

New data on the Middle Miocene flora of Northwest Bulgaria

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Abstract. Two leaf imprints have been studied of the Middle Miocene flora from Ruzhintsi village, Northwest Bulgaria. One was determined as *Macclintockia basinervis* and the second as *Tristaniopsis* aff. *laurina*. New evidence has been obtained that *Macclintockia* is affiliated to the *Myrtaceae* family. In that context, the Australian species *Melaleuca quinquenervia* has been acknowledged as the nearest living relative to the first fossil species. In the course of determination of the second leaf imprint, a considerable morphological identity has been found with another representative of the family *Myrtaceae*, again from the Australian flora, namely, *Tristaniopsis laurina*. That recent species has been acknowledged as the nearest relative to the fossil material, for the taxonomic determination of which the combination *Tristaniopsis* aff. *laurina* was applied.

Key words: Bulgaria, *Macclintockia basinervis*, *Melaleuca*, Middle Miocene, *Myrtaceae*, paleoflora, *Tristaniopsis*

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Introduction

There are 32 studied locations of the Sarmatian s.l. macroflora in Northwest Bulgaria (Palamarev & Petkova 1987), most of them dated to the Middle Miocene (Volhynian = Late Serravalian) and only few to the Late Miocene (Bessarabian = Early Tortonian (see Ivanov & al. 2019). The local palaeoflora in the area of Ruzhintsi Vilage, Vidin District, is the richest among the other Middle Miocene floras. It comprises 102 fossil species. In spite of the fact that macrofossils from that location, stored in the paleo-

botanical collection of the Institute of Biodiversity and Ecosystem Research (IBER) with the Bulgarian Academy of Sciences, have been thoroughly studied, two imprints of so far indetermined leaf laminas have been found there. The present study deals with the elucidation of their taxonomy. The two studied imprints have been acknowledged as being affiliated to the family *Myrtaceae*. Presently, representatives of this family are extremely rare in the European flora. Only the species *Myrtus communis* L. occurs in the European part of the Mediterranean. That is why, new data about taxa from this family are extremely important for revealing its distribution, both geohis-

torically and phytogeographically. Exceptionally important is the fact that one of the imprints belongs to the species *Macclintockia basinervis* (Rossm.) Knobloch, which holds an unspecified position of its genus in respect to which dicotyledon family it should be affiliated. The present study provides morphological evidence in support of one of the numerous assumptions stated during earlier investigations of this issue. The authors assume that genus *Macclintockia* is affiliated to the *Myrtaceae* family, and for a recent analogue of the fossil species *M. basinervis* they acknowledge the Australian species *Melaleuca quinquinervia* (Cav.) S.T. Blake. Considering the strong morphological identity of the leaf lamina of the second studied object with that of the recent Australian species *Tristaniopsis laurina* (Sm.) P.G. Wilson et J.T. Waterh, the authors have assumed as correct to use the taxonomic combination *Tristaniopsis* aff. *laurina* (Sm.) P.G. Wilson et J.T. Waterh, in order to determine the affiliation of the fossil material.

The *Myrtaceae* family is present in the Bulgarian paleoflora in the form of macroremains, with stratigraphic distribution mainly during the Paleogene of two species of genus *Myrtus* L.: *M. rectinervis* Saporta (Černjavská & al. 1988) and *M. palaeomestensis* Palam., Kitan. fil. et Bozukov (Palamarev & al. 1999a); two species of genus *Rhodomyrtophyllum* Ruffle & Jähnichen: *Rhodomyrtophyllum reticulatum* (Rossm.) Knobloch & Kvaček (Palamarev & al. 1999b) and *Rhodomyrtophyllum sinuatum* (Bandulska) Walther (Palamarev & Staneva 1995); one species of genus *Callistemophyllum* Ett.: *Callistemophyllum melaleuceforme* Ettingsh. (Palamarev 1963); one species of genus *Eucalyptus* L'Hér.: *Eucalyptus oceanica* Unger (Palamarev 1967); and one species of genus *Eugenia* L.: *Eugenia splendens* Petrescu, Margarit, G. & Margarit, M. (Palamarev & Petkova 1994).

