

THE PLIOCENE LEAF FLORA FROM PODARI, DOLJ COUNTY

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Abstract. This work presents, for the first time, the macrofloristic content of the Pliocene sediments that outcrop at Podari locality, near Craiova city, SW Romania. Numerous fossil plant leaves were discovered with medium preservation - grouped in nine morpho-taxons. These taxa include the fern *Salvinia* sp., dicotyledonous leaves *Vitis strictum* (Goeppert) Erw. Knobloch, *Populus populina* (Brongniart) Erw. Knobloch, *Podocarpium podocarpum* (Al. Braun) Herendeen, *Quercus praecastaneifolia* Erw. Knobloch, *Rosa* sp., *Byttneriophyllum tiliaefolium* (Al. Braun) Erw. Knobloch & Z. Kvaček, *Acer* aff. *platanoides* Linnaeus, and monocotyledonous leaves *Typha latissima* Al. Braun. This palaeofloristic assemblage suggests warm-temperate mixed forests, gallery-type forests, and hygrophite and hydrophytes vegetation.

Keywords: fossil flora, plant impressions, Pliocene, insect feeding, swamp forests.

Rezumat. Flora pliocenă de la Podari, județul Dolj. Această lucrare prezintă, în premieră, conținutul macrofloristic al sedimentelor pliocene care aflorază în localitatea Podari, lângă orașul Craiova, în sud-vestul României. Au fost descoperite, cu predilecție, numeroase frunze de plante fosile. Gradul lor de conservare nu este foarte bun. Am avut ocazia să recunoaștem nouă morfo-taxoni, asupra cărora am efectuat analize morfometrice și descrieri detaliate. Acești taxoni sunt: feriga *Salvinia* sp., frunze dicotiledonate de *Vitis strictum* (Goeppert) Erw. Knobloch, *Populus populina* (Brongniart) Erw. Knobloch, *Podocarpium podocarpum* (Al. Braun) Herendeen, *Quercus praecastaneifolia* Erw. Knobloch, *Rosa* sp., *Byttneriophyllum tiliaefolium* (Al. Braun) Erw. Knobloch & Z. Kvaček, *Acer* aff. *platanoides* Linnaeus și frunze de monocotiledonate aparținând speciei *Typha latissima* Al. Braun. Acest ansamblu paleofloristic sugerează prezența pădurilor mixte cald-temperate, a pădurilor de tip galerie și existența vegetației higrofitice și hidrofitice.

Cuvinte cheie: floră fosilă, impresiuni de plante fosile, Pliocen, urme de hrănire lăsate de insecte fosile, păduri de mlaștină.

INTRODUCTION

A new fossil flora is systematically described based on leaf morphology and on other particular characters of several plant species. The hand specimens were collected from the Podari locality, Craiova region of the Dacian Basin, Southern Romania. The outcrop studied from Podari occurs south-west of Craiova (seven kilometers away from it), about one kilometer from the right bank of the river Jiu, at the base of the Solomon hill (see Fig. 1). The section is almost 20 meters thick. The sedimentary sequence is represented by semi-consolidated yellow-reddish mica sands, brown siltstones with rare phosphate or calcareous nodules, sands with cobble-gravel channel beds (flow structures), greenish clays with rare mollusk fossils, lumachelle (mollusk shell debris) with reddish sandy cement and reworked clay lithoclasts, gray clays with layers of oxidized sands, and reddish-brown siltites with whole mollusk shells having closed valves. This corresponds to a deltaic plain, with sedimentary deposits produced by river overflows (overbank sediments), fluvial channel sand sheets and quartzitic pebble lag deposits, channel fill deposits and oxbow lakes with relatively fine-grained material. The fossil plants are preserved as reddish carbonaceous compressions or impressions on siltstones and they were collected from the upper part of the sequence. The macrofossil assemblage consists of vertebrates (bones of large vertebrates that are under study at the Oltenia Museum Craiova), micromammals (FERU et al., 1979, RĂDULESCU et al., 1999, ȘTIUCĂ et al., 2003), fish teeth (TRIF et al., 2016) and a wide spectrum of invertebrates – bivalves, gastropods. The micromammal biochronology and mollusk zonation (sculptured unionids, small gastropods, Viviparidae, see Plate II, Photo 11) indicated an Upper Pliocene age (Middle Romanian-Pelendavian, after PANĂ et al., 1981).

