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A STUDY OF DISPERSED CUTICLES, FOSSIL SEEDS AND CONES FROM SARMATIAN (UPPER MIOCENE) DEPOSITS OF SOPRON-PIUSZ PUSZTA (W HUNGARY)

B. ERDEI[1] and M. LESIAK[2]

[1]*Department of Botany, Hungarian Natural History Museum*
H-1476 Budapest, Pf. 222, Hungary
[2]*W. Szafer Botanical Institute, PAN*
PL-31 512 Kraków, Lubicz str. 46, Poland

The flora of Sopron-Piusz puszta (W Hungary) excavated from layers of the upper part of Sarmatian was studied. The flora has provided dispersed cuticles, some seeds and cones, namely, taxa of Taxodiaceae, Pinaceae, Lauraceae, Buxaceae, Magnoliaceae, Rutaceae, Juglandaceae, Loranthaceae. Due to its limited number of specimens and allochthonous mode of fossilization, the flora is not suitable for detailed palaeoecological and palaeoclimatological reconstructions of the strict area, however, it has some important implications. Systematic results are discussed from taphonomical, palaeoecological and palaeoclimatological points of view.

Key words: Sarmatian, Gilbert-type delta, coalified plant debris, palaeoecology, palaeoclimatology

INTRODUCTION

In 1994 layers containing plant fossils of younger Sarmatian age came up during the excavation of the gravel quarry of Sopron-Piusz puszta (Western Hungary) (Fig. 1). Iváncsics Jenő, the chief geologist of the Transdanubian Group of the Geological Survey, called our attention to the presence of the flora. The study of the site began much earlier (in 1996) and some results were published in Hungarian (ERDEI 1996). The presented study completes these results with new findings and aims to assess its palaeoecological and palaeoclimatological implications.

The site with its coalified material is a unique one, since, other Sarmatian localities from Hungary are characterised by mostly imprints without any organic matter. It should also be mentioned that Sarmatian sites are situated mostly in northeastern Hungary, whereas, in the western part of the country only Várpalota and Sopron-Piusz puszta are known.

The site is situated in the Sopron–Kismarton basin filled with Neogene sediments. The gravel quarry is located near the eastern margin of the basin about 600 m to the west of the Kőhida-fault zone (ROSTA 1993).

Geological setting

The geological setting is discussed on the basis of ROSTA (1993) and FODOR *et al.* (1989). The oldest formations of the region are Palaeozoic crystalline rocks forming the basement of the basin (Fig. 2). The overlying rocks above a great unconformity are of Neogene since Mesozoic and Palaeogene sequences are missing. The deposition of Neogene sediments started in the Early Miocene. At the beginning of the Badenian subsidence of the region had begun but its was lower than that of sedimentation (Badenian Clay, Lajta Limestone), thus, filling up of the region took place. The Kőhida-fault zone was formed, as early as the end of the Badenian. The subsidence started again during the Sarmatian and resulted in a sedimentation similar to that of the Badenian. It was during the middle part of the Sarmatian when uplift of the frame of the Sopron–Kismarton basin started. Sand and gravel characterised the Upper Sarmatian deposits and finally the stage ended with a regression. During the Early Pannonian due to the repeated subsidence of the basin lacustrine sediments of great thickness were deposited. In the middle part of the Pannonian the area became subaerially exposed and Pleistocene sedimentation was characterised by sandy and clayey loess and gravel.

ROSTA (1993) recognised a Gilbert-type delta in the Miocene of the region (Fig. 3). In the 30 m thick sequence she has identified 7 facies based on petrological, sedimentological and palaeontological characteristics (Fig. 4). The sequence represents two cycles of a Gilbert-type delta having the second one incomplete. The "A" facies of the prodelta is constructed of mainly unsorted sandy gravel interfingered by laminated coaly clay streaks of 1–10 cm thickness. These layers consist the plant debris being likely to have originated from the delta plain represented by "D" and "E" facies. "B" and "C" facies are identified as the deltafront. "F" facies is a new deltafront covered discordantly with open water sediments ("G" facies). According to molluscs, ostracods and foraminifers the "A"–"E" facies are of Sarmatian (Late Sarmatian) age. In facies "F" the appearance of Lower Pannonian ostracods is recorded.

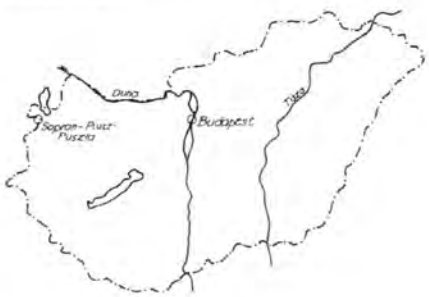


Fig. 1. Geographical position of the site.

MATERIAL AND METHODS

In addition to the coalified plant debris representing mostly the fossil material of the site there are few macroscopically recognisable remains, namely, some

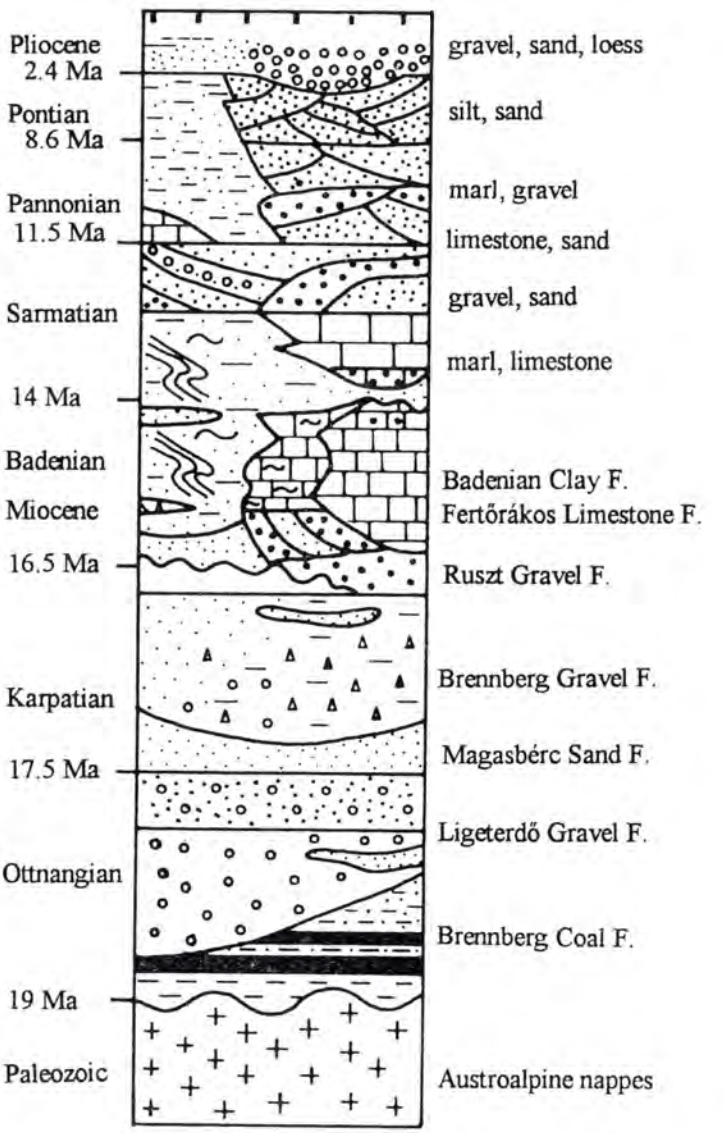


Fig. 2. Stratigraphic column of the Sopron–Kismarton basin (after FODOR *et al.* 1989).

cones and seeds. Due to the mode of preservation mainly "cuticula dispersae" observations of the coalified organic debris that remained after washing out of the sediments were carried out.

