The fossil macroflora of the Vulche Pole Molasse formation (SE Bulgaria)

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Abstract. Thirty-eight species of material originating from the uppermost sediments of the Vulche Pole Molasse formation (SE Bulgaria) have been found (two taxa of the same material have been determined up to genus level). The species Myrica kymeana, Zanthoxylum juglandinum and Sapindus graecus have been registered for the first time for the Bulgarian fossil flora. On the basis of the dominant role of Lauraceae and the ancient species Macclintockia basinervis in the composition of that flora, the age of the flora-bearing sediments was presumed to be rather late Oligocene than the formerly considered late Oligocene–early Miocene.

Key words: Bulgaria, early Miocene, fossil macroflora, late Oligocene, Vulche Pole Molasse formation

Introduction

The Vulche Pole Molasse formation fills a subequatorial post-sedimentary structure: Bryagovo depression. It is located to the south of Ibredzhek horst and along Zlatoustovo fault (East Rhodopes). The formation comprises mainly conglomerates, sandstones, shales, and lignite coal seams, etc. (Harkovska & al. 2005). It was considered as deposited in continental (lake-marshy or alluvial) environment (Goranov 1960; Lambeva & Tonchev 1988) during late Oligocene – early Miocene (Vaptsarov 1970; Boyanov & Goranov 2001).

Material and methods

The researched material represents 135 rock fragments with vegetation macroimprints on them. It was collected in the period 1986-1988 by Prof. E. Palamarev, A. Petkova and R. Ardzhiyska in the vicinities of the villages Vulche Pole and Zlatoustovo (Fig. 1). According to A. Goranov (personal commun.), the macroflora originated from shallow excavations of the uppermost and, respectively, the latest sediments of the Molasse formation.

The ichnophytological method (Zhilin 1969) was used for determining the macroremains. The morphological characteristics of the leaf imprints belonging to the species new for the Bulgarian paleoflora are described according to Dilcher (1974). The order of the families in the text and table follows Takhtajan (1987), while the genera and species are arranged in alphabetical order.
Results

Composition of the flora

Lauraceae

Daphnogene bilinica (Unger) Kvaček & Knobloch (Pl. I, Fig. 5)
Material: 2 leaf impressions (HVP-109, Zl-252).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Daphnogene cinnamomea (Rossm.) Knobloch (Pl. I, Fig. 4)
Material: 12 leaf impressions (HVP-10, 19, 20, 30, 103, 109, 122, 144a, 156, 158, 169, 252).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & al. (1999). The specimens studied here showed no deviations.

Daphnogene cinnamomifolia (Brongn.) Unger (Pl. I, Fig. 3)
Material: 1 leaf impression (HVP-3).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Daphnogene lanceolata Unger (Pl. I, Fig. 6)
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev (1964). The specimens studied here showed no deviations.

Daphnogene spectabilis (Heer) Knobloch (Pl. II, Fig. 3)
Material: 2 leaf impressions (HVP-129, 208).
Remarks: In the article by Palamarev & Staneva (1995) the species was only mentioned in the composition of the paleoflora, without any description of the fossil material, or a photograph. The fragmentation of our material did not permit any integral description of the lamina, but its correspondence to the type material of Heer (1856) gave us grounds to mention the presence of this species in the paleoflora of the Vulche Pole Molasse formation.

Daphnogene ungeri Heer (Pl. IV, Fig. 6)
Material: 2 leaf impressions (HVP-82, 85).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Bozukov (1998). The specimens studied here showed no deviations.

Laurus pliocenica (Saporta & Marion) Kolak. (Pl. III, Fig. 3)
Material: 3 leaf impressions (HVP-117, 149, 189).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Litsea acutimontanum Mai (Pl. I, Fig. 2)
Material: 3 leaf impressions (HVP-26, 144b, 182).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Bozukov (1998). The specimens studied here showed no deviations.