MATERIAL AND METHODS

The fossil plants are represented by numerous detached and often fragmentary vegetative organs, mainly of angiosperms. The specimens show details of leaf shape, margin, tooth morphology, and several well-preserved orders of venation that can be compared favorably with extant or fossil relatives. Morphological observations of the fossil materials were made with magnifying lens and with a Zeiss stereoscopic microscope. The plant remains are kept in the collections stored at the Paleobotany Section from National Geological Museum, of the Geological Institute of Romania. The morphological descriptions follow the indications proposed by DILCHER (1974), HICKEY (1979) and WING et al., 1999. Systematic organization and taxonomic terminology are based on the works of KUBITZKI (1993) and TAKHTAJAN (2009).

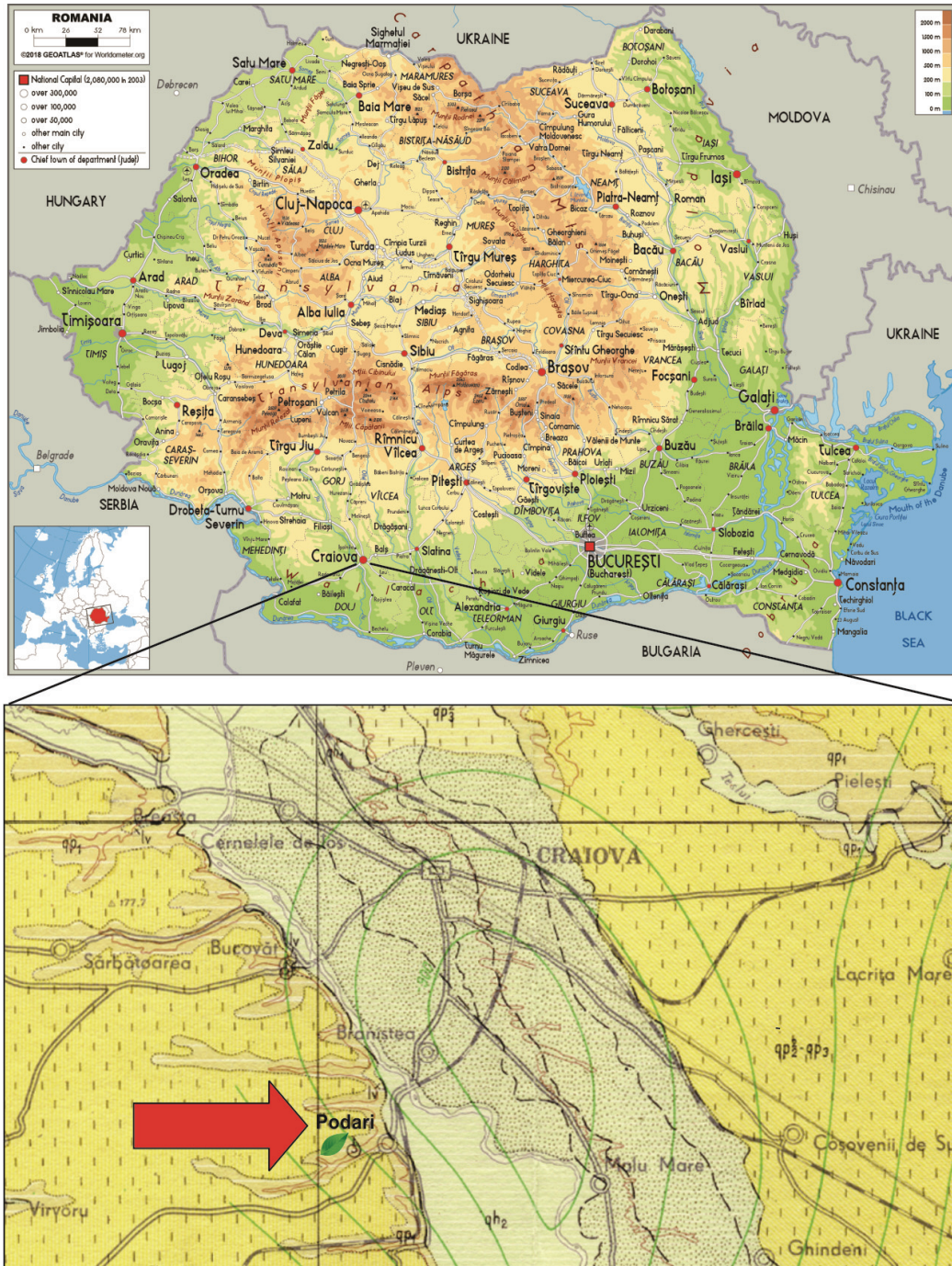


Figure 1. The location of the outcrop from Podari, indicated by lines on the physical map of Romania. Geological map of Romania, scale 1: 200,000, 41- Craiova sheet (MURGEANU et al., 1968).

RESULTS IN SYSTEMATIC PALAEOBOTANY

Polypodiopsida Cronquist, Takhtajan & Zimmermann 1966.

Order Salviniales Link 1833

Family Salviniaceae Martinov 1820

Genus *Salvinia* Séguier 1754

Salvinia sp.

Pl. I, Photo 1

Material. PDA 3618, PDA 3619.

Description. The macrofossils are represented by isolated floating leaves, round to ovoidal, 12 mm long, 10 mm wide, primary vein fine, more visible near the base of the lamina and indistinct towards the tip. No secondary lateral veins can be seen; the adaxial surface of the leaf is covered by multiple areoles (made by connections between inter-secondary veins and tertiares), quadrangular or hexagonal, approximately isodiametric to the centre but slightly elongated near the

margin of the lamina, each areola protects a tubercle (trichome) but our specimens do not preserve such details due to the coarse-grained sediments; the texture of the leaf surface is typically rugous/tuberculate. *Salvinia* has a unique morphology among ferns but we only collected vegetative parts. This aquatic fern is lacking roots, three spirally arranged leaves are attached along the stem, a pair of leaves are floating, and the third is submerged, hairy and have sporocarps attached.