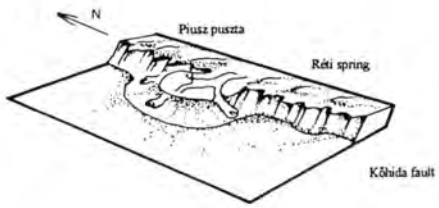


Fig. 3. Palaeogeographical reconstruction of the eastern margin of the Sopron-Kismarton basin in the "Upper" Sarmatian. The sedimentation took place in Gilbert-type delta in the northern part and in steep coastal environment in the south (after ROSTA 1993).

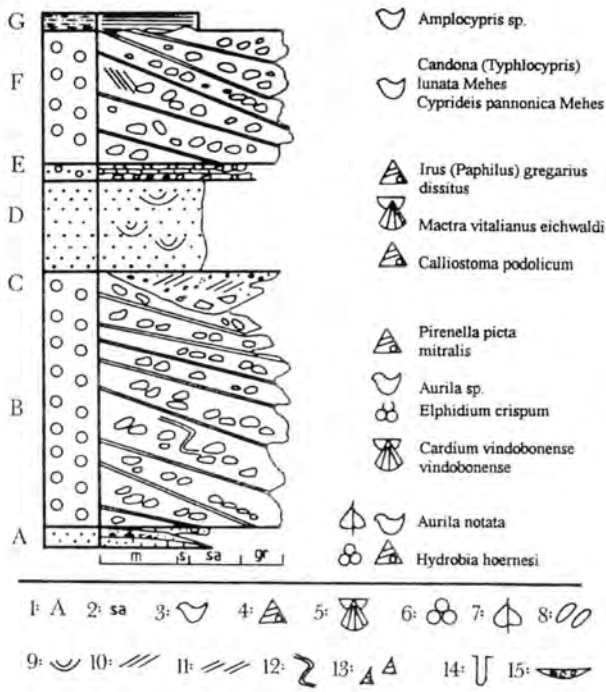


Fig. 4. Stratigraphic column of the Piusz puszta quarry representing a Gilbert-type delta. Facies "A" means the prodelta, the facies "B" and "C" are considered as the deltafront, the delta plain is characterized by the facies "D" and "E", overlain by the new deltafront (facies "F"). The uppermost facies "G" was deposited in off-shore environment. 1. facies name, 2. grain size, m = mud, clay, s = silt, sa = sand, gr = gravel, 3. ostracod, 4. gastropod, 5. bivalve, 6. foraminifer, 7. plant debris, 8. imbrication, 9. through cross-stratification, 10. planar cross-stratification, 11. foresets, 12. slide, 13. rip-up clasts, 14. trace fossils, 15. channel (after ROSTA 1993).

Small amounts of plant debris after having been washed out were placed in *cc.* HF for a day or more if it was required. Then fragments were treated due to poor preservation with HNO_3 (*cc.* or sometimes diluted solution) instead of Schultze's solution and then with a 5% solution of KOH. Finally they were mounted in glycerine.

By the morphological descriptions DILCHER's (1974) and ELSIK's (1983) terminology was followed.

SYSTEMATIC PART

MYCOPHYTA (Ascomycetes)
Trichothyriaceae

Trichothyrites sp.
(Fig. 5)

1978 *Trichothyrites* sp.; ELSIK, p. 336, Text-fig. 3. L.
Material: BP 99.511.1.

Description: The stroma attached to a dispersed cuticle is radially constructed with ostiolum in the centre. Its diameter is 180 μm. Hyphae and spores were not found. The cuticle is rather degraded. Because of the absence of stomata its closer affinities cannot be defined.

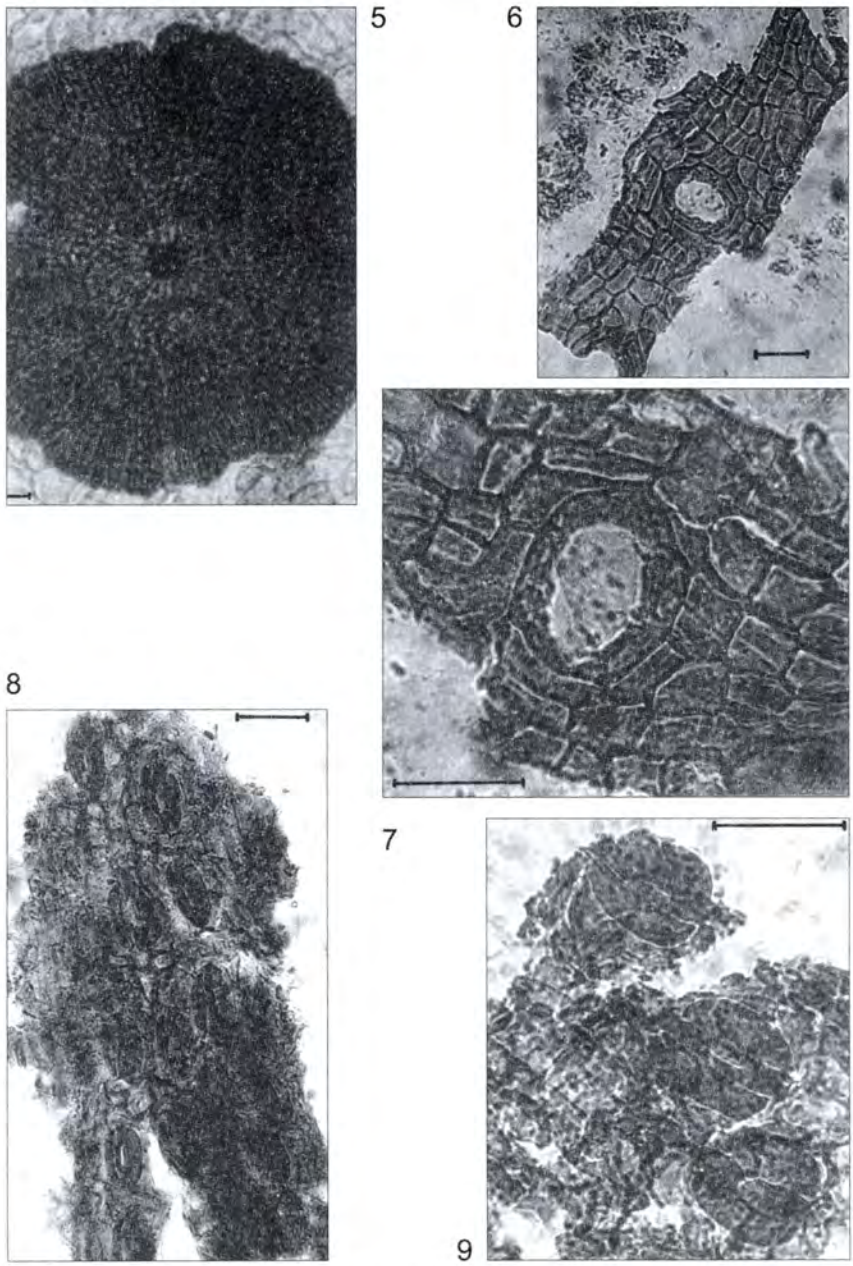
Discussion: Fossil remains of the *Trichothyrites* genus represent a new taxon in our Sarmatian floras. Fossil remains of the genus are known from deposits ranging from Eocene to Pleistocene (ELSIK 1978). *Trichothyrites* fruiting bodies often occur on *Buxus pliocenica* Sap. et Mar. leaves coming from the Pliocene flora of Gérce (W Hungary).

