bílina, Ležáky Most, and Libouš Pruněřov.

**Emended description:** Leaves petiolate, rather large, typically 90 to 120 mm (up to 200 mm) long and 50 to 70 mm (maximum 100 mm) wide, obovate to elliptic, cuneate (occasionally truncate to subcordate) at the base, acute to acuminate at the apex, entire or exceptionally with one or two triangular low teeth in the upper half; petiole up to 30 mm long; venation brochidodromous (with exceptional semicraspedodromous secondaries leading to the teeth), midrib thick and prominent, occasionally slightly bent, secondaries 9–14 in number on either side, alternate to sub-opposite, partly once forked, at angles of 90° (in the lower part) to 40° (in the apex), looping along the margin in regular rounded arches, intersecondaries rare, at right angles to the midrib as short weak veins, tertiary veins thin and irregularly forked, forming large fields slightly oblique to secondaries, higher-order veins in polygonal meshes, ultimate areoles including regularly one simple free-ending veinlet; leaves hypostomatic, firm to chartaceous. Adaxial cuticle smooth or faintly striate showing polygonal cells about 15 µm across with straight to slightly curved anticlinal walls, and solitary trichome bases, abaxial cuticle faintly papillate, with papillae rounded, rather widely spaced, granulate, stomata anomocytic, wide part, irregularly disposed and of variable size 20–37 µm long, elliptical, with large aperture bordered by thin stomatal ledges usually not thickened in polar parts. Unicellular spatulate trichomes about 50 µm long or their tiny bases scattered among stomata and dense on veins.

### forma *haidingeri* Z. Kvaček, f. nov.

Figs 18.2, 5

- ? 1866 *Laurus haidingeri* Ettingshausen, p. 174, partim, Pl. 30, Figs 5, 8 (non 9, lectotype of *L. haidingeri*) (Břežánky – Priesen)  
 ? 1868 *Laurus nectandroides* Ettingshausen, p. 194, partim, Pl. 31, Fig. 1 (non Figs 2a–b, 6–7, 10) (Břežánky – Priesen).  
 ? 1868 *Cinchonidium bilinicum* Ettingshausen, p. 207, partim, Pl. 35, Fig. 31 (non Figs 28–30) (Břežánky – Priesen).  
 2000 *Nyssa* cf. *haidingeri* (Ettingshausen) Kvaček & Bůžek sensu Sakala, p. 71, Pl. 11, Fig. 3 (Bílina Mine)

**Holotype designated herein:** Specimen No. NM G 8881 (collections of National Museum Prague) illustrated in Fig. 18.2.

**Locus typicus:** Opencast Bílina Mine, Most Basin (northern Bohemia, Czech Republic).

**Stratum typicum:** Horizon 30 of the Holešice Member (Most Formation); Lower Miocene, Middle Burdigalian, ca. 19 to 18 Ma.

**Etymology:** Named after Austrian geologist Wilhelm Haidinger (\*1795 †1871) in recognition of his contribution to the knowledge of the Tertiary.

**Occurrence:** Known from the type locality only.

**Description:** Leaves petiolate, oblanceolate or lanceolate to narrow obovate, 60–80 mm long and 15–20 mm wide, narrowly cuneate at the base and bluntly acute at the apex, always entire. Venation brochidodromous, usually poorly seen due to carbonized leaf tissue, midrib straight, secondaries relatively dense and steep, at an angle of 30–35° (rarely slightly wider), looping along the margin in rounded arches, higher-order venation poorly preserved. Leaves coriaceous, hypostomatic. Adaxial cuticle showing polygonal cells 12.5–30 µm across with almost straight anticlines. Abaxial cuticle densely papillate, papillae radially striated (“vermicular” pattern) with rarely observable sunken stomata similar to those of forma *bilinica*, spatulate trichomes rarely preserved.