Remarks and discussions. *Salvinia* belongs to a group of free-floating heterosporous water ferns, with its oldest stratigraphic record in the Late Cretaceous (Campanian-Maastrichtian) followed by a sharp decrease in biodiversity during the Palaeocene, according to DE BENEDETTI et al., 2021. The depositional paleoenvironment was represented by young habitats with abundant slow-flowing fresh water supply (lakes, slow streams) or brackish conditions (marshes, ponds, lagoon/barrier complexes), free niches where aquatic plants could thrive. Competition in the new habitats with other evolving and more successful groups of aquatic plants was in the favor of flowering plants (aquatic weeds). The morphological analysis of the sterile organs (floating leaves) suggests autochthonous preservation, where it originally grew.

Magnoliophyta Cronquist, Takhtajan & Zimmermann 1966

Order Rhamnales Dumortier 1829

Family Vitaceae Jussieu 1789 nom. cons.

Genus *Vitis* Linnaeus 1753

Vitis strictum (Goeppert 1855) Erw. Knobloch 1969

Pl. I, Photo 2

Material. PDA 3620, PDA 3621.

Description. The leaves are almost entire, trilobated, elliptic, slightly asymmetric, ?⁽¹⁾78 mm long, ?105 mm wide, with no petiole preserved but the attachment of petiole to the leaf seems to be of the pulvinate type, the base angle is wide-obtuse, the apex angle is obtuse, the base shape is wide lobated, the lateral lobes of the lamina are similar to the middle one, maximum 35 mm in width. The sinuses between lobes are rounded and deep, each primary lobe is generated apically from large teeth, as a pair of inequally pseudo-lobes; the margin is dentated, with large, rare and irregular, blunt to acuminate, triangular, oblique upward teeth. Venation is actinodromous, basal perfect, with three primary veins. The primary median vein is very strong, straight, primary lateral veins are curved upwards and entering the lateral lobes, the secondary veins are alternating, craspedodromous, arched and ending in teeth, while the tertiary veins are fine, perpendicularly disposed to the secondaries and generating quadrangular areoles.

⁽¹⁾By using the „?“ character I want to highlight the fact that the measurements are incomplete.