Most recent species of the family are tropical and parasitic on the stroma or mycelium of other microscopic epiphyllous fungi (BÁNHEGYI *et al.* 1985).

GYMNOSPERMATOPHYTA
Taxodiaceae
Taxodiaceae gen. et sp. 1

Material: BP 99.496.1.

Description: Cuticle is of medium thickness. Cells are isodiametric, only marginal cells seem to be a bit elongated. Length of cells is 43.7–87.5 μm, width is



Figs 5–9. – **5** = *Trichothyrites* sp. fruiting body, BP 99.511.1. (scale bar = 10 μm), – **6** = Gymnospermae gen. et sp. indet., BP 99.500.1. (scale bar = 50 μm). – **7** = the same, (scale bar = 50 μm). – **8** = Taxodiaceae gen. et sp. 2. cuticle with stomata, BP 99.499.1. (scale bar = 50 μm). – **9** = Taxodiaceae gen. et sp. 2. cuticle with stomata, BP 99.497.1. (scale bar = 50 μm).

22.5–37.5 μm. Anticlinal cell walls are strongly thickened. Stomata are randomly arranged and their shape is more circular than that of the other specimens. The guard cells and stomatal pores with their 48–53 μm and 18.75–37.5 μm length are considerably large. Type of stomata is cyclocytic with one subsidiary cell on one pole and two subsidiaries on the other. Guard cells are sunken. Outer stomatal ledge is strongly thickened and sometimes weakly developed T-shaped thickenings are noticeable.

Taxodiaceae gen. et sp. 2
(Figs 8–9)

Material: BP 99.497.1; BP 99.498.1; BP 99.499.1.

Description: Fragments of cuticles are of medium thickness. Due to poor preservation the anticlinal cell walls are hardly observable. Stomata are more elongated and their arrangement seems to be more regular than that of the specimen No. BP 99.496.1 of Taxodiaceae gen. et sp. 1, but not parallel. The length of guard cells (outer stomatal ledge) is 47–52 μm, their width is 31.3–37.5 μm. The length of stomatal pores in specimens No. BP 99.497.1 and BP 99.499.1 are 12.5–21.3 μm and 20–25 μm, respectively. The latter one seems to have larger stomatal pores, however, it should be taken into consideration that the latter fragment must have been strongly compressed, since the stomata are also narrower and more elongated. Type of stomata is cyclocytic with sunken guard cells. Well developed, T-shaped thickenings are striking.

Discussion: Stomata of *Taxodium dubium* (Sternb.) Heer described from the Pliocene flora of Ruszów by HUMMEL (1983, p. 15, Pl. 2, Figs 1–6) are well comparable. According to the description made by HUMMEL, leaves are amphistomatic, orientation of stomata is variable but generally their longitudinal axis is not parallel with that of the leaf. Type of stomata is amphi- or monocyclocytic. Stomata are sunken and the outer stomatal ledge forms a thickened annulus on the surface of the epidermis. T-shaped thickenings are often developed but not generally present (HUMMEL's opinion is that the presence of T-shaped thickenings depends also on the degree of maceration). FERGUSON (1971) described some *Taxodium* remains (Pl. 2, Figs E–F) from the Miocene flora of Kreuzau and remarked that species of Taxodiaceae provide very similar characteristic features of the cuticle, however, that of *Taxodium* and *Glyptostrobus* are distinguishable. Stomata of *Glyptostrobus* are mostly arranged parallel to the longitudinal axis of the leaf, but those of *Taxodium* are either aligned transversely to the length of the leaf or orientated in various directions. Unfortunately, the cuticle

fragments discussed here are too small to define the exact arrangement and position of stomata.

Gymnospermae gen. et sp. indet.
(Figs 6–7)

Material: BP 99.500.1.

Description: The cuticle is of medium thickness and constructed of isodiametric cells the length and width of which are 16.3–33.8 μm and 15–25 μm, respectively. Anticlinal walls are straight, uniformly thickened and sometimes weakly rounded. The construction of the one and only stoma (and the remains of two others at the margin of the cuticle) which is much bigger than the epidermal cells proves its gymnospermous affinities. Presumably, the arrangement of stomata is parallel with the longitudinal axis of epidermal cells. Type of stomata must have been cyclocytic with 6 subsidiary cells surrounding the 50 μm long stomatal pore. Subsidiaries are smaller than epidermal cells. Unfortunately, guard cells have fallen out during fossilization or preparation.

ANGIOSPERMATOPHYTA
Magnoliaceae

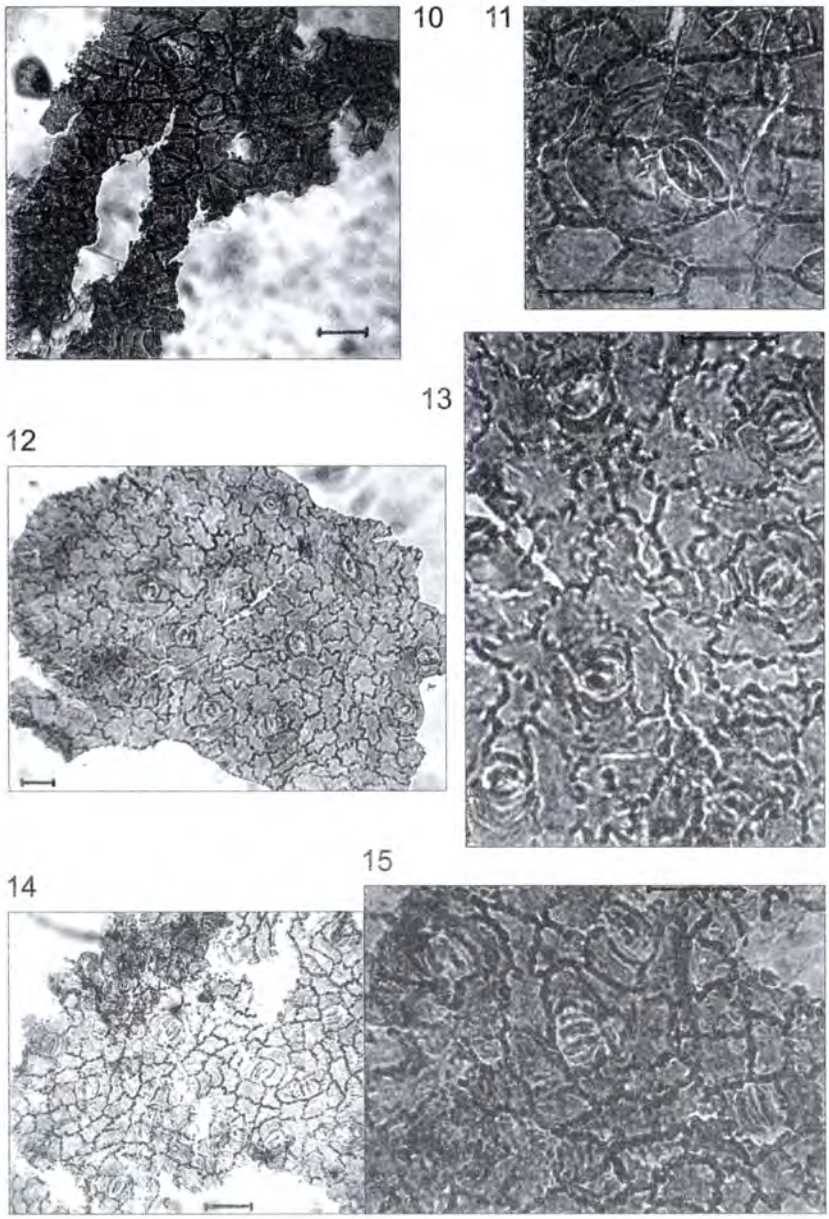
Magnolia liblarensis (Kräusel et Weyland 1959) Kvaček 1979
(Figs 16–17)

1959 *Papilionaceophyllum liblarense* Kräusel et Weyland; KRÄUSEL and WEYLAND, p. 111, Taf. 24, Figs 37–41; Taf. 25, Figs 42–47; Taf. 26, Fig. 48, Abb. 10–11.