Litsea ocoteifolia (Ettingsh.) Imkhan. (Pl. I, Fig. 7)
Material: 4 leaf impressions (HVP-169, 214, 221, 223).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev (1963). The specimens studied here showed no deviations.

Litsea primigenia (Unger) Takht. (Pl. II, Fig. 1)
Material: 2 leaf impressions (HVP-191, 192).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Neolitsea palaeosericea Takht. (Pl. III, Fig. 7)
Material: 10 leaf impressions (HVP-33, 80, 87, 96, 107, 174, 176, 195, 217; Zl-178).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev (1964). The specimens studied here showed no deviations.

Ocotea heeri (Gaudin) Takht. (Pl. II, Fig. 2)
Material: 4 leaf impressions (HVP-22, 64, 98, 138).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Persea braunii Heer (Pl. III, Fig. 4)
Material: 1 leaf impression (HVP-29).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.
Sassafras ferretianum A. Massal. (Pl. I, Fig. 1)
Material: 1 leaf impression (HVP-73).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Platanaceae
Platanus platanifolia (Ettingsh.) Knobloch (Pl. V, Fig. 1)
Material: 1 leaf impression (HVP-213).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Ulmaceae
Ulmus pyramidalis Göpp. (Pl. III, Fig. 5)
Material: 5 leaf impressions (HVP-44, 90, 155, 195; Zl-191a, b).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Zelkova zelkovifolia (Unger) Bůžek & Kotl. (Pl. III, Fig. 2)
Material: 2 leaf impressions (HVP-25, 205).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Fagaceae
Dryophyllum dewalquei Saporta & Marion (Pl. II, Fig. 6)
Material: 5 leaf impressions (HVP-4, 40, 150, 178, 213).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1966). The specimens studied here showed no deviations.

Fagus pliocenica Saporta (Pl. IV, Fig. 1)
Material: 1 leaf impression (HVP-94).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Quercus lyellii Heer (Pl. V, Fig. 3)
Material: 1 leaf impression (HVP-228).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Trigonobalanopsis rhamnoides (Rossm.) Kvaček & H. Walther (Pl. V, Fig. 4)
Material: 1 leaf impression (HVP-200).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Betulaceae
Betula subpubescens Göpp. (Pl. II, Fig. 4)
Material: 2 leaf impressions (HVP-31, 253).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Myricaceae
Myrica hakeaefolia Unger (Pl. IV, Fig. 9)
Material: 5 leaf impressions (HVP-47, 186, 154, 194, 216).
Remarks: A detailed description of the species in the Bulgarian paleoflora was given by Konstantinov (1937). The specimens studied here showed no deviations.

Myrica kymeana (Unger) Berger (Pl. V, Fig. 2)
1953. Berger, p. 36, Fig-text 1.
1867. Grevillea kymeana Unger, p. 57, Pl. 6, Fig. 31; Pl. 8, Figs. 15-31.
Material: 1 leaf impression (HVP-28a, b).
Description: Shape linear; base and tip missing, probably acute; margin entire, slightly undulated. Venation reticulodromous; the midrib straight; secondary veins alternating, at 30° angle towards the midrib, strongly arched towards the lamina tip; intercalary veins absent; tertiary veins not observed. Size of the fragment: length 3.5 cm, width 0.8 cm.
Remarks: The species is new for the fossil flora of Bulgaria. Its stratigraphic area is the Lower-Middle Miocene, and its geographic area covers the Aegean parts.
of Greece (Unger 1867; Berger 1953). During a revision of the species described by Unger, Berger (1953) did not point out a recent analogue to the fossil species. In our opinion, judging by the dentation of the lamina and by the angle formed by the secondary veins with the midrib, the fossils resemble the recent species *Myrica cerifera* L., distributed in the southern part of North America. The difference between the fossil and recent species is in the longer and narrower lamina of the fossil species.