The *Myrtaceae* family is represented as microfossils (pollen) by one species, *Duplopollis myrtoides* (Černjavská & al. 1988), in the Bulgarian Paleogene (Hvoina, Pavelsko sandy argillaceous formation, Upper Eocene – Lower Oligocene). Representatives of the genera *Myrtus* and *Eucalyptus* have been acknowledged as recent analogues of the fossil species.

The species *Macclintockia basinervis* (Rossm.)

Knobloch has been registered in Bulgaria in three regions of the local paleoflora of the Rhodope Mountains (South Bulgaria). Its oldest location has been dated to Late Eocene – Early Oligocene (Černjavská & al. 1988). During the Miocene, the species still existed in the Rhodopes. It has been registered at the Oligocene/Miocene boundary (Bozukov & al. 2008) and in the Middle Miocene (Bozukov 1996, 2000). Mention deserves the fact that, so far, the find of that species from the Middle Miocene (Middle Badenian = Early Serravalian) was the latest in age and that the territory of the present-day Rhodope Mountains has been acknowledged as the latest European refugium of that species (Bozukov 2005).

Geological settings

Paleogeography of the Forecarpathian Basin, as well as changes in its evolution during the Neogene, are relatively well known. A shallow brackish basin covered wide territories in the Northwest Bulgaria in the Volhynian (= Late Serravalian). The mollusk associations evidenced that the salinity of the Volhynian depositional environments could be assumed mostly at around 14-18 ‰. The longitudinal depression (the so-called Marginal Stable Area: see Fig. 1.) was still active, and in the peripheral parts of the Basin, a lot of swamp and nearly freshwater ponds existed within the delta systems of inflowing rivers. The studied paleoflora originated from an outcrop in the village of Ruzhintsi (Vidin District), on the riverine side of Lom River. The sediment succession is represented by sandy clays and clays, occasionally, with a lot of fossil leaves and decomposed plant tissue (see Palamarev & Petkova 1987 and references therein). According to Kojumdžieva & al. (1989), that section is part of the Krivodol Formation assigned to the Middle Miocene. More precisely, the age of the sediments is thought to be the Late Middle Miocene, according to the fossil finds of mollusks, foraminifers and ostracods (see Ivanov & al. 2002 and Ivanov 2020, and references therein). That part of the Basin has been distinctly richer in plant macrofossils than the other parts of the Northwest Bulgarian Miocene sediments.

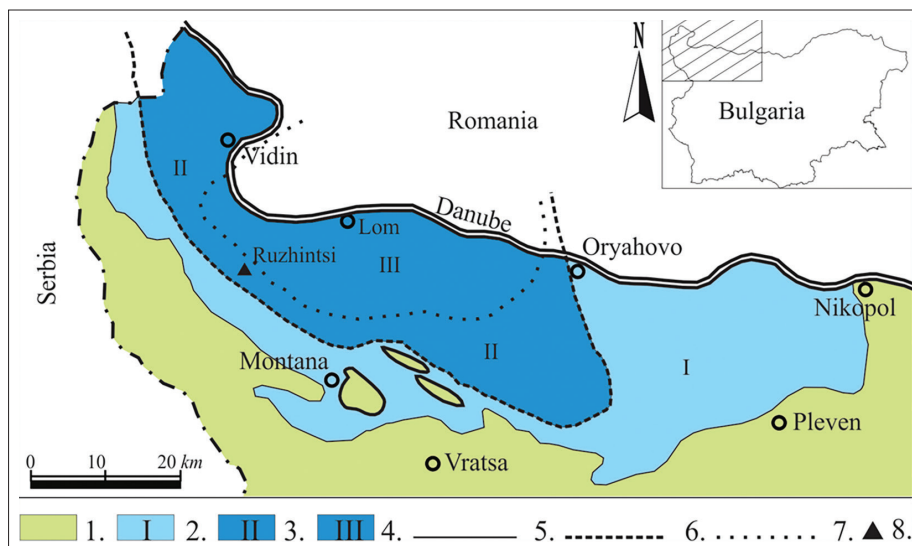


Fig. 1. Sketch map showing the structural/paleogeographic areas in Northwest Bulgaria during the Neogene, as well as the locations of Ruzhintsi outcrop (see Ivanov et al. 2002). Legend: (1) areas outside the Forecarpathian Basin (land); (2) marginal stable area; (3) Miocene longitudinal depression; (4) Lom depression; (5) boundary of the Basin; (6) boundary of the Miocene longitudinal depression; (7) boundary of the Lom depression; (8) Ruzhintsi outcrop.