1979 *Magnolia liblarensis* (Kräusel et Weyland) Kvaček; KVAČEK, p. 172, Pl. 37, Figs 2–5.

Material: BP 99.501.1.

Description: A thin cuticle with isodiametric cells. Anticlinal cell walls are hardly to be seen, but epidermal cells seem to be pentagonal or hexagonal and the weakly thickened cell walls are presumably undulating. The arrangement of the heavily compressed stomata is random. The length and width of a relatively better preserved stoma is 25 μm and 22.5 μm, respectively. Stoma type appears to be anomocytic (however, in fact it is paracytic, see in KVAČEK 1979). There are numerous, considerably thickened, round shaped formations to be recognised on the cuticle which represent simple hair bases (modified hair base cells are not observable). Unfortunately, there is no hair remained. A secretory body together with the



Figs 10–15. – **10** = *Laurophyllum* sp. cuticle with stomata, BP 99.504.1. (scale bar = 50 μm). – **11** = The same (scale bar = 50 μm). – **12** = *Laurophyllum pseudoprinceps* Weyland et Kilpper cuticle with stomata, BP 99.503.1. (scale bar = 50 μm). – **13** = The same (scale bar = 50 μm). – **14** = *Laurophyllum pseudoprinceps* Weyland et Kilpper cuticle with stomata, BP 99.502.1. (scale bar = 50 μm). – **15** = The same (scale bar = 50 μm).

hair bases being characteristic of the species well corresponds to the presumed affinity. Its diameter is 62.5 μm and the drop itself is an amorphous one without any crystalline or regular structure.

Discussion: KVAČEK (1979) has described the species from the European Tertiary with the remarks that subepidermal secretory bodies and hair bases are very typical of the species. Earlier the species had been described as *Papilionaceophyllum liblarense* by KRÄUSEL and WEYLAND (1959). The species is characteristic of the Upper Miocene and Pliocene. Among others, it has also been recorded from Pannonian and Lower Pliocene deposits of Romania and from Miocene lignits of Rhineland, Lausitz. It is possible that seeds described by MAI as *Magnolia lignita* represent the same species (KVAČEK 1979).

Lauraceae

Laurophyllum pseudoprinceps Weyland et Kilpper 1963 (Figs 12–15)

1963 *Laurophyllum pseudoprinceps* Weyland et Kilpper; WEYLAND and KILPPER, p. 100, Pl. 23, Figs 14–19, Text.-fig. 6.

1976 *Laurophyllum pseudoprinceps* Weyland et Kilpper; KNOBLOCH and KVAČEK, p. 51, Taf. 26, Figs 5–8.

1988 *Laurophyllum pseudoprinceps* Weyland et Kilpper; KVAČEK, p. 348, Pl. 2, Fig. 5.

Material: BP 99.502.1; BP 99.503.1.

Description: Cuticle fragments of medium thickness with several stomata. The size of the isodiametric cells ranges between 20–50 μm. Their arrangement is pentagonal and hexagonal. The anticlinal cell walls are weakly undulating and thickened. The randomly arranged stomata are 25–32 μm long and 20–25 μm wide. Type of stomata is paracytic, or brachyparacytic. Subsidiary cells are of similar size as epidermal cells. Length of stomatal pore is 6–10 μm. The outer stomatal ledge is considerably thickened.

Discussion: Characteristic features of the species are wide stomata of paracytic type with thickened outer stomatal edge and the type of epidermal cell wall thickenings. According to KVAČEK (1988) the type of stomata is in fact amphibrachyparacytic. There are several records of the species, *e. g.* from the Bohemian Miocene (KNOBLOCH and KVAČEK 1976), from Austria (KOVAR-EDER 1982) and from Germany (MAI and WALTHER 1978).

Since the shape of stomata of *L. pseudoprinceps* is similar to that of *Ocotea* Aubl. species, it is often assigned, as a possibility, to the fruits of that genus (BŮŽEK *et al.* 1996).

Laurophyllum sp.
(Figs 10–11)

Material: BP 99.504.1.

Description: A cuticle fragment of medium thickness. Length and width of the isodiametric cells are 28–50 μm and 17–32 μm, respectively. Their arrangement is pentagonal, sometimes hexagonal. Anticlinal cell walls are straight and heavily thickened. The randomly arranged stomata are 25–31 μm long and 13–15 μm wide, respectively. Stomatal pore is mostly of 10 μm. Type of stomata seems to be paracytic.

Loranthaceae
Viscophyllum sp.
(Figs 14–16)

Material: BP 99.498.1; BP 99.505.1.

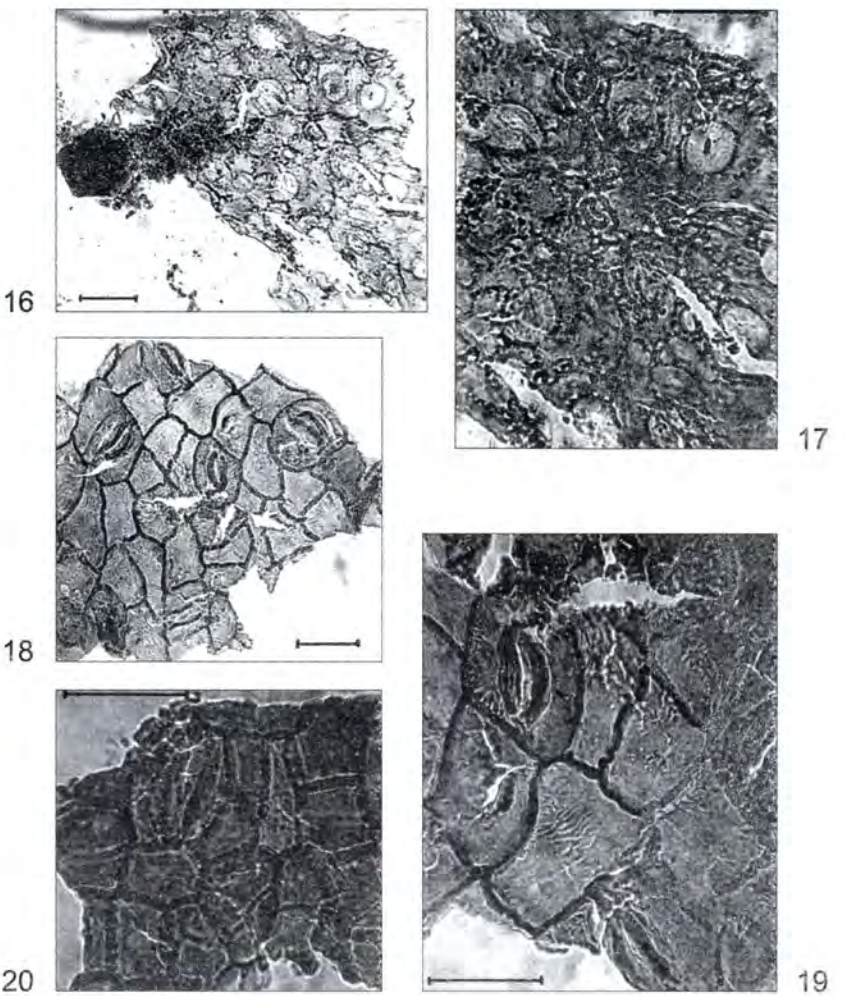
Description (BP 99.498.1): A relatively thick cuticle with isodiametric cells. The arrangement of the 22.5–43.8 μm long and 15–31.3 μm wide cells is pentagonal. The anticlinal walls are straight and heavily thickened. There is only one stoma preserved of considerably great size, its length and width are 50 μm and 25 μm, respectively. Its type seems to be paracytic.