**Juglandaceae**

*Engelhardia orsbergensis* (P. Wessel & C.O. Weber) Jähnichen, Mai & H. Walthier (Pl. II, Fig. 5)

*Material:* 1 leaf impression (HVP-175).

*Remarks:* A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

**Theaceae**

*Eurya aff. acuminatissima* Merr. & Chun (Pl. IV, Fig. 3)

*Material:* 1 leaf impression (Zl-189).

*Remarks:* A detailed description of the taxa in the Bulgarian paleoflora was given by Bozukov & Palamarev (1995). The specimens studied here showed no deviations.

**Ebenaceae**

*Diospyros anceps* Heer (Pl. IV, Fig. 8)

*Material:* 3 leaf impressions (HVP-18, 63, 134).

*Remarks:* A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

**Rosaceae**

*Rubus merianii* (Heer) Kolak. (Pl. II, Fig. 7)

*Material:* 1 leaf impression (HVP-71).

*Remarks:* A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

**Meliaceae**

*Cedrela attica* (Unger) Palam. & Petkova (Pl. III, Fig. 6)

*Material:* 2 leaf impressions (HVP-49, 55).

*Remarks:* A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

**Rutaceae**

*Zanthoxylum juglandinum* A. Braun (Pl. IV, Fig. 2)

1851. *Z. juglandinum* A. Braun, p. 87.
1859. Heer, p. 86, Pl. 127, Figs 22-25; Pl. 154, Fig. 36.
1997. Petrescu & al., p. 77, Pl. 5, Fig. 12.

*Material:* 1 leaf impression (HVP-163).

*Description:* Shape narrow ovate; base acuneate asymmetrical; the upper part acute, margin entire and only close to the lamina tip some dentate outlines are observed. Venation brochidodromous; the midrib straight; secondary veins 6-7 pairs, alternate and opposite, arched, at an angle of 50° on the one side of the midrib and at 30° on the other; intercalary veins missing; network of tertiary veins obscure. Size: length 2.5 cm, width 1.1 cm.

*Remarks:* The species is new for the Bulgarian fossil flora. Its stratigraphic area is Oligocene–Upper Miocene, and its geographic area has so far comprised Switzerland and Romania (Heer 1859; Givulescu 1962; Petrescu & al. 1997). *Zanthoxylum americanum* Mill. distributed in North America has been accepted as contemporary analogue of the fossil species. This is a deciduous shrub or small tree with pinnate leaves. Shade-tolerant. It was probably part of the undergrowth. With its limited distribution in terms of geographic area and frequency of occurrence in the paleofloras, as well as with its lack of pretentiousness to living conditions, this species would hardly provide important information for reconstruction of the paleoflora.

**Sapindaceae**

*Sapindus graecus* Unger (Pl. III, Fig. 1)

1867. Unger, p. 73, Pl. 12, Figs 1-23.

*Material:* 2 leaf impressions (Zl-186, 196).

*Description:* Shape narrow elliptic; base acute, upper part attenuate; margin entire, slightly undulated. Venation brochidodromous; the midrib slightly arched; secondary veins 15-16 pairs, alternate or opposite, straight, at an angle of 55° towards the median; intercalary veins observed between most secondary veins, tertiary veins not observed. Size: length 4.9 cm, width 1.1 cm.

*Remarks:* The species is new for the Bulgarian fossil flora. Its stratigraphic area is Oligocene – Upper Miocene, while its geographic area has so far comprised the Euboea Island (Greece) (Unger 1867) and Armenia, Georgia (Palibin 1937, 1939). Our find confirms the limited distribution of this species only on the territory of Southeast Europe. According to Unger (1867), a recent analogue of the fossil species should be sought among the South African representatives of the genus.
Sapindus falcifolius (A. Braun) A. Braun (Pl. V, Fig. 7)  
**Material:** 5 leaf impressions (HVP-205; Zl-183, 185, 197, 202).  
**Remarks:** A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Celastraceae  
*Celastrus oeningensis* Wonnacott (Pl. IV, Fig. 5)  
**Material:** 1 leaf impression (HVP-250).  
**Remarks:** A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Rhamnaceae  
*Berchemia multinervis* (A. Braun) Heer (Pl. V, Fig. 5)  
**Material:** 1 leaf impression (HVP-197).  
**Remarks:** A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1987). The specimens studied here showed no deviations.