Material and methods

The studied material is stored in the paleobotanical collection of the Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences (PC-IBER). It consists of leaf imprints on sedimentary rocks. The flora-bearing rocks close to Ruzhintsi Village, Vidin District (NW Bulgaria) (Fig. 1), belong to the Krivodol Formation (Kojumdzhieva & al. 1989).

Leaves from the Leaf Collection of Recent Plants of the Paleobotany and Pollen Analysis Department at IBER (LC-PPA) have been used for comparison during the present studies.

Determination of the leaf types followed the scheme for leaf morphology of the angiosperms plants of Dilcher (1974). The photographs were taken with a digital camera Panasonic DC-FZ82.

Results

Systematics

Class Magnoliopsida

Family Myrtaceae

Genus *Macclintockia* Heer

Macclintockia basinervis (Rossm.) Knobloch

1840. *Phyllites basinervis* Rossmässler, p. 37, Pl. 9, Figs 41-42.

1865. *Daphnogene excellens* Eichwald, p. 62, Pl. 3, Fig. 9.

1956. *Macclintockia excellens* (Eichw.) Stanislavskiy, p. 1188, Pl. 1, Figs 1-10; Pl. 2, Figs 1-5; Pl. 3, Figs 1-5; Text-figs 1-2.

1962. *M. basinervis* (Rossm.) Knobloch, p. 121, Pl. 6, Fig. 5.

1963. Knobloch, p. 193, Pl. 1, Fig. 9; Pl. 7, Figs 1-5, Pl. 8, Figs 1-3; Pl. 9, Fig. 1; Text-figs 23, 26-29, 32.

1988. *Cocculus (Macclintockia) kanii* (Heer) Sap. & Mar.; Černjavská & al., p. 30, Pl. 1, Fig. 3.

1996. *Macclintockia basinervis* (Rossm.) Knobloch; Bozukov, p. 71, Pl. 1, Figs 1-5.

2000. Bozukov, p. 28, Pl. 3, Fig. 1.

2005. Bozukov, p. 12, Pl. 1, Figs 1-6.

Material: Leaf imprint P-3879 (Pl. I, Fig. 1)

Description

Shape: narrow elliptic or narrow lanceolate; base acute normal; apex not preserved; leaf margin entire. Venation acrodromous, basal, perfect; midrib straight, considerably thinner towards apex; basal veins thinner than midrib, at an angle of 18-19° from midrib, slightly arch-shaped, originating from a little thickening at the transition between petiole and midrib; secondary veins thinner than the basal ones, two pairs preserved, arched, at an angle of 30-40° from midrib; intercalary veins not preserved; tertiary veins random reticulate. Size: length 6.0 cm, width 2.6 cm. Petiole 1.0 cm long and 0.2 cm wide.

Comparison

The studied imprint of the leaf lamina under No P-3879 carries the morphological characteristics of the species *M. basinervis* (Rossm.) Knobl. Although the upper part of the lamina was missing, the shape of the preserved part, morphology of the petiole, venation and leaf margin provide sufficient evidence for such a determination. There are many descriptions and data on the morphology of the fossil species (Bozukov 1996; Knobloch 1962, 1963; Stanislavskiy 1956). That is why, the authors have studied the identity of the fossil material with recent plants, in order to determine its probable nearest living relative (NLR) and, hence, the taxonomic affiliation of genus *Macclintockia*.

In the authors' opinion, among recent species, the Australian representative of the family *Myrtaceae*, the species *Melaleuca quinquenervia* (Cav.) S.T. Blake (Pl. I, Fig. 2), shows the strongest identity with the morphology of the here studied fossil species. In that species, on one twig, both leaves with four and leaves with two basal veins (Pl. II, Fig. 7) could be observed. The leaves with two basal veins have almost identical morphology with the fossil material. There is difference only in the thickness and direction of the secondary veins, which branch out from the midrib. In the fossil material, the secondary veins are more prominent and are more distinctly linked to the basal veins, while in the recent species, the secondary veins are thinner, branch out at a lesser angle from the midrib and end short of the basal veins. The other parameters such as the lamina type, its shape and leaf margin are identical. The petiole calls for special attention, because its shape, size and manner in which the veins branch from it are very characteristic both for the fossil and for the recent species. It is particularly the morphological differences of the petioles in *Macclintockia basinervis*, where they are wide and flat, and those in *Cocculus laurifolius* DC (Pl. I, Fig. 3), where they are thin and with three ribs, that have given grounds to the authors to reject the assumption that genus *Macclintockia* is affiliated to the *Menispermaceae* family.