**Discussion:** Kvaček and Bůžek (1972) neglected two specimens of *Nyssa* from the level of the Břežánky Clay published as *Laurus bilinica* and *Apocynophyllum cinanchum* by Unger (1866) prior *Laurus haidingeri* Ett. The latter was incorrectly chosen for their new combination of *Nyssa haidingeri* against the priority principle. Therefore, *Laurus bilinica* is selected here as a basionym for the new name (combination), which must be introduced, according to the rules, for this foliage morphotaxon widespread in the Most Basin. Although Ettingshausen (1868: 196) noticed *Laurus bilinica* to be very similar to his newly described *L. haidingeri*, he believed that the type specimen of the former is a leaflet, whose petiolule joins the main petiole of a composite leaf, which is not true, and interpreted it as digitate foliage of Bombacaceae (see under *Bombax salmaliæfolium* Ettingshausen 1869, p. 12).

Two forms of leaves can be recognized in the type area of *N. bilinica* according to the texture, form and cuticle structure. The blade of the standard *N. bilinica* forma *bilinica* is thinner and much larger and wider and bears occasionally a tooth or two on its margin. Its epidermal structure with less distinct papillae and stomata at the level with ordinary cells (Fig. 18.4) suggests a mesophytic form. The blade of *N. bilinica* f. *haidingeri* is much narrower and more coriaceous. According to denser pu-

bescence, stronger papillae and sunken stomata (Fig. 18.5), this leaf type is rather xeromorphic. Two interpretations can be offered to explain these extreme cases. The mesomorphic foliage may belong either to shade leaves growing on the same individual in lower positions, or to an ecotype probably of a shrubby growth habit spread in the swamp undergrowth. The xeromorphic type of foliage is best interpreted as sun leaves of individuals of the tree habit; alternatively, it may belong to an ecotype growing on less inundated habitats. *N. bilinica* forma *haidingeri* seems to be less common (Sakala 2000 – as *Nyssa* cf. *haidingeri*) and indeed it may represent one of rare mesophytic elements of the swamp assemblage. A treatment of the two forms as independent morpho-species is unlikely because transitional forms connect both entities. A similar variation can be noticed in the foliage of a closely related *Nyssa* population occurring at Salzhausen in Wetterau and known as *Nyssa gmelinii*. At that site, however, entire and slender “sun leaves” known as *Anona lignitum* Unger prevail over “shade leaves” assigned to *Quercus gmelinii* A. Braun by Unger (1860, Pl. 4, Figs 1–6). The latter differ from *N. bilinica* in their more distinctly and coarsely dentate margins and also in their more distinctly sculptured papillae on the abaxial cuticle (see also Kvaček – Walther 1981, as “*Quercus*” *gmelinii*). Before the revision of Braun’s type specimens is made, the Middle Miocene population from Wetterau is considered herein as closely related but distinct from that of the Lower Miocene at Bilina. The Oligocene *N. altenburgensis* Walther & Z. Kvaček (in Kvaček – Walther 1981) differs from *N. bilinica* in its strongly dentate leaves and from *N. gmelinii* in its non-papillate abaxial epidermis.

As already concluded by Kvaček – Bůžek (1972), the leaves can be reliably assigned to the genus *Nyssa* on account of spatulate trichomes typically present on the leaf surface of *Nyssa*, but also, e.g., of *Alangium* and *Camptotheca*. Among extant *Nyssa* species, the papillate abaxial leaf surface is found in the *Nyssa javanica* complex, *N. ogeche* and *N. aquatica*. *N. ogeche* has mostly entire leaves, although shallow dentate leaf forms can occasionally occur (see Kvaček – Walther 1981, Pl. 14, Fig. 3). The abaxial cuticle is papillate with papillae covered by a “vermicular” sculpture (“Kronchenpapillen” *sensu* Weyland 1957). Simple trichomes or their bases are dense, although spatulate trichomes are nearly lacking (Eyde 1997: 108). This is in contrast to the epidermal structure of *N. bilinica*, where spatulate trichomes are common and simple trichomes (bases) are rare. The leaves of *N. aquatica* are typically widely dentate with several teeth on either side. The papillation is stronger,