Description (BP 99.505.1): Relatively thick cuticle with isodiametric cells the length and width of which show greater values than the previous one, 50–87.5 μm and 31.3–50 μm. Their arrangement is pentagonal or hexagonal. Anticlinal cell walls are straight and uniformly thickened. The randomly orientated stomata (guard cells) are 37.5–50 μm long and 18–19 μm wide, respectively. Length and width mesaured together with the subsidiary cells are 56–62.5 μm and 35–44 μm, respectively. Length of stomatal pore ranges between 20–27.5 μm. Type of stomata is paracytic, however, in several cases it appears to be peri- or desmocytic.

Discussion: Based on the structure of the epidermis and the dimensions of stomata it is assigned surely to Loranthaceae (*Viscum*). Several *Viscum* remains are known from the literature. First of all *Viscum morlotii* (Ung.) Knobloch et Kvaček (KNOBLOCH and KVAČEK 1976, p. 67, Taf. 33, Figs 4–11) is to be mentioned from the Bohemian Miocene, and from the floras of Wiesa, Turow, Düren, Kreuzau.

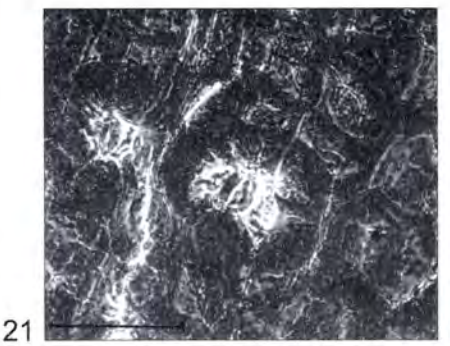
Buxaceae
Buxus pliocenica Saporta et Marion 1876
(Figs 23–24)

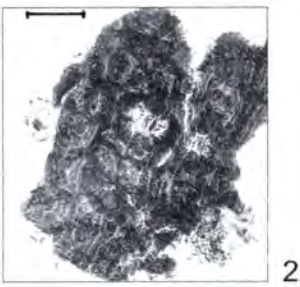
1982 *Buxus pliocenica* Saporta et Marion; KVAČEK *et al.*, p. 383, Pl. 4, Figs 1–4.
1997 *Buxus pliocenica* Saporta et Marion; HABLY and KVAČEK, p. 46, Pl. 33, Fig. 173.
Material: BP 99.506.1; BP 99.507.1.



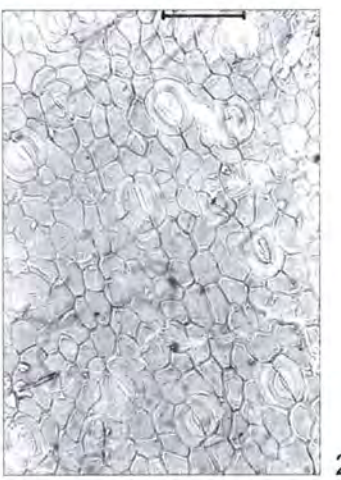
Figs 16–20. – **16** = *Magnolia liblarensis* (Kräusel et Weyland) Kvaček cuticle with stomata, characteristic hair bases and a secretory body, BP 99.501.1. (scale bar = 50 μm). – **17** = The same (scale bar = 50 μm). – **18** = *Viscophyllum* sp. cuticle with stomata, BP 99.505.1. (scale bar = 50 μm). – **19** = The same (scale bar = 50 μm). – **20** = *Viscophyllum* sp. cuticle with a stoma, BP 99.498.1. (scale bar = 50 μm).

Description (BP 99.506.1): The cuticle is of medium thickness with presumably isodiametric anticlinal walls. Their arrangement seems to be pentagonal. Anticlinal cell walls are straight and weakly thickened. Stomata are randomly ar-


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Figs 21–26. – **21** = *Wackersdorfia dubia* Peters cuticle with a stoma, BP 99.508.1. (scale bar = 50 μm). – **22** = The same (scale bar = 50 μm). – **23** = *Buxus pliocenica* Saporta et Marion cuticle with stomata, BP 99.507.1. (scale bar = 50 μm). – **24** = *Buxus pliocenica* Saporta et Marion cuticle with stomata, BP 99.506.1. (scale bar = 50 μm). – **25** = *Dicotylophyllum* sp. 1. cuticle with stomata, BP 99.509.1. (scale bar = 50 μm). – **26** = *Dicotylophyllum* sp. indet. cuticle, BP 99.510.1. (scale bar = 50 μm).

ranged. Length and width of stomata are 28.8–37.5 μm and 20–28.8 μm, respectively. Stomatal pore is 12.5 μm long. Type of stomata seems to be anomocytic. The outer stomatal ledge is heavily thickened.

Description (BP 99.507.1): Thin cuticle with isodiametric cells. The hardly recognizable anticlinal cell walls are straight and thickened. The length and width of the randomly orientated stomata are 22.5–25 μm and 15–18.8 μm, respectively. Their smaller size may be attributed to its strongly compressed state. Length of stomatal pore ranges between 6.3–12.5 μm. Type of stomata cannot be accurately defined due to preservation.

Discussion: According to KVAČEK *et al.* (1982) stomata seem to be anomocytic, however, since the lateral subsidiary cells are sunken, they should be defined as cryptolaterocytic.