Remarks and discussions. *Vitis* is frequently found in the Pliocene deposits of Romania (GIVULESCU, 1990), and its nearest living relative is *Vitis cordifolia* Michaux, a woody liana living in the mixt mesophytic forests of the Atlantic shore of the U.S.A. (Virginia, Carolina, North Texas). *Vitis* suggests the occurrence of tall trees along the slopes surrounding lakes, as this sun-seeking creeper is often found in growing relations with moisture-loving trees and shrubs like poplars, oaks, etc. *Vitis* is an opportunistic species, with climbing habit, vegetating along woodland borders fixed on riverbanks, and documents a warm-temperate-milder climate (TIFFNEY & BARGHOORN, 1976).

Order Violales Mabberley 2000

Family Salicaceae Mirbel 1815

Genus *Populus* Linnaeus 1753

Populus populina (Brongniart 1822) Erw. Knobloch 1964

Pl. I, Photo 3

Material. PDA 3630, PDA 3631, PDA 3632

Description. The leaves are ovate, symmetrical, ?56mm long, 80 mm wide, the base is missing, the apex is convex to rounded, obtuse, the margins are crenate to weak serrate, sinuses are large, rounded. The teeth are curved upwards, with the apical side straight-concave, and the basal side convex, straight to slightly concave, the glandular teeth are still preserved on some leaf fragments. The venation is semicraspedodromous, the primary vein is strong, slightly bent in the middle part of the lamina, at least four pairs of secondary veins run from the midvein at angles of about 35-45°, forming big loops near the margin, others end in the teeth of the leaf margin, secondary veins divide one or more times at different distances from the leaf margin. The tertiary venation is dense, simple or bifurcate, forming a random network.

Remarks and discussions. *Populus populina* corresponds morphologically to *Populus tremula* Linnaeus or to *Populus alba* Linnaeus (STRIEGLER, 2017, pioneer species, both growing in Eurasian, alluvial forests) or *Populus monilifera* Aiton (KOVAR-EDER, 1988, a fast-growing dominant species in riverfront forests, from Central-North America, Saskatchewan to Manitoba, south to Texas and New Mexico). It is a classic riparian element (HABLY, 2020) in periodically flooded areas.

Order Fabales Bromhead 1838

Family Fabaceae Lindl. 1836 (= Leguminosae Jussieu 1789 nom. cons.)

Subfamily Caesalpinioideae DC. 1825

Genus *Podocarpium* Al. Braun 1836 ex Stizenberger 1851

Podocarpium podocarpum (Al. Braun 1836) Herendeen 1992

Pl. I, Photo 4

1996 *Podocarpium podocarpum* (Al. Braun 1836) Herendeen 1992; Bůžek, Holy & Z. Kvaček, p. 30, Pl. XX, Figs. 9-15

Material. PDA 3635, PDA 3636.

Description. The leaflet shape is rounded to broadly ovate, detached (paripinnate compound leaves), sessile, 12 mm long, 11.5 mm wide. The base is rounded to cuneate, entire-margined, the apex is obtuse, the margins are irregularly simple, bluntly serrate to crenate, the teeth are simple, slightly wavy/rounded; venation is semicraspedodromous, with the primary vein obvious and very strong in the first half of the lamina and thinner to the apex, straight to slightly bent, up to six pairs of fine secondaries are generated, diverging from the midvein at angles of about 50-70°, few single intersecondaries are obvious. The secondaries form wide loops along/parallel to the edge, they are inserted opposite in the basal part of the lamina and alternate to the apex, the lateral veinlets enter marginal teeth, the tertiary veins are reticulate, forming asymmetrical networks with higher-order vein matrix; the texture of the leaflet is coriaceous.

Remarks and discussions. *Podocarpium* (formerly *Podogonium* Heer 1857) is a typical Pliocene leguminous foliage, the most common legume in the Neogene of Eurasia (HERENDEEN, 1992). It inhabited gallery forests (hygrophilous form), but it could also adapt physiologically to dry (xeric) habitats (thermophilic form). This species generated some evolved plastic response system to temporally heterogeneous environments, and it was adapted to a warm and humid environment (LI et al., 2018).