papillae are covered by a very pronounced “vermicular” sculpture consisting of dense radial wavy striae. In the *N. javanica* complex leaves are entire. The abaxial surface is papillate to a variable degree. Some populations show abaxially conspicuous dense papillae, which cover stomata, like in *N. bilinica* forma *haidingeri*. Although the degree of papillation is variable, the *N. javanica* complex is uniform in its general epidermal structure, well differentiated from the *N. sinica* complex (incl. *N. silvatica*) and *N. talamancana* that lack papillae. *N. javanica* and its closely related species match best *N. bilinica* in their leaf morphology and epidermal anatomy. It would be desirable to conduct a broader study on ecotypical variation in extant species.

**Occurrence:** Holešice Member, Čermníky, Libědice, Vršovice near Louny, Bilina Mine, Bilina Delta, Břešťany Clay.

Magnoliophyta fam. inc.

#### Genus *Pseudotrapa* Z. Kvaček, gen. nov.

Type: *Pseudotrapa buzekii* Z. Kvaček, sp. nov.

Diagnosis: That of the species.

Etymology: Referring to the similarity to *Trapa* L.

#### *Pseudotrapa buzekii* Z. Kvaček, sp. nov.

Fig. 19

1971 *Trapa* sp.; Bůžek, p. 72, Pl. 26, Figs 13–14 (Čermníky).

**Holotype** designated here: No. NM G 8416a, illustrated in Fig. 19.1 (collections of the National Museum, Prague) and the counterpart DB 36–27 in Figs 19.2,5,6.

**Locus typicus:** Opencast Bilina Mine, Most Basin (northern Bohemia, Czech Republic).

**Stratum typicum:** Horizon 36 of the Holešice Member (Most Formation); Lower Miocene, Middle Burdigalian, ca. 19 to 18 Ma.

**Etymology:** Named after Čestmír Bůžek (\*1933 †1992), in recognition of his contribution to the Czech Tertiary palaeobotany.