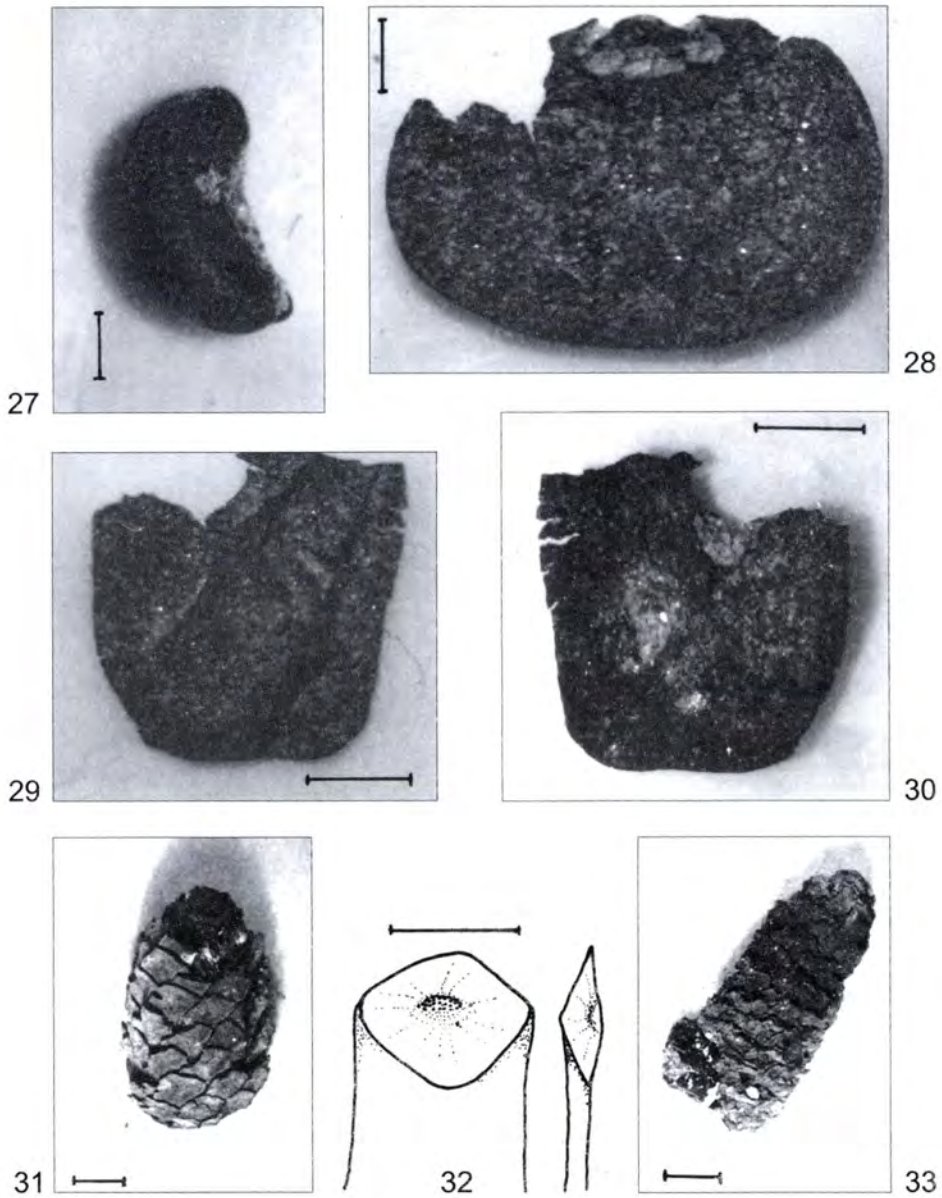
In Hungary, *Buxus pliocenica* fossils (with cuticles) were described from the Pliocene alginite flora of Gérce, as the one and only evergreen element of the Mixed Mesophytic Forest (FISCHER and HABLY 1991). In Eurasia, *Buxus* leaf fossils are known from Tertiary and Quaternary deposits, first of all from Central and Eastern Europe (Stare Gliwice, Moravská Nová Ves, KVAČEK *et al.* 1982; Willershausen, STRAUS 1969), Turkey, Georgia and from Kazakhstan. Based on fossils from Tertiary deposits, two main European lineage are distinguishable (KVAČEK *et al.* 1982). The more primitive and extinct lineage is that of *Buxus egeriana* Kvaček, Bůžek et Holý. The second one, *Buxus pliocenica* Sap. et Mar., characterised by smaller leaves, comes from younger sediments, from the Middle and Upper Miocene.

Considering the ecological requirements of *Buxus*, most species favour rather open areas with at least 800 mm annual mean precipitation, but they are well adapted to a seasonal climate. Exceptionally, they enter semiarid to arid regions (KVAČEK *et al.* 1982).

?Lauraceae, ?Helobiae
Wackersdorfia dubia Peters 1963
(Figs 21–22)

1963 *Wackersdorfia dubia* Peters; PETERS, p. 9, Taf. 2, Figs 10–14.
Material: BP 99.508.1.

Description: A thick cuticle with presumably isodiametric cells. Anticlinal cell walls, if observable, are straight and heavily thickened. Some stomata are recognizable, but their type cannot be identified. Length and width of the randomly



Figs 27–33. – **27** = *Toddalia* sp. seed, BP 99.512.1. (scale bar = 1 mm). – **28** = *Magnolia* sp. seed, BP 99.515.1. (scale bar = 1 mm). – **29** = *Pterocarya limburgensis* C. et E. M. Reid fragment of endocarpium, BP 99.514.1. (scale bar = 1 mm). – **30** = The same (scale bar = 1 mm). – **31** = *Pinus salinarum* (Partsch) Zabłocki cone, BP 99.516.1. (scale bar = 1 cm). – **32** = *Pinus salinarum* (Partsch) Zabłocki cone scale, BP 99.516.1. (scale bar = 0.5 cm). – **33** = ?*Picea* sp. cone, BP 99.525.1. (scale bar = 1 cm).

arranged stomata are 15–17.5 μm and 7.5–15 μm, respectively. Outer stomatal ledges are thickened.

Discussion: It was described from Miocene brown coal deposits (Wackersdorf) by PETERS (1963). It was assigned with a question mark to *Helobiae*. However, JÄHNICHEN (manuscript) identified it as the cuticle of the exocarp of *Ocotea rhenana* Menzel and, moreover, he did not exclude the possible affinity with the recent *Ocotea foetens* Benth. et Hook. (Canary Islands).

Dicotylophyllum sp. 1
(Fig. 25)

Material: BP 99.509.1.

Description: The cuticle is of medium thickness with 15–25 μm long and 10–18.8 μm wide isodiametric cells. Their arrangement is pentagonal and hexagonal. Anticlinal cell walls are straight and the surface of the cuticle is wrinkled. Stomata are randomly orientated. Length and width of stomata are 15–27.5 μm and 18.8–22.5 μm, respectively. Stomatal pores are closed and very narrow with a length of about 10 μm. The type of the subsidiary cells around the guard cells cannot be accurately defined.

Discussion: The wrinkled surface of the cuticle recalls the cuticle of *Illipophyllum thomsoni* Kräusel et Weyland (KRÄUSEL and WEYLAND 1959, Taf. 28, Fig. 71; Taf. 29, Figs 72–75), assigned to the family Sapotaceae.

Dicotylophyllum sp. indet.
(Fig. 26)

Material: BP 99.510.1.

Description: The cuticle is thin with isodiametric cells arranged hexagonally and polygonally. Anticlinal cell walls are thin and weakly undulate. Cuticle is poorly preserved and stomata may have fallen out during fossilization or preparation.

Discussion: The structure of the cuticle recalls the family Lauraceae.

CONES AND SEEDS

GYMNOSPERMATOPHYTA

Pinaceae

Pinus salinarum (Partsch 1847) Zabłocki 1928
(Figs 31–32)

1928 *Pinus salinarum* (Partsch) Zabłocki; ZABŁOCKI, p. 184, Taf. 7, Figs 1–4.
1986 *Pinus salinarum* (Partsch) Zabłocki; MAI, p. 580, Taf. 45, Figs 3–5, Abb. 2.
Material: BP 99.516.1; BP 99.517.1; BP 99.518.1; BP 99.519.1; BP 99.520.1.

Description: Several poorly preserved cones among which only one specimen shows the characteristic asymmetric shape of the species. The length and width of the cones are 4.5–6.5 cm and 3–3.5 cm, respectively. Their shape is ovate and their apex is slightly rounded. The cone scales are 0.8–1 cm long and 1–1.5 cm wide. The apophysis is strongly flattened and seems to be hexagonal, sometimes quadrangular. Umbo is small, round and mucronate. Mucro is small and round.

Discussion: The species belonging to *Diploxylon* Koehne Sect. *Halepensis* Loudon represents a new taxon in the Hungarian fossil floras. Similar fossils are known from several European Middle Miocene floras (Wieliczka, Stare Gliwice, Goljany).

Pinus halepensis Mill. serves well as a modern equivalent of the fossil species. It is a Western Mediterranean element occurring in Spain, North Africa, and Asia Minor at elevations lower than 750 m above the sea level (MAI 1986).

?Picea sp.
(Fig. 33)

Material: BP 99.521.1; BP 99.522.1; BP 99.523.1; BP 99.524.1; BP 99.525.1; BP 99.526.1; BP 99.527.1; BP 99.528.1; BP 99.529.1; BP 99.530.1.