Stratigraphic distribution: Eocene – Middle Miocene (Bozukov 2005). According to Bozukov (2000),

this species has been registered for the Middle Miocene flora of Satovcha, dated by him as Middle Badenian (= Early Serravalian) (Bozukov 2002). The new find belongs to sediments from the Volhynian age (= Late Serravalian) (Kojumdzieva & al. 1989), which also marks a slight rise in the upper boundary of the stratigraphic distribution of the species.

Genus *Tristaniopsis* Brongn. et Gris

Tristaniopsis aff. *laurina* (Sm.) P.G. Wilson & J.T. Waterh

Material: Leaf imprint P-3647a-b (Pl. I, Fig. 5)

Description

Shape: narrow elliptic; base not preserved, probably acute; apex acute; leaf margin entire. Venation pinnate, brochidodromous; midrib thick at the base, considerably thinner towards apex; secondary veins - 25 pairs preserved, much thinner than midrib, slightly arched, at an angle of 50-60° from midrib, connected with each other almost at the leaf margin; intercalary veins between the secondary veins in the middle of leaf lamina; tertiary veins not visible. Size: length 9.0 cm, width 2.0 cm.

Comparison

Many genera and species of the family *Myrtaceae* characteristically have a great number of closely set secondary veins, and in the brochidodromous type of venation, the tops of the secondary veins merge into one vein following the leaf margin of the lamina. Or secondary veins themselves end in such a vein. For instance, in the genera *Calistemon* (Pl. I, Fig. 4), *Eugenia*, *Myrtus*, etc. Considering the fact that such a vein has not been observed in the here studied fossil material, those genera have been excluded. There are also some genera from the same family, in which such vein is not formed as, for instance, the genera *Psidium* (Pl. I, Fig. 6) and *Tristaniopsis*. A morphology identical to the leaf morphology of the studied fossil material has been observed in the recent species *Tristaniopsis laurina* (Sm.) P.G. Wilson et J.T. Waterh (Pl. II, Fig. 8). That was the reason to mention it as NLR of the here studied material and to use the combination *Tristaniopsis* aff. *laurina* for denoting its taxonomic affilia-