**Occurrence:** Čermníky and the type locality only.

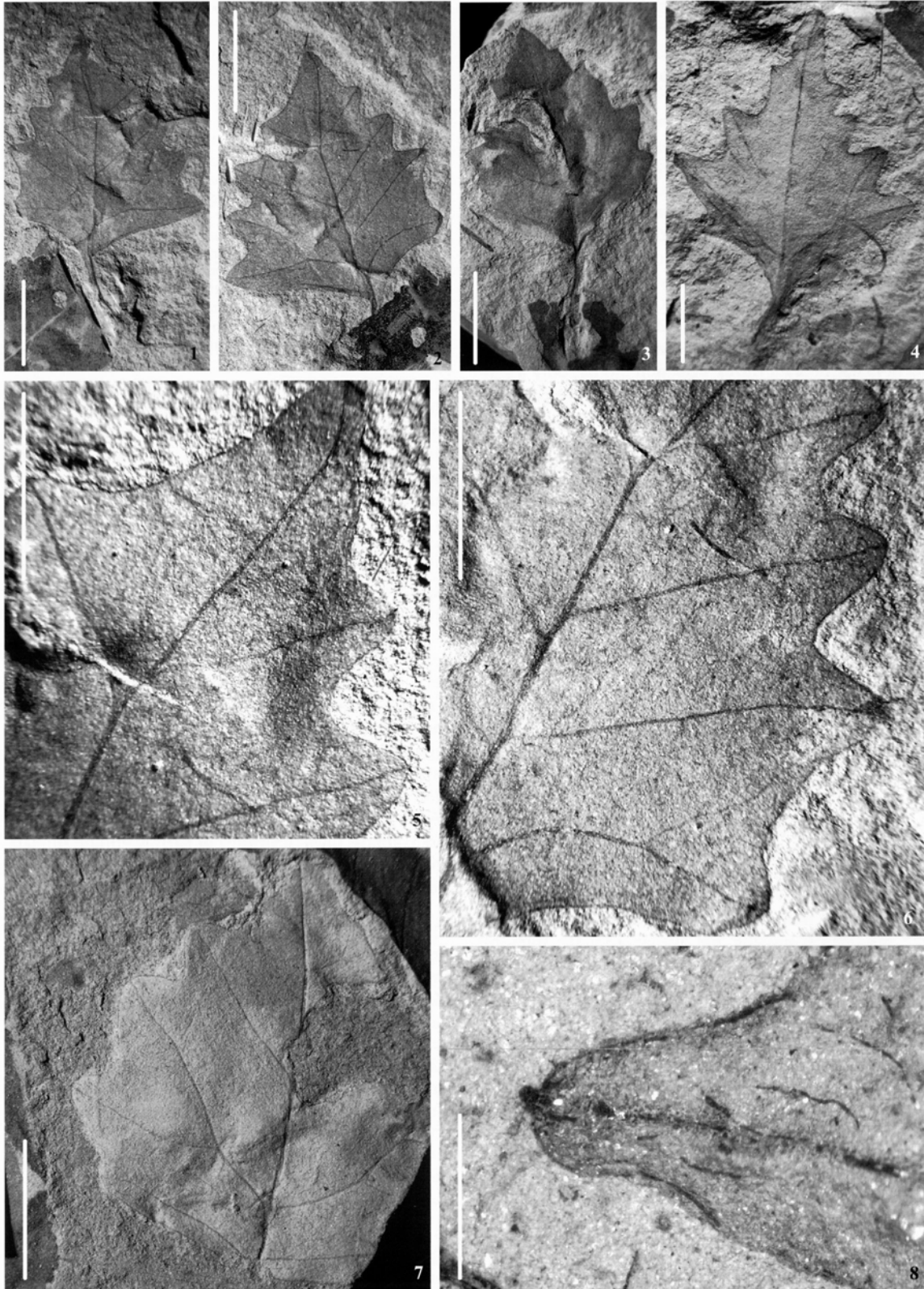
**Diagnosis:** Foliage similar to *Trapa* in its form and venation, but different in having fewer blunt teeth that end in a simple sphaerulate tip.

**Description:** Leaves petiolate, preserved portion of the petiole up to 7 mm long, slender, not swollen, lamina 15–25 mm long and 15–25 mm broad, rhomboidal, with the maximum width in the lower half, coarsely and bluntly simple dentate. Apex acute to acuminate, bluntly rounded, corresponding in its form to the marginal teeth, base widely cuneate, narrowly decurrent on the petiole. Teeth coarse, simple, symmetrical, on the apex blunt, simple sphaerulate (never with double spines),



Fig. 19. 1–8 – *Pseudotrapa buzekii* Z. Kvaček, gen. et sp. nov. 1 – holotype, NM G 8416. Bilina Mine, Horizon 36 (scale bar 10 mm). 2 – counterimpression of the holotype, BD s.n. Bilina Mine, Horizon 36 (scale bar 10 mm). 3 – complete leaf with long petiole. No. NM G 8417. Bilina Mine, Horizon 36 (scale bar 10 mm). 4 – smaller leaf, NM G 8418, Bilina Mine, Horizon 36 (scale bar 5 mm). 5 – counterimpression of the holotype, detail of the apex, DB 36–27. Bilina Mine, Horizon 36 (scale bar 5 mm). 6 – counterimpression of the holotype, detail of the base, DB 36–27, Bilina Mine, Horizon 36 (scale bar 5 mm). 7 – large leaf, DB MG(36)27, Bilina Mine, Horizon 36 (scale bar 10 mm). 8 – detail of the specimen in fig. 4 showing tooth tip and strands on veins, NM G 8418. Bilina Mine, Horizon 36 (scale bar 2.5 mm).





mostly 4 on each leaf side corresponding to the secondaries or their branches, vein entering tooth apex slightly swollen and forming a tiny rounded tip, sinuses rounded. Venation craspedodromous, midrib stout, prominent, secondaries in 3–4 pairs, partly forked, lower at wide angles, abmedially bent, higher at an angle of ca. 60°, tertiary veins very delicate, arising steeply from the secondaries and forming elongate meshes sometimes with adhering yellowish strands (? secretory ducts).