Apocynaceae  
*Apocynophyllum neriifolium* Heer (Pl. IV, Fig. 4)  
**Material:** 1 leaf impression (HVP-204).  
**Remarks:** A detailed description of the species in the Bulgarian paleoflora was given by Palamarev & Petkova (1994). The specimens studied here showed no deviations.

Asclepiadaceae  
*Periploca cf. kryshtofovichii* Kornil. (Pl. IV, Fig. 7)  
**Material:** 7 leaf impressions (Zl-184, 188, 193, 195, 198, 200, 254).  
**Remarks:** A detailed description of the taxa in the Bulgarian paleoflora was given by Palamarev & Petkova (1975). The specimens studied here showed no deviations.

Arecaceae  
*Palmophyllum sp.* (Pl. V, Fig. 9)  
**Material:** 1 leaf impression (HVP-251).  
**Remarks:** A detailed description of the plants in the Bulgarian paleoflora was given by Palamarev & al. (1992). The specimens studied here showed no deviations.

Typhaceae  
*Typha sp.* (Pl. V, Fig. 6)  
**Material:** 1 leaf impression (HVP-254).  
**Description:** Shape linear; base and tip missing. Venation parallelodromous; veins without anastomoses between them. Size of the fragment: length 5.7 cm, width 0.6 cm.  
**Remarks:** Such leaf fragments were described for the Bulgarian Middle Miocene (Petkova 1967) and Pliocene (Stefanov & Jordanov 1934; Kitanov & Nikolova 1956) under the name of *Typha angustifolia* L. foss. Owing to the insufficient material for a more precise determination and the earlier assumed age of the investigated flora, we reject the assumption that this is the recent species *Typha angustifolia* L. or its fossil form, but use the combination *Typha sp.* instead.

Incertae sedis  
*Macclintockia basinervis* (Rossm.) Knobloch (Pl. V, Fig. 8)  
**Remarks:** A detailed description of the species in the Bulgarian paleoflora was given by Bozukov (1996). The specimens studied here were smaller in size than those described by Bozukov (op. c.) from the Middle Miocene flora of Satovcha (West Rhodopes) and are analogical to those from the Paleogene flora of Hvoina (Central Rhodopes) (Černjavska & al. 1988).

**Discussion**

The flora is composed of representatives of 19 families and genus *Macclintockia*, belonging to an undetermined family. The family *Lauraceae* stands out against the rest with the great number of its genera (eight), while its genus *Daphnogene* is represented by six species. On the other hand, genus *Daphnogene lanceolata* was dominant and outlined the pattern of the vegetation, judging by the greatest number of fossils in respect to the remaining species in the studied flora (Table 1). Next with the greatest number of genera comes family *Fagaceae* (four), but it was poorly represented quantitatively, considering the number of leaf imprints. The families *Ulmaceae* and *Betulaceae* are represented by two genera each. These two families, with the rest represented by one genus only and, respectively, by one or two species of that genus, are remarkable for their low percentage participation in the composition of the flora.
Table 1. Composition of the investigated fossil flora and distribution of the species in it in percentage. The species designated with (*) are new for the fossil flora of Bulgaria.