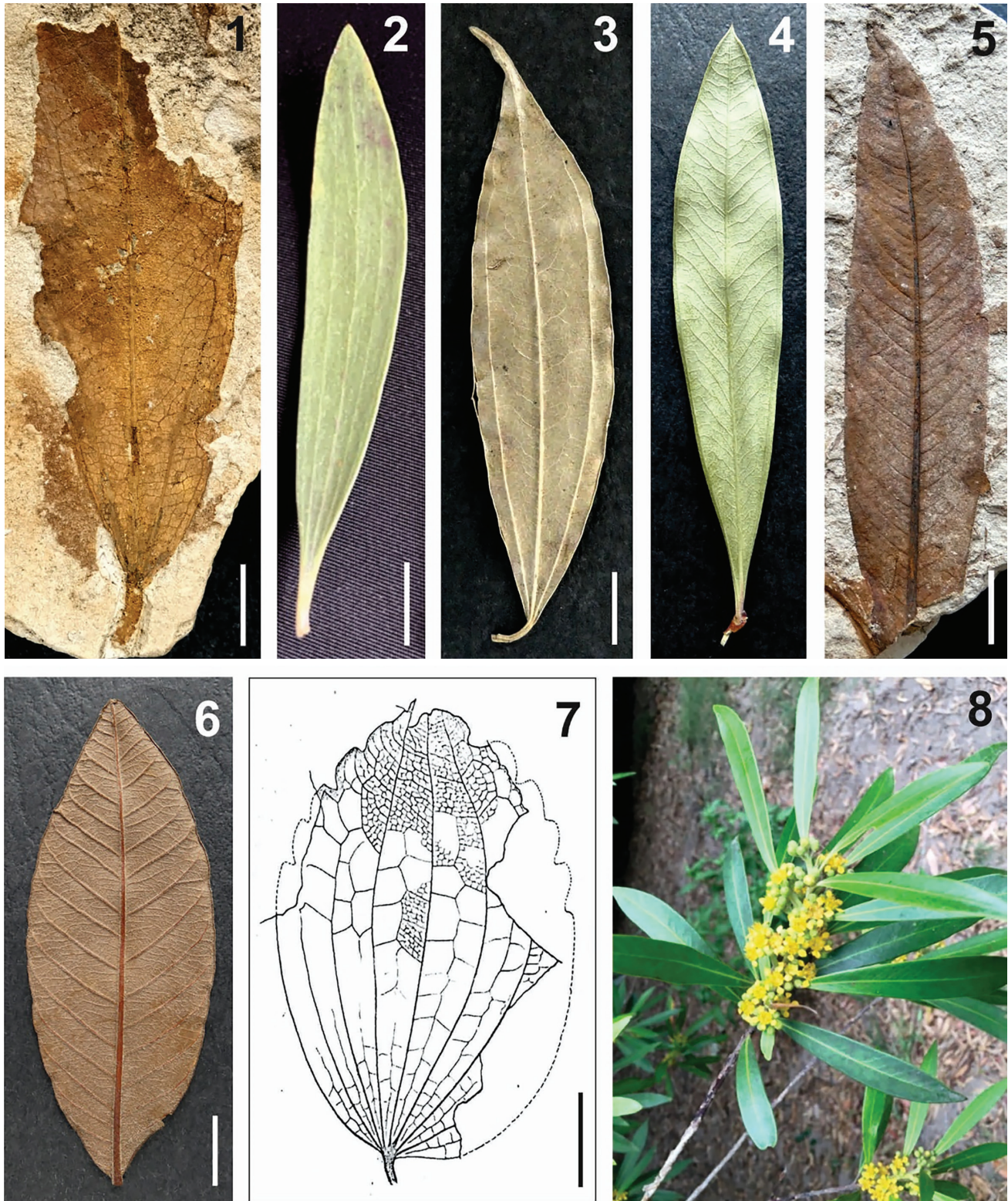


Plate I 1. *Macclintockia basinervis* (P-3879, PC-IBER); 2. *Melaleuca quinquenervia* (LC-PPA); 3. *Cocculus laurifolius* (LC-PPA); 4. *Callistemon viminalis* (Sol. ex Gaertn.) G. Don (LC-PPA); 5. *Tristaniopsis aff. laurina* (P-3647a, PC-IBER); 6. *Psidium guajava* L. (LC-PPA); 7. *Macclintockia dentata* (after Heer 1871); 8. *Tristaniopsis laurina* (after <https://spain.inaturalist.org/photos/57995718>). Measuring bar – 1 cm.

tion. The only leaf imprint at the authors' disposal did not permit clear-cut determination of the fossil.

Discussion

The genus *Macclintockia* was introduced by Heer (1868) from the Paleocene deposits of West Greenland. Originally, the following three species were included into the genus: *M. dentata* Heer (Pl. I, Fig. 7), *M. lyallii* Heer (Pl. II, Fig. 1), and *M. trinervis* Heer (Pl. II, Fig. 2). Subsequently, Saporta et Marion (1878) described the species *M. heersiensis* Sap. et Mar. (Pl. II, Fig. 3) from the Paleocene flora of Gelinden (Belgium). Comprehensive data on the polymorphism of leaves of *M. basinervis* has been presented by Stanislavskiy (1956), who studied the Eocene flora from Rudnya Baranovskaya (Ukraine), where *M. basinervis* was playing a dominant role.

Many authors assume that *Macclintockia* leaves show similarities to the leaves of species of different families, namely, *Lauraceae*, *Melastomaceae*, *Menispermaceae*, *Myrtaceae*, *Proteaceae*, and *Urticaceae*, but such leaves are mainly treated as *incertae sedis*.