Order Fagales Engler 1892

Family Fagaceae Dumortier 1829

Genus *Quercus* Linnaeus 1753

Quercus praecastaneifolia Erw. Knobloch 1998

Pl. I, Photo 5

1998 *Quercus praecastaneifolia* Erw. Knobloch; Knobloch, p. 30-31, Text-fig. 11 a-b, Pl. XIII, Fig. 4, Pl. XV, Figs. 1-6.

2019 *Quercus praecastaneifolia* Erw. Knobloch; Z. Kvaček, Teodoridis & Denk, p. 667-669, Figs. 7 b-f & 17 j.

Material. PDA 3645, PDA 3646, PDA 3647

Description. The leaves are lanceolate to obovate, 70-160 mm long, 20-30 mm wide, slightly asymmetric, incomplete, with base and apex missing. The margins are regularly lobate with at least 11 lobes on each side of the lamina, sometimes lobes have rounded mucronate or blunt teeth, sinuses are rounded. The venation is craspedodromous, the primary vein is straight or slightly curved to the base, very strong, the secondary veins are straight or slightly arching towards the insertion to the midrib, at least 11 pairs, pinnate, regularly spaced, subopposite and diverging from the midvein at angles of about 40-60°, tertiary veins are very thin, perpendicular or oblique to the secondaries.

Remarks and discussions. Fossil leaves of the genus *Quercus* were widely reported from the Neogene of Romania and Europe, but the morphological variation at species level is high. The widespread distribution of lobed or roburoid *Quercus* species (wind-pollinated taxa) was recorded in the Pliocene by the emergence of a seasonal climate, similar to the current one, in response to increased topographic diversity (AXELROD, 1983). According to Z. KVAČEK et al. (2019), *Quercus praecastaneifolia* belongs to the *Quercus* section or white oaks, with the closest current survivors in the mixt deciduous temperate or warm-temperate forests of East Asia (e.g. *Q. griffithii* Hook. f. & Thomson ex Miquel, *Q. aliena* Blume, *Q. dentata* Thunberg in Murray). *Quercus praecastaneifolia* could vegetate in open places on hilly slopes surrounding the coastal areas. It was able to compete favorably with other broad-leaved forms, being widespread and abundant in the arborescent angiosperm flora of Podari, but it did not survive the Quaternary glaciations. Plant-insect interactions occur on the leaves of *Q. praecastaneifolia*, especially traces of feeding (circular perforation with remains of tissue necrosis) left by insects in the central area of the leaf (in the middle of the distance between the main vein and the edge, between two secondary veins).

Order Rosales Bercht. & J. Presl 1820

Family Rosaceae Jussieu 1789 nom. cons.

Genus *Rosa* Linnaeus 1753

Rosa sp. Pl. I, Photo 6

Material. PDA 3655, PDA 3656

Description. The leaflet is elliptic-ovate, 30-24 mm long, 20-23 mm wide, with no petiole preserved. The base is acute, convex, asymmetrical, the apex is incomplete. The margins are irregular, sharply simple-serrate; the venation is semicraspedodromous rosoid, the teeth are tiny or large and variable in shape, they have a straight apical part and a slightly convex basal part. The midvein is strong, slightly curved in the middle, the secondary veins are fine, obvious and gently curved upwards at the distal part where they form loops (with some quadrangular areoles). At least six pairs of secondary veins occur, simple or bifurcated, inserted to the main rib at angles of 90° to 45°, while the tertiary veins form a fine random network. The texture of the leaflet is subcoriaceous.

Remarks and discussions. *Rosa* is known as a frequent colonizer of humid and xeric areas with high resistance to rapid environmental changes (taxa adapted to many habitats). It was capable to conquer and to persist in new, open habitats because of its vegetative reproduction and hybridization. *Rosa* is a genus of deciduous flowering shrubs that presents a very common and distinctive leaflet morphotype, together with other fossil plants within Rosaceae. It is relatively rarely collected as fossils. Our specimen demonstrates the lack of sufficient diagnostic characters to place in a fossil/extant species.

Order Malvales Jussieu 1789 ex Bercht. & J. Presl 1820

Family Malvaceae Jussieu 1789 nom. cons. s.l.