Description: Unfortunately, a more exact identification of the rather poorly preserved cones is impossible. Their length and width range between 4–6 cm, and 2–2.5 cm, respectively. Shape of the cones is ovate. The heavily damaged cone scales are striped and their margin seems to be entire.

Discussion: The first occurrence of the *Picea* A. Dietr. genus in Central Europe is recorded from the Lower Oligocene and later during the Upper Miocene and Pliocene its remains appear more and more frequently. The occurrence of this genus generally suggests an equalised and cooler climate (MAI and WALTHER 1988). The species belonging to this genus are evergreen and occur in forests of

cooler or higher regions of the temperate and subtropical areas of the Northern Hemisphere. Species of southerly distribution require relatively humid climate, whereas, the northern species are quite resistant even at higher rates of continentality. Nearly half of its species are known from West- and Middle China (KRÜSSMANN 1960).

ANGIOSPERMATOPHYTA

Magnoliaceae

Magnolia sp. (*M. cor* Ludwig?)

(Fig. 28)

Material: BP 99.515.1.

Description: The length and width of the somewhat heart-shaped seed is 5 mm and 7 mm, respectively. The chalaza region is convex with clearly observable heteropyle and condylus. Testa is smooth.

It shows great similarity to *M. cor* Ludwig (MAI 1975, p. 564, Taf. 33, Figs 1–7).

Discussion: Fossil seeds of *Magnolia* are frequently found members of fossil floras. *Magnolia cor* Ludwig has been described from several Pliocene and Pleistocene floras as well, however, it represents a new member of the Hungarian fossil floras. As modern equivalents, first of all *Magnolia stellata* (Sieb. et Zucc.) Maxim. and *M. salicifolia* Maxim. are mentioned (MAI 1975). Both species occur in the mixed mesophilous forests of Middle China and Japan (MAI 1975).

Juglandaceae

Pterocarya limburgensis C. et E. M. Reid 1915

(Figs 29–30)

1915 *Pterocarya limburgensis* C. et E. M. Reid; REID and REID, p. 73, Taf. 4, Figs 15–21.

1997 *Pterocarya limburgensis* C. et E. M. Reid; MAI and PALAMAREV, p. 486, Taf. 1, Fig. 8; Taf. 2, Figs 6, 8.

Material: BP 99.514.1.

Description: A small fragment of an endocarpium which is 3 mm long and 2.5 mm wide. Some ribs are clearly observable.

Discussion: The species is also known from the Pannonian lignite flora of Bükkábrány (LÁSZLÓ 1989). In addition, the species was described from numerous European fossil floras, among others from the Pliocene floras of Swalmen,

Brunssum and Tegelen and from the Miocene floras of Stare Gliwice, Baldevo and Balscha (MAI 1995). MAI and PALAMAREV (1997) mention a Chinese species, *Pterocarya hupehensis* Skan as a possible modern equivalent of the fossil one.

Rutaceae
Toddalia sp. (T. ?*maii* Gregor)
(Fig. 27)

Material: BP 99.512.1.

Description: The seed is kidney-shaped, its length is 4 mm with a height of 2 mm and a breadth of 1.2 mm. Hylum and chalaza regions are clearly observable.

Discussion: The kidney-shaped seed may represent the small-sized group of *Toddalia* seeds the members of which are *T. maii* Gregor, *T. maerkeri* Gregor and *T. excavata* (Chandler) Gregor occurring frequently in the Miocene of Central Europe (GREGOR 1984). The European occurrence of the genus with its 8 fossil species ranges from the Upper Eocene to the Lower Pliocene (MAI and PALAMAREV 1997). This is the first (and only) record of the genus from Hungarian fossil floras.

T. asiatica (L.) Lam. is mentioned generally as a modern equivalent of the fossil species. The monotypic *Toddalia* Jussieu genus, regarded as an indicator of warm and humid climate, is a member of evergreen and mixed mesophilous forests in Southwestern Africa, Madagascar, Mauritius, India, the Himalayas, Sumatra, Java, Borneo, the Philippines, Taiwan, Southern Japan and in the southeastern regions of China (GREGOR 1979).

DISCUSSION

Although the flora presented from Sopron-Piusz puszta, due to its limited number of specimens and allochthonous mode of fossilization, is not suitable for detailed palaeoecological and palaeoclimatological reconstructions of the strict area, it has some important implications. Since the flora has been fossilized in delta plain sediments and its material must have been deposited from a great catchment area, it may point to some of the diversity of the vegetation surrounding the river bank. According to GASTALDO *et al.* (1989) delta plain sediments and deposits of rivers with extensive catchment area may provide a good picture about the diversity of the former vegetation. However, in the case of Sopron-Piusz puszta an accurate palaeoecological evaluation is hindered first of all by the small number of fossil remains.

The heavily fragmented leaves and poorly preserved seeds suggest long transportation routes. Cones are relatively well preserved which may be attributed to shorter transport or rather to their more resistant woody structure concerning the processes of fossilization and transport.

Gymnosperms (47.2%) and angiosperms (50.9%) are represented with nearly the same proportions, however, this may be a distorted picture due to the resistant structure of gymnosperm cuticles. With these remarks in mind some palaeoecological and palaeoclimatological implications of the flora are concluded as follows.

Leaf fragments, seeds and cones from Sopron-Piusz puszta represent several vegetation types which thrived even at a great distance from each other. The occurrence of some taxa refers to certain vegetation types. The presence of taxodiaceous plants and *Pterocarya* may suggest a swampy or riparian vegetation. Lauraceous taxa, *Toddalia* and *Magnolia* presumably contributed to the formation of mixed mesophilous forests. *Pinus salinarum* based on its Mediterranean affinities, refers to a forest appearing in relatively dry conditions compared to the forest types mentioned above. *Buxus pliocenica* suggests rather mesophilous conditions, that is to say, it is more likely to have turned up in a mixed, but at least partly open, mesophilous forest. The stroma of *Trichothyrites* refers to humid, subtropical conditions (PHADTARE 1989).

From a palaeoclimatological point of view it is important to emphasize the occurrence of a thermophilous element, namely *Toddalia*, from the "Late" Sarmatian (or more precisely, the upper part of Sarmatian) Sopron flora. The palaeoclimatological implications of the flora are in agreement with the results of the palaeoclimatological reconstruction of other Hungarian Sarmatian floras (ERDEI 1999). The Sarmatian floras of Erdőbénye (Kővágó-oldal, Barnamáj, Ligetmajor), Tállya and Felsőtárkány from the northeastern part of Hungary suggest a warm temperate climate with 13–15 °C mean annual temperature and at least 800–1000 mm mean annual precipitation. The flora of Sopron corresponds well with these results. More or less similar climatic values must have been characteristic of the palaeoflora in both regions.

* * *

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REFERENCES

BÁNHEGYI, J., TÓTH, S., UBRIZSY, G. and VÖRÖS, J. (1985): *Magyarország mikroszkopikus gombáinak határozókönyve.* 2. Eumycotina (Ascomycetes: A Discomycetestől, Basidiomycetes, Deuteromycetes). (A dictionary of the Hungarian microfungi). – Akadémiai Kiadó, Budapest, pp. 517–1152.

BŮŽEK, C., HOLÝ, F. and KVAČEK, Z. (1996): Early Miocene Flora of the Cypris Shale (Western Bohemia). – *Acta Musei Nationalis Pragae, Series B., Historia Naturalis* **52**(1–4): 1–72.