**Discussion:** This kind of foliage was first recovered at Čermníky and assigned directly to *Trapa* by Bůžek (1971, p. 72), although the apomorphic trait, the double spines on the tooth tips (Stockey – Rothwell 1997), is missing. Later on, more abundant documentation of this plant has been recovered in the Bilina Mine, Horizon 36. None of the specimens have shown double-spines on the teeth to corroborate Bůžek's opinion. So far, only a single doubtful fruit of *Hemitrapa* has been recovered in the area of the Bilina Delta in the opencast Ležáky Mine (Wójcicki – Z. Kvaček 2002b, Fig. 1). The fruits occurring in the same sedimentary complex in the Bilina Mine but in other horizons than *Pseudotrappa* differ in many respects from those of water nuts and have been assigned to an independent genus *Schenkiella* Wójcicki et Z. Kvaček (2002a). These fruits are absent from the locality of Čermníky and probably have nothing to do with *Pseudotrappa* at all. Leaves very similar to those of *Pseudotrappa buzekii* have been described as *Trapa assmanniana* (Goepf.) Gothan from the Oligocene flora of Ashutas in Kazakhstan (Kryshtofovich 1956), again not accompanied with the fruits of *Trapa* – *Hemitrapa*. These leaves differ from the northern Bohemian fossils in higher numbers of teeth (5 on each side), which are sharp. The published pictures do not show the leaf tips in detail and leave the affinity to *Trapa* open. Should this record be related to *Pseudotrappa*, it would add another phytogeographic link between Kazakhstan and central Europe in mid-Tertiary via the Turgai migration route. The other fossil leaf assigned to *Trapa* was recorded by Goepfert (1855 – see also Wójcicki – Zastawniak 2002, as *Trapa assmanniana*) from Sośnica, Late Neogene of Poland, but the specimen is missing, not available for the study of the tooth tips.

In spite of a quite similar leaf shape, the affinities of *Pseudotrappa* to *Trapa* are doubtful.

#### **Morpho-genus *Smilacinites* Z. Kvaček, morpho-gen. nov.**

**Type:** *Smilacinites ungeri* Z. Kvaček, sp. nov.

**Diagnosis:** That of the species.

**Etymology:** Referring to the similarity to *Smilacina* Desf. (currently included into *Maianthemophyllum* Weber).

#### ***Smilacinites ungeri* Z. Kvaček, sp. nov.**

Figs 20, 21

**Holotype** designated here: No. NM G 8411, illustrated in Fig. 20.1 (collections of the National Museum, Prague).

**Locus typicus:** Opencast Bilina Mine, Most Basin (northern Bohemia, Czech Republic).

**Stratum typicum:** Horizon 47 of the Holešice Member (Most Formation); Lower Miocene, Middle Burdigalian, ca. 19 to 18 Ma.

**Etymology:** Named after Franz Unger (\*1800 †1870), in recognition of his contribution to the European Tertiary palaeobotany.

**Occurrence:** At the type locality only – Bilina Mine, horizons 28 (together with *Salvinia*, *Nelumbium* and monocots), 47 (with *Salvinia*, *Azolla*, *Elephantosotis*, *Lemna*, *Hydrochariphyllum*) and 21 (with *Salvinia*, *Limnobiophyllum* and other monocots).