In the authors' opinion, the genus *Macclintockia* belongs to the family *Myrtaceae*. They accept as evidence the morphological identity of the species *M. lyallii*, *M. trinervis* and *M. basinervis* with recent species from genus *Melaleuca* L. And more specifically, *M. lyalii* resembles the species *M. dealbata* S.T.Blake (Pl. II, Fig. 6), distributed in West and North Australia and in New Guinea. The shape of leaves both in the fossil and in the recent species is narrow elliptic or narrow oblanceolate. Venation is acrodromous, basal, perfect. Midrib is slightly thicker than the basal veins, which are four in number. Identically for both fossil and recent species, the secondary veins, which branch out from midrib, and the basal veins fuse together and form intercalary veins exactly in the middle between midrib and the basal veins, or in the middle between basal veins. The secondary veins, which branch out of the outlying basal veins, are arched and form loops between themselves close to the leaf margin. The tertiary veins form areoles

identical in form and shape. The petioles are also identical in width and length in the fossil and the recent species. The basal veins originate from the end of the petiole. The only difference has been detected in the type of the leaf margin. In the fossil species, it is dentate close to the leaf top, with two or three pairs of dents, very obscure.

The recent species *M. quinquenervia* manifests leaf polymorphism, expressed in leaves with two basal veins and leaves with four basal veins on one twig. Also, the shape of the leaf lamina could be narrow elliptic, oblanceolate or narrow obovate (Pl. II, Fig. 7). Venation is acrodromous, basal, perfect. It is precisely the leaves with two basal veins that are identical with those of the fossil species *M. trinervis*. This is expressed in the shape and arrangement of the secondary veins. Those of them that branch out from midrib are arched and directed towards the top of the leaf lamina, without merging with the pair of basal veins. The secondary veins, which branch out from the outlying basal veins, are arched and anastomous close to the leaf margin. The shape of the leaves is lanceolate, narrow elliptic or oblanceolate. The petioles are identical in width and length in the fossil and the recent species. The basal veins originate from the end of the petiole. In the fossil species, the leaf margin is dentate in the upper third of the leaf. Once again, this is the only difference in the leaf morphology of the two compared species.

The fossil species *M. heersiensis* has a similar leaf morphology, but in it, only two pairs of dents are developed close to the top of the leaf lamina.

Mention deserves the fact that the recent species *M. quinquenervia* and *M. dealbata* have an entire leaf margin, while the fossil species *M. heersiensis*, *M. trinervis* and *M. lyallii* have a dentate leaf margin close to the top of the lamina, or in its top half. Seward and Conway (1935) had unified those three species, along with *Daphnogene kanii* Heer (1808) [= *Cocculus kanii* (Heer) Saporta & Marion] (Pl. II, Fig. 4), which has an entire leaf margin, into one species, *Macclintockia kanei* (Heer) Seward & Conway. Probably, those authors had also considered it possible for the leaf margin to vary from entire to dentate at the top half of the leaf lamina.