<table>
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<th>Taxa</th>
<th>Number of specimens</th>
<th>VP</th>
<th>ZL</th>
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<td>34. Celastrus oeningensis</td>
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<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Rhamnaceae</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35. Berchemia multinervis</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Apocynaceae</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>36. Apocynophyllum neriifolium</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td><strong>Asclepiadaceae</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37. Periploca krishtofovichii</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td><strong>Arecaceae</strong></td>
<td></td>
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<tr>
<td>38. Palmophyllum sp.</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Typhaceae</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39. Typha sp.</td>
<td>1 –</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>Incertae sedis</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40. Macclintockia basinervis</td>
<td>17</td>
<td>2</td>
<td>2</td>
<td>11.8</td>
</tr>
</tbody>
</table>

Legend: VP – Vulche Pole; ZL – Zlatoustovo; % – percentage of the total number.

The total number of taxa determined to the level of species in the paleoflora is 38. There are two taxa determined to generic level. No representatives of ferns and gymnosperms have been identified.

The palefloristic study of the Vulche Pole Molasse formation identified three species for the first time on the territory of Bulgaria: *Myrica kymeana*, *Zanthoxylum juglandinum*, and *Sapindus graecus*.

In the composition of the analysed flora, special attention deserves the species *Macclintockia basinervis*. Its ancient origin (see Bozukov 1996) and the fact that it was widely distributed in the Vulche Pole Molasse formation, almost as widely as the species *Daphnogene lanceolata* (Table 1), testify to its uniqueness for the territory of Bulgaria. Besides from the studied deposits (Bozukov 2005), the species *Macclintockia basinervis* is also known in Bulgaria from the floras of Hvoina (late Eocene–early Oligocene) (Černjavska & al. 1988) and Satovcha (middle Miocene) (Bozukov 1996; 2000), but it has played an insignificant role there. The paleoflora where that species had dominated is known from the Eocene in the Ukraine (Stanislavskiy 1956), hence the co-dominant role of *M. basinervis* in the studied flora could serve as evidence of its relatively ancient character. Along with this, the obvious supremacy of family *Lauraceae* over the rest, both in terms of species diversity and quantity, suggests that the age of the flora-bearing element was rather late Oligocene.

Another argument in support of this assumption is provided by the early Oligocene flora of Kamenity (Czech Republic) (Knobloch 1963). The author determined the paleoflora from this location as an association of the *Sequoia–Castanopsis–Daphnogene–Macclintockia–Steinhauera* type.

One of the reasons for the genera *Macclintockia* and *Daphnogene* to retain their co-dominant role until late Oligocene in the flora of Vulche Pole Molasse was probably the geographic location. The investigated location lies far more to the south than those in the Ukraine and Czechia and, respectively, the climatic conditions had longer favoured the development of representatives of the paleotropic vegetation and their dominant role.

**Acknowledgments.** This study is a contribution to the Project B-1525 (NSF, Bulgaria).
Figs 1-7. Photographs of fossil specimens:
1, Sassafras ferrettianum, HVP-73 (×2); 2, Laurophyllum acutimontanum, HVP-26 (×2); 3, Daphnogene cinnamomifolia, HVP-3 (×2);
4, D. cinnamomea, HVP-252 (×2); 5, D. bilinica, Zl-252 (×2); 6, D. lanceolata, HVP-187 (×2); 7, Litsea ocoteifolia, HVP-214 (×2).
Plate II

Figs 1-8. Photographs of fossil specimens:
Plate III

Figs 1-7. Photographs of fossil specimens:
Plate IV

Figs 1-9. Photographs of fossil specimens:
Plate V

Figs 1-9. Photographs of fossil specimens:
1, *Platanus platanifolia*, HVP-213 (×1.5); 2, *Myrica kymeana*, HVP-28 (×2); 3, *Quercus lyellii*, HVP-208 (×2); 4, *Trigonobalanopsis rhamnoides*, HVP-200 (×2); 5, *Berchemia multinervis*, HVP-197 (×2); 6, *Typha* sp., HVP-254 (×2); 7, *Sapindus falcifolius*, HVP-205 (×2); 8, *Macclintockia basinervis*, HVP-116 (×2); 9, *Palmophyllum* sp., HVP-251 (×1).
References