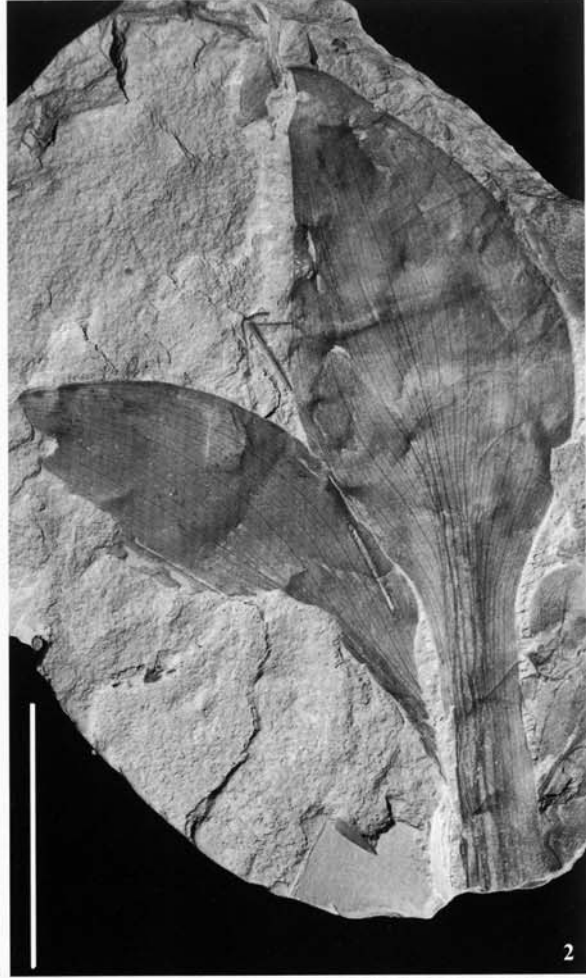
**Diagnosis:** Monocots with sheathed broad spatulate to broadly lanceolate leaves similar to *Maianthemophyllum* in venation, differing in fine dense oblique anastomoses connecting two adjacent parallel veins as well as long stout and winged petioles.