Genus *Byttneriophyllum* Erw. Knobloch & Z. Kvaček 1965 ex Givulescu 1970

Byttneriophyllum tiliaefolium (Al. Braun 1845) Erw. Knobloch & Z. Kvaček 1965, Pl. I, Photo 7

Material. PDA 3657, PDA 3658

Description. Fragments of very large leaves (megaphyll) were collected, oval-elliptic and asymmetrical in shape, simple, 74 mm long, 74 mm wide, with no petiole preserved. The apex angle is obtuse, the apex shape is rounded to slightly emarginate or weak acuminate, the margin is entire. The venation is brochidodromous, palmate, the fifth primary veins radiate from the base, the primary central vein is strong, sinuate, the other four primaries are arched upwards. The secondaries are numerous, subparallel, arched upward and ending in loops in the marginal side of lamina, departing at angles of 30°-40° from the midvein. The tertiaries are perpendicularly disposed on secondaries and they are forming a network of elongated parallelograms, the higher order venation is simple or bifurcate, forming a polygonal network (orthogonal reticulate).

Remarks and discussions. This extinct taxon is very common in the Pliocene upland floras of Romania, where it developed explosively mainly in coal-generating basins with a lignite facies (ȚICLEANU 1989). There it formed quite frequently monotypic assemblages (monocoenoses). *Byttneriophyllum* is a tall tree that is known for its large winged fruits (samaras of *Banisteriaecarpum giganteum* (Goepfert) Kräusel), wood (*Wataria parvipora* K. Terada & M. Suzuki), and especially huge leaves. It grew in swamp forests in a coal-generating facies (in the Pliocene coal deposits in the province of Oltenia, SW Romania), together with other deciduous species such as *Glyptostrobus europaeus* (Brongniart) Unger, *Betula macrophylla* (Goepfert) Heer and *Alnus cecropiifolia* (Ettingshausen) Berger. *B. tiliaefolium* flourished since the early Miocene when the global planetary temperatures increased, and survived during the Late Miocene Climate Transition (LMCT), characterized by global climate changes, from stable warm and humid conditions recorded in the Early Miocene, to a seasonal climate with variability in temperature and rainfall, just to disappear during the Quaternary.

Order Sapindales Dumortier 1829

Family Sapindaceae Jussieu 1789

Genus *Acer* Linnaeus 1753

Acer aff. *platanoides* Linnaeus 1753, Pl. II, Photo 8

2019 *Acer* aff. *platanoides* Linnaeus; Z. Kvaček, Teodoridis & Denk, p. 667, Figs. 11c; 18k, l.

Material. PDA 3665, PDA 3666, PDA 3667

Description. Leaves are palmately pentalobate, simple, incompletely preserved, long petiolate, petiole dilated at base, 18 mm long, lamina 255-260 mm long, 250-255 mm wide, 32 mm maximum width at the primary lobe, slightly asymmetric. The base is rounded to truncate, the margin is lobed or irregularly crenate, having sharp teeth on lobes, bluntly dentate in the upper two thirds of the lamina, with missing apex. The venation is palmate (primary vein splits into other several primary veins which diverge from a single central point), actinodromous suprabasal. Three primary veins, include the vertical primary vein which is stout, lateral primary and lower secondary veins departing at angles of 35°-50°, the higher secondary veins running at wider angles. The intersecondary veins are forming areoles without free-ending veinlets, the tertiary veins are irregularly reticulate; and the lamina is chartaceous.

Remarks and discussions. *Acer* is a frequent member of the riparian forests (intrazonal vegetation developed along streams or braided rivers). These depositional environments were very dynamic due to the strong influx of new sediments, for the large amounts of water discharge, but also the eustatic changes that the shoreline underwent when the river overflowed. *Acer* aff. *platanoides* shows a close resemblance to the modern *Acer platanoides* L. (Europe-Caucasus) and to *Acer miyabei* Maximowicz (N Japan), as fast-growing trees, usually living at the hills bases or along river banks, where they receive a significant runoff from surface water.

Order Typhales Mabblerley 2000

Family Typhaceae Jussieu 1789

Genus *Typha* Linnaeus 1753

Typha latissima Alexander Braun 1851, Pl. II, Photo 9

Material. PDA 3670, PDA 3671

Description. Fragments of long leaves were collected, they are simple, oblong, symmetrical, with no base and apex preserved, 228-270 mm long, 11-12 mm wide, margins are entire to irregular (gnawed). The venation is parallelodromous, the primary vein is strong, straight, the secondaries are parallel with the primary vein, equidistant, the tertiaries are perpendicular on the secondaries forming a regulated network of alternating cells, quadrangular, with walls which are 1 mm long and 0.3 mm wide.