DILCHER, D. L. (1974): Approaches to the identifications of Angiosperm leaf remains. – *The Botanical Review* **40**(1): 1–157.

ELSIK, W. C. (1978): *Classification and geologic history of the microthyriaceous fungi.* – IV. Int. Palynol. Conf., Lucknow, India, (**1976–77**): 331–342.

ELSIK, W. C. (1983): Annotated glossary of fungal palynomorphs. The AASP. INC. Workgroup on fossil fungal palynomorphs. – *AASP Contributions Series* **11**: 1–35.

ERDEI, B. (1996): Új szarmata makroflóra Sopron-Piusz pusztáról. (New Sarmatian macroflora from Sopron-Piusz puszta). – *Studia Naturalia* **9**: 83–97.

ERDEI, B. (1999): Magyarországi szarmata flórák paleoökológiai és paleoklimatológiai vizsgálata. (A palaeoecological and palaeoclimatological study of Hungarian Sarmatian floras). – Doctoral Thesis, Budapest, 148 pp. (manuscript).

FERGUSON, D. K. (1971): The Miocene flora of Kreuzau. Western Germany. 1. The leaf remains. – North Holland Publishing Company, Amsterdam, London, 297 pp.

FISCHER, O. and HABLY, L. (1991): Pliocene flora from the alginite at Gérce. – *Annls hist.-nat. Mus. natn. Hung.* **83**: 25–47.

FODOR, L., BENKLOVICS, L., GERNER, P., MAGYARI, Á., PALOTÁS, K. and ROSTA, É. (1989): *A Sopron-Kismartoni medence tektonikája a neogénben.* (Neogene tectonics of the Sopron-Kismarton Basin). – Programfüzet, Magyarhoni Földtani Társulat Vándorgyűlése. (Abstract, Annual Meeting of the Hungarian Geological Society.) Sopron, 1989. May 19–20, p. 43.

GASTALDO, R. A., BEARCE, S. C., DEGGES, C. W., HUNT, R. J., PEBBLES, M. W. and VIOLETTE, D. L. (1989): Biostratinomy of a Holocene oxbow lake: a backswamp to midchannel transect. – *Rev. Palaeobot. Palynol.* **58**: 47–59.

GREGOR, H. J. (1979): Systematics, biostratigraphy and palaeoecology of the genus Toddalia Juss. (Rutaceae) in the European Tertiary. – *Rev. Palaeobot. Palynol.* **28**: 311–363.

GREGOR, H. J. (1984): Subtropische Elemente im europäischen Tertiär. IV. Onagraceae, Rutaceae, Vitaceae, Theaceae und Elaeagnaceae. – *Documenta naturae* **16**: 1–37.

HABLY, L. and KVAČEK, Z. (1997): Early Pliocene plant megafossils from the volcanic area in West Hungary. – *Studia Naturalia* **10**: 5–152.

HUMMEL, A. (1983): The Pliocene leaf flora from Ruszów near Zary in Lower Silesia, SW Poland. – *Prace Muzeum Ziemi Z.* **36**: 1–104.

JÄHNICHEN, H.: *The true affinity of Wackersdorfia dubia (?Helobiae) Peters (1963) from the Miocene Bavarian/Oberpfalz brown-coal.* – Manuscript, 1 pp.

KNOBLOCH, E. and KVAČEK, Z. (1976): Miozäne Blätterfloren vom Westrand der Böhmischen Masse. – *Rozpravy ÚÚG* **42**: 1–131.

KOVAR-EDER, J. (1982): Eine Blätter-Flora des Egerien (Ober-Oligozän) aus marinen Sedimenten der Zentralen Paratethys im Linzer Raum (Österreich). – *Beiträge zur Paläontologie von Österreich* **9**: 1–209.

KRÄUSEL, R. and WEYLAND, H. (1959): Kritische Untersuchungen zur Kutikularanalyse tertiärer Blätter IV. – *Palaeontograph. Abt. B.* **105**: 101–124.

KRÜSSMANN, G. (1960): *Handbuch der Laubgehölze.* Band I. – Paul Parey, Berlin und Hamburg, 495 pp.

KVAČEK, Z. (1979): *Some members of Magnoliaceae from the European Tertiary.* – Palaeont. Conference 77, Charles University, Prague, pp. 169–182.

KVAČEK, Z. (1988): The Lauraceae of the European Paleogene, based on leaf cuticles. – *Cour. Forsch. Inst. Senckenberg,* **107**: 345–354.

KVAČEK, Z., BŮŽEK, C. and HOLÝ, F. (1982): Review of Buxus fossils and a new large-leaved species from the Miocene of Central Europe. – *Rev. Palaeobot. Palynol.* **37**: 361–394.

LÁSZLÓ, J. (1989): *Visonta és Bükkábrány összehasonlító paleobotanikai vizsgálata makroflóra alapján.* (A comparative palaeobotanical study of the macroflora of Visonta and Bükkábrány.) – Szakdolgozat. ELTE Őslénytani Tanszék, Budapest, 124 pp. (manuscript).

MAI, D. H. (1975): Beiträge zur Bestimmung und Nomenklatur fossiler Magnolien. – *Feddes Repertorium* **86**(9–10): 559–578.

MAI, D. H. (1986): Über Typen und Originale tertiärer Arten von Pinus L. (Pinaceae) in mitteleuropäischen Sammlungen. Ein Beitrag zur Geschichte der Gattung in Europa. – *Feddes Repertorium* **97**(9–10): 571–605.

MAI, D. H. (1995): Tertiäre Vegetationsgeschichte Europas. – Fischer, Jena, 691 pp.

MAI, D. H. and PALAMAREV, E. (1997): Neue paläofloristische Funde aus kontinentalen und brackischen Tertiärformationen in Bulgarien. – *Feddes Repertorium* **108**(7–8): 481–506.

MAI, D. and WALTHER, H. (1978): Die Floren der Haselbacher Serie im Weisselster-Becken (Bezirk Leipzig, DDR). – *Abh. Staatl. Mus. Mineral. Geol.* **28**: 1–200.

MAI, D. H. and WALTHER, H. (1988): Die pliozänen Floren von Thüringen, Deutsche Demokratische Republik. – *Quartärpaläontologie* **7**: 55–297.

PETERS, I. (1963): Die Flora der oberpfalzer Braunkohlen und Ihre ökologische und stratigraphische Bedeutung. – *Palaeontograph. Abt. B.* **112**: 1–50.

PHADTARE, D. (1989): Palaeoecologic significance of some fungi from the Miocene of Tanakpur (U. P.) India. – *Rev. Palaeobot. Palynol.* **59**:127–131.

REID, C. and REID, E. M. (1915): The Pliocene flora of the Dutch-Prussian border. – *Meded. Rijkskopsp. Delftstoffen* **6**: 1–178.

ROSTA, É. (1993): Gilbert-típusú delta a Sopron-környéki szarmata pannóniai üledékekben. (Gilbert-type delta in the Sarmatian-Pannonian sediments, Sopron, NW Hungary.) – *Földtani Közlöny* **123**(2): 167–193.

STRAUS, A. (1969): Beiträge zur Kenntniss der Pliozänflora von Willershausen. (VI). Die Gattung Buxus. – *Argumenta Palaeobotanica* **3**: 57–64.

WEYLAND, H. and Kilpper, K. (1963): Kritische Untersuchungen zur Kutikularanalyse tertiärer Blätter VI. – *Palaeontograph. Abt. B.* **113**: 93–116.

ZABŁOCKI, J. (1928): Tertiäre Flora des Salzlagers von Wieliczka I. – *Acta Societatis Botanicorum Poloniae* **5**(2): 174–208.

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