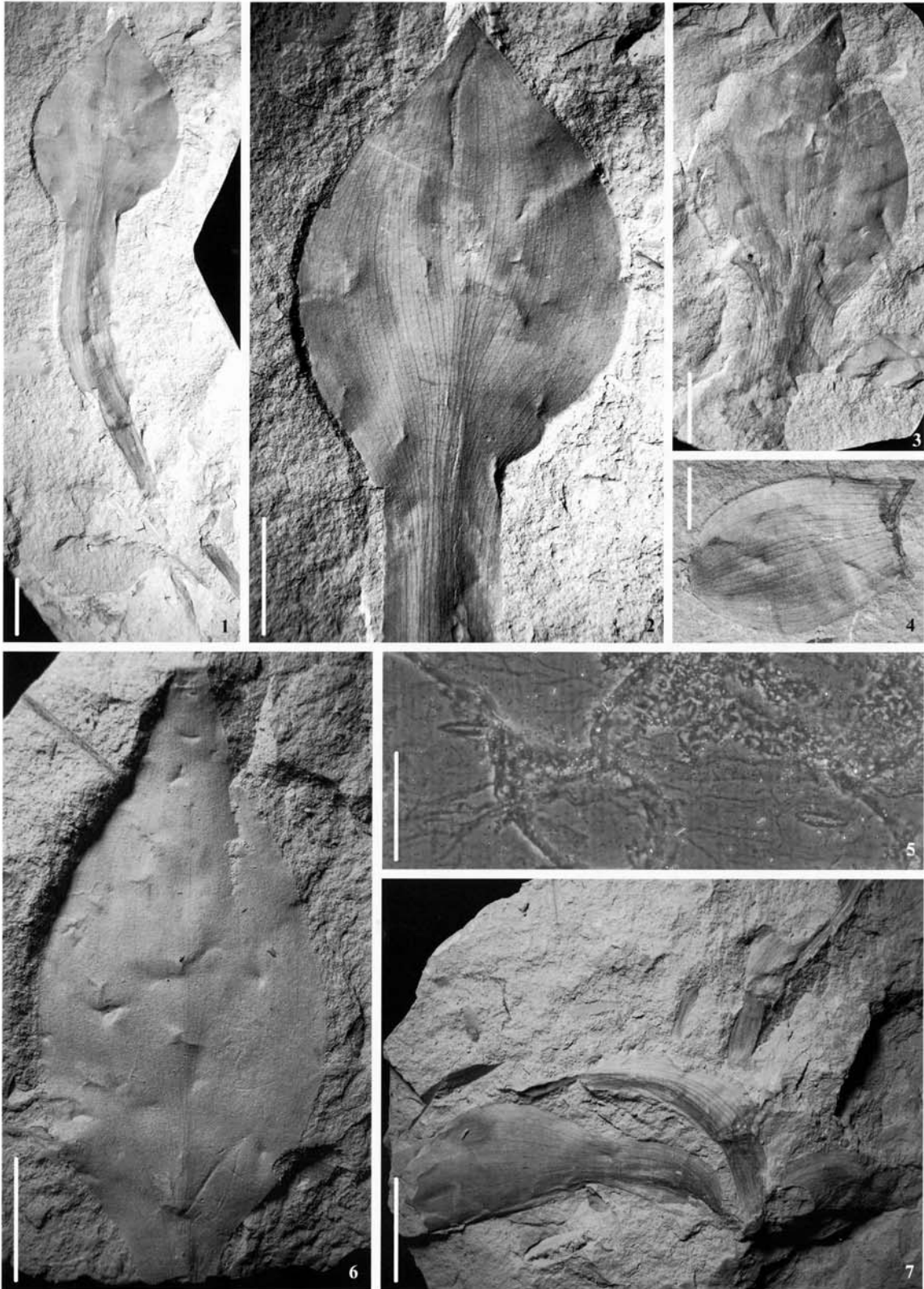
**Description:** Herbs rooted by slender short articulate rhizome and simple univeined straight root-like appendages (length incompletely preserved), with simple short axes about 0.5–1 cm thick, bearing alternate long-sheathed entire leaves with a petiole up to 8 cm long or sessile (at the base of the stem), blade broadly lanceolate to spatulate, typically 8–14 cm long and 3–6 cm wide, apex apiculate to acuminate, base widely cuneate, long decurrent passing into a very broad petiole without ocrea (Fig. 21.1), basal leaves shorter, broadly oval to suborbicular, sessile (20.1, 21.4). Venation parallel, without a prominent midrib, parallel veins vaguely differentiated in thickness into 2–3 orders, two thicker interspaced by 1–3 thinner, about 1 mm apart in the medial zone (20.3, 21.2), fine dense anastomoses of the same thickness, oblique, slightly irregular on basal leaves, and connecting two adjacent parallel veins (Fig. 20.4). Epidermal structure incompletely preserved, delicate cuticles (on collodium peels) showing longitudinally disposed, widely scattered, almost linear apertures of narrow elliptic stomata about 25–30 µm long of unknown type, without subsidiary cells preserved.

**Discussion:** In the first reports (Kvaček 1998, p. 121, Fig. 4.7), this plant was referred to as “Unidentified monocot”. A similar leaf apex was described as *Smilacina prisca* Unger (1866, Pl. 20, Fig. 1) from the Middle Miocene (Sarmatian) of Radoboj. Another, yet more incomplete leaf apex matching *Smilacinites* in its venation was briefly reported as *Pontederites hesperia* Knowlton (1922, Pl. 36, Fig. 6) from the Eocene Green River Formation in Colorado. Neither of the quoted type specimens is complete enough to be safely identified with the above described plant. *Smilacinites ungeri* is sterile and even in view of its complex characteristics not referable with certainty to a