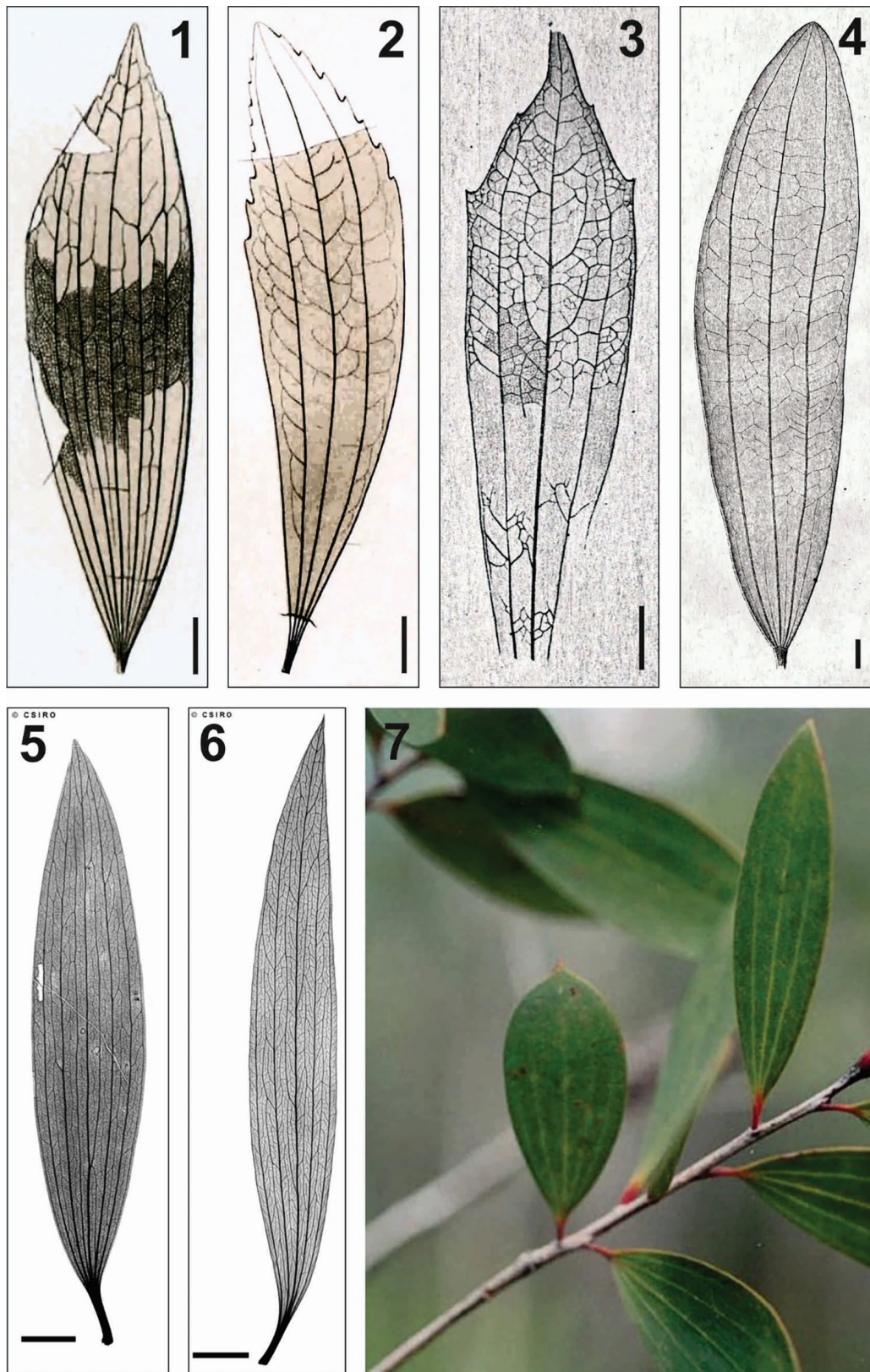


Plate II 1. *Macclintockia lyallii* (after Heer 1868); 2. *M. trinervis* (after Heer 1868); 3. *M. heersiensis* (after Saporta & Marion 1878); 4. *Cocculus kanii* (after Saporta & Marion 1873); 5. *Melaleuca viridiflora* (after <https://apps.lucidcentral.org>); 6. *M. dealbata* (after <https://apps.lucidcentral.org>); 7. *M. quinquenervia* (after <https://florida.plantatlas.usf.edu>). Measuring bar – 1 cm.

The same variations have been found in the fossil species *M. basinervis* (Stanislavskiy 1956). In it, the leaf margin is characteristically entire, but there are also leaf forms with from one to three pairs of dents close to the top of the leaf. That fossil species differs from the leaf forms of *M. quinquenervia* in the secondary veins, which branch out from midrib and merge with the basal veins. In that fossil species, elliptic leaf forms occur, with acrodromous, basal, imperfect venation. Nevertheless, there is an obvious identity of venation in the leaf lamina and originating of the basal veins from the end of the petiole.

The fossil species *M. dentata* has characteristically broadly elliptic shape of the leaves, dentate leaf margin in the upper half of the leaf and six basal veins. Similar to the above-mentioned recent species, its secondary veins merge in mid-space between the basal veins and form intercalary veins, parallel to the midrib and basal veins. In the recent species *M. viridiflora* (Pl. II, Fig. 5), a similar transition has been observed towards formation of six basal veins via transformation of the intercalary into basal veins. A relatively identical morphology with that of the *Macclintockia dentata* species have the species described from the northern and northeastern parts of Russia (Budantsev 1990; Moiseeva 2011), with a stratigraphic range of Upper Cretaceous – Middle Paleogene (Eocene). Their identity is expressed in the elliptic to broadly elliptic shape of the leaf lamina and dentate leaf margin. In respect to the number of basal veins and shape of the leaf lamina, the fossil species from the northern and northeastern parts of Russia are close to the recent species *Melaleuca viridiflora* Gaertn., distributed mainly in North Australia.