Remarks and discussions. *Typha* represents rooted dwellers or aquatic weeds communities documenting shallow, open waters. The nearest living relative of *Typha latissima* is the modern *T. latifolia* L. (broadleaf cattail), a wetland perennial herbaceous plant species that can grow up to a water depth of 1 meter. This plant can be found in water or near water, sometimes floating towards zones with deeper water, in periodically flooded areas, as it prefers fresh water but can also grow in brackish marshes by the seashore.

CONCLUSIONS

The paleoenvironment of the Podari is an extensive delta plain, with sands representing channels and crevasse-splays, and with siltstones, clays, charcoal, and plant remains, in interdistributary bays, marshes, and lake deposits (delta top settings). This includes habitats such as lowland flood-plains, coastal plains, mires, and areas that were regularly or periodically flooded, and were therefore subjected to rapidly changing environmental conditions. The sedimentation conditions changed so rapidly that numerous bivalves were discovered with both valves still attached (see Pl. II, Photo 10), open (butterfly-positioned shells) or closed. Rare shells were preserved in a unique taphonomic position preserving their original mother-of-pearl nacre.

The distribution and main components of the Pliocene mesophytic forest communities in Podari were related to diverse environments and to complex topography. These Pliocene forests are similar with modern mixed (broad-leaved deciduous) mesophytic forests. The plant megafossil record is not significantly different from other Pliocene sites in Romania, with dominant deciduous broad-leaved taxa (Arcto-Tertiary elements) like *Quercus*, *Acer*, *Populus*, *Rosa*, *Vitis*, *Byttneriophyllum*, *Typha*, *Podocarpium*, as representatives of zonal and azonal habitats, and hydrophyte ferns (*Salvinia*). Until now, we have not been able to identify any fossil remains of conifers from the Podari site. The floral spectrum is similar to the one in the Pırtești de Sus site (Lower Sarmatian, Suceava County, Moldavian Platform) described by ȚABĂRĂ & FLOREA, 2007, which, was preserved in similar environmental conditions.