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Fig. 20. 1–4 – *Smilacinites ungeri* Z. Kvaček, gen et sp. nov. 1 – holotype, incomplete whole plant with rhizome, NM G 8411. Bilina Mine, Horizon 47 (scale bar 10 mm). 2 – two typical aerial leaves, DB MG(47)25, Bilina Mine, Horizon 47 (scale bar 30 mm). 3 – detailed venation of aerial leaf, NM G 8412. Bilina Mine, Horizon 47 (scale bar 10 mm). 4 – Holotype, detail of the leaf venation, NM G 8411. Bilina Mine, Horizon 47 (scale bar 5 mm).





particular family of monocotyledons. The associated fossil vegetation suggests that this monocot was aerial (not submerged because of stomata – Fig. 21.5), growing as a rooted aquatic herb intermixed with sedges on borders of ox-bow lakes (Kvaček 1998, Fig. 4.7). In the growth form and habitat, it recalls *Hanguana malayana* from tropical swamps in Ceylon but the latter differs in a prominent midrib in leaves. Forest floor populations of *Hanguana* in SE Asia are rather different in their growth habit not matching the fossils studied. No other genus of the known monocotyledonous aquatic plants can be suggested as an exact equivalent. Grasses (e.g., *Arundo*) differ in having the ocrea on leaves.

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Fig. 21. 1–7 – *Smilacinites ungeri* Z. Kvaček, gen. et sp. nov. 1 – typical aerial leaf attached to the stem, NM G 8413. Bílina Mine, Horizon 47 (scale bar 20 mm). 2 – detailed venation of fig. 1, NM G 8413. Bílina Mine, Horizon 47 (scale bar 20 mm). 3 – smaller aerial leaf, DB MG(47)24. Bílina Mine, Horizon 47 (scale bar 20 mm). 4 – sessile (? submerged) leaf near the plant base, DB MG(47)26. Bílina Mine, Horizon 47 (scale bar 20 mm). 5 – cuticle with two stomata (in phase-contrast light), NM G 8419b. Bílina Mine, Horizon 47 (scale bar 50 µm). 6 – typical aerial leaf, NM G 8414. Bílina Mine, Horizon 47 (scale bar 20 mm). 7 – fragmentary plant with typical aerial leaves, NM G 8415. Bílina Mine, Horizon 47 (scale bar 20 mm).

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### Spodnomiocenní sladkovodní a bažinné ekosystémy mostecké pánve (severní Čechy) se zvláštním zřetelem k profilu dolu Bílina

Podle posledních sedimentologických a paleontologických studií je sestaven přehled různých stadií vývoje spodnomiocenních ekosystémů uvnitř mosteckého souvrství, uhlonosné výplně mostecké pánve v severních Čechách. Podařilo se rozpoznat několik typů prostředí se specifickými společenstvy rostlin a živočichů – slatinné uhlotvorné rašeliniště s nízkým přínosem živin a s hladinou spodní vody blízko nebo nad povrchem půdy vzácně dosahující stadia vrchoviště, mělké tůně mrtvých ramen s různou kvalitou vody, minerální zánětlivý močál podél přítoků a uvnitř delt pokrytý těžkými jílovitými-prachovitými půdami nerovnoměrně zásobovanými živinami a vysokou hladinou spodní vody, zaplavované deltové plošiny, říční nivy a valy s provzdušněnými písčito-jílovitými půdami dobře zásobovanými živinami a vláhou, sušší stanoviště mimo dosah záplav a rozsáhlé jezero obklopené vyvýšenými svahy. Fosilnímu záznamu rostlin, hmyzu a nižších obratlovců jsou věnovány podrobné rozborů současně se vztahy k prostředí. Připojeny jsou charakteristiky nově stanovených taxonů – Pisces: *Umbra longidorsalis* Böhme, sp. nov., Plantae: *Biliniaporites multilamellatus* Konzalová, gen. et sp. nov., *Nyssa bilinica* (Unger) Z. Kvaček, comb. nov., *Nyssa bilinica* forma *haidingeri* Z. Kvaček, forma nov., *Pseudotrappa buzekii* Z. Kvaček, gen. et sp. nov. a *Smilacinites ungeri* Z. Kvaček, gen. et sp. nov.