With the above examples of identity of the leaf morphology of the fossil and recent species, the authors confirm their assumption that the genus *Macclintockia* should be acknowledged as close to the genus *Melaleuca* and as member of the family *Myrtaceae*, respectively. Differences in the type of the leaf margin could be attributed to the evolution of the recent species. Quite possibly, the fossil genus was not an ancestor of the genus *Melaleuca*, but they had both originated from a species distributed in the Northern Hemisphere, whose descendants had disappeared from the

territory of Europe, while in Asia and America those descendants had found their way to Australia, where they have been preserved ever since.

Another evidence of the close connection between the fossil genus *Macclintockia* and the recent genus *Melaleuca* is aptitude of the species of the recent genus to the shorelines of water basins and swampy plains with high annual rainfalls. For instance, *M. quinquenervia* is distributed in estuarine swamps and lake margins, where the annual rainfall is 1200–1400 mm. This species is dominant in the swamp forests, or dominates with species of genus *Eucalyptus*. *M. quinquenervia* tolerates drought and salinity, but is intolerant of frost (<https://www.wet Tropics.gov.au/site/user-assets/docs/factsheets/wtmaVMW7B50a-59g.pdf>; Benson & McDougall 1998). Many authors (Brown 1962; Budantsev 1990; Koch 1963; Wolfe 1968) have assumed that the habitats of the genus *Macclintockia* were mainly seashores, river estuaries or low riverine plains, which had assisted its wide distribution in the Paleogene and its quick demise after the lowering of the sea level during the Neogene.

The assumption of aptitude of the *Macclintockia basinervis* species for shoreline zones is supported by the fact that NLR of the other representative of family *Myrtaceae* from the same location analyzed here, has shown the same ecological requirements. *Tristaniopsis laurina* usually grows near the eastern coastline of Australia and along the banks of streams in warm-temperate and riparian rainforests, where the annual rainfall is above 700 mm (Benson & McDougall 1998).

The ecological characteristics of the assumed recent analogues of the analyzed fossil taxa provide further information about the climate conditions in which the local palaeoflora from Ruzhintsi had existed. They stand evidence of high annual rainfalls and absence of frosts, which is a prerequisite for a rich flora, with a mix of Palaeotropical and Arctotertiary elements.

Conclusions

The taxa *Macclintockia basinervis* and *Tristaniopsis* aff. *laurina* identified by the authors further enrich the composition of the richest local Middle Miocene flora

in Northwest Bulgaria. A taxon related to genus *Tristaniopsis* has been identified for the first time in the Bulgarian palaeoflora. The presence of *M. basinervis*, even with a sole leaf imprint, against the background of the rich fossil material from the location at Ruzhintsi village proves lack of frosts across the year and stands evidence to the favourable climatic conditions under which the identified in that paleoflora Palaeotropical and Arctotertiary representatives had existed.

The presence of the *Macclintockia basinervis* species in the Middle Miocene flora of Ruzhintsi village confirms the fact that the territory of Bulgaria was the last refuge of that Paleogene relict in Europe and, along with that, of its genus too. Furthermore, the stratigraphic range of the genus has been also expanded: from Upper Cretaceous (Santonian-Campanian) to Middle Miocene (Upper Serravallian).

The morphological comparisons drawn by the authors between the species of genus *Macclintockia* with species of the recent genus *Melaleuca* support the assumption that the fossil genus is affiliated to the *Myrtaceae* family. In this context, it could be maintained that the two taxa studied here, *Macclintockia basinervis* and *Tristaniopsis* aff. *laurina*, are the last representatives of that family in the Bulgarian palaeoflora. The climatic changes, that had set in after the Middle Miocene, had probably caused for some genera of that family to disappear from the Northern Hemisphere, and for other to migrate southwards towards Southeast Asia and Australia, where they got established and remained as recent representatives of the family.

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