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Plate I

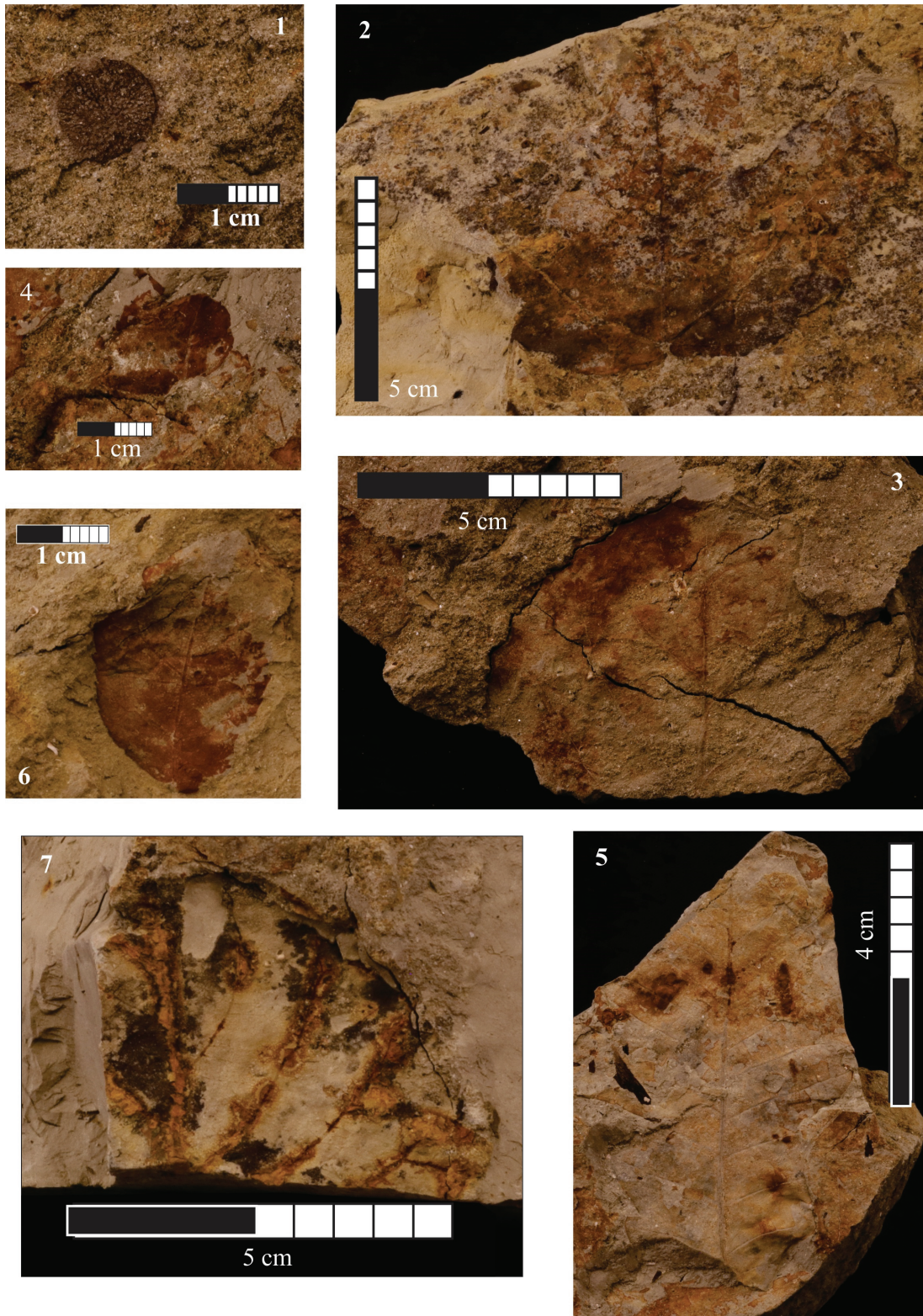


Photo 1. *Salvinia* sp.; Photo 2. *Vitis strictum* (Goeppert) Erw. Knobloch; Photo 3. *Populus populina* (Brongniart) Erw. Knobloch; Photo 4. *Podocarpium podocarpum* (Al. Braun) Herendeen; Photo 5. *Quercus praecastaneifolia* Erw. Knobloch; Photo 6. *Rosa* sp.; Photo 7. *Byttneriophyllum tiliaefolium* (Al. Braun) Erw. Knobloch & Z. Kvaček. (All photos are original).

Plate II

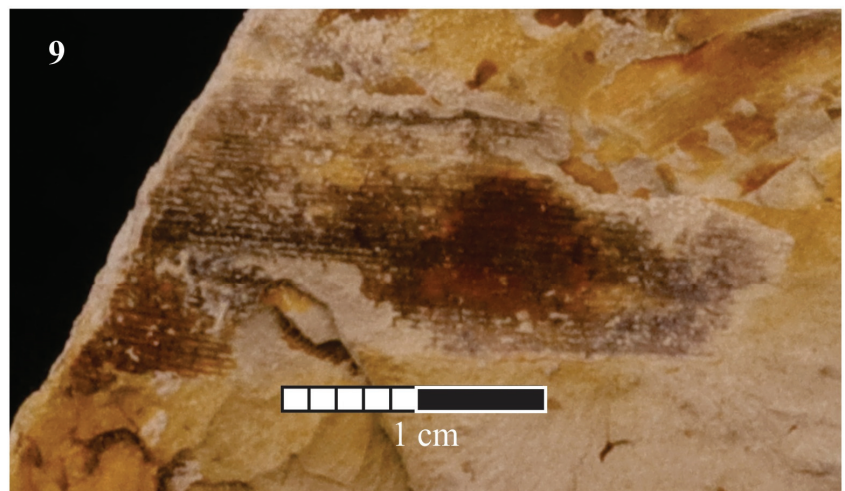


Photo 8. *Acer* aff. *platanoides* Linnaeus; Photo 9. *Typha latissima* Alexander Braun;
Photo 10. *Unionidae* shells, butterfly-positioned, nacre intact; Photo 11. *Viviparus turgidus* Bielz. (All photos are original).