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A New Species of the Genus *Platimeliphyllum* N. Maslova from the Paleocene of the Amur Region, Russia

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Abstract—A new species, *Platimeliphyllum valentinii*, is described from the Paleocene of the Amur Region on the basis of macromorphological and epidermal characters. It was shown that leaves of *Platimeliphyllum* N. Maslova associate with two fundamentally different types of reproductive structures: platanaceous *Archaranthus* N. Maslova et Kodrul and *Bogutchanthus* N. Maslova, Kodrul et Tekleva, which combines characters of the Platanaceae and Hamamelidaceae. The higher evolutionary stability of leaf structures in comparison with reproductive organs is discussed.

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Key words: fossil leaves, reproductive structures, Platanaceae, Hamamelidaceae, Paleocene, Amur Region.

INTRODUCTION

Leaves that are assigned to the Platanaceae were common in floras of the Northern Hemisphere during the Cretaceous and Early Paleogene. The oldest finds of leaf remains assigned to this family are dated to the Early Cretaceous (Hickey and Doyle, 1977). The diversity of the Platanaceae considerably increased during the Late Cretaceous, and then decreased from the Paleocene, until a single genus remained in the Oligocene and Miocene. Nowadays, the family Platanaceae is monotypic.

The modern genus *Platanus* L. features highly polymorphic leaves, both at generic and specific levels. For example, the range of leaf blades in *P. acerifolia[MB1]* Willd. includes entire leaves with pinnate venation and lobate leaves varying from weakly lobate to lobate with deep sinuses, with three or five lobes, or asymmetrical (with one lateral lobe) (Maslova et al., 2005; Maslova, 2007). The lobate leaf with variously developed basal veins is the most characteristic morphotype of *Platanus*. It appeared as early as the Early Cretaceous and has remained virtually unchanged until now. Compound (Crane et al., 1988, 1993; Johnson, 1996; Kvaček et al., 2001) and simple entire-margined (Bůžek et al., 1967; Maslova, 2002a) leaves are also known in fossil Platanaceae.

The genus *Platimeliphyllum* N. Maslova was established to describe entire leaves with craspedodromous venation, variously developed basal veins, and a dentate margin from the Upper Paleocene–Lower Eocene deposits of the Kamchatka Peninsula and Sakhalin Island. Members of this genus show a peculiar combination of platanaceous and hamamelidaceous characters. *Platimeliphyllum* has symmetrical and asymmetrical leaf blade morphotypes with typically platanaceous convex-concave and concave-concave teeth or hamamelidaceous low triangular or rounded teeth. Along with macromorphological characteristics of both families, platanaceous epidermal characteristics were revealed in *P. palanense* (Budants.) N. Maslova (Maslova, 2002a).

Leaves of *Platimeliphyllum* were found in association with staminate inflorescences of *Chemurnautia* N. Maslova, which also have characters of the Platanaceae. The cooccurrence of inflorescences of *Chemurnautia* and leaves of *Platimeliphyllum* in several nearly coeval localities of the Kamchatka Peninsula (Snatol River, Napana Formation, Upper Paleocene; Chemurnaut Bay, upper part of the Kamchik Formation–lower

Explanation of Plate 10

Figs. 1–9. *Platimeliphyllum valentinii* sp. nov., leaf impressions: (1) GIN, no. AB1-126; (2) GIN, no. AB3-44; (3) GIN, no. BG-67; (4) GIN, no. AB1-163; (5) GIN, no. AB3-92; (6) GIN, AB3-115, rounded marginal teeth; (7) GIN, no. A3-39, convex-concave and triangular marginal teeth with a pointed apex, (8) GIN, no. AB1-463; (9) holotype GIN, no. AB3-115. Arkhara-Boguchan brown coal field, Amur Region; Tsagayan Formation, Lower Paleocene. Scale bar 10 mm.

Plate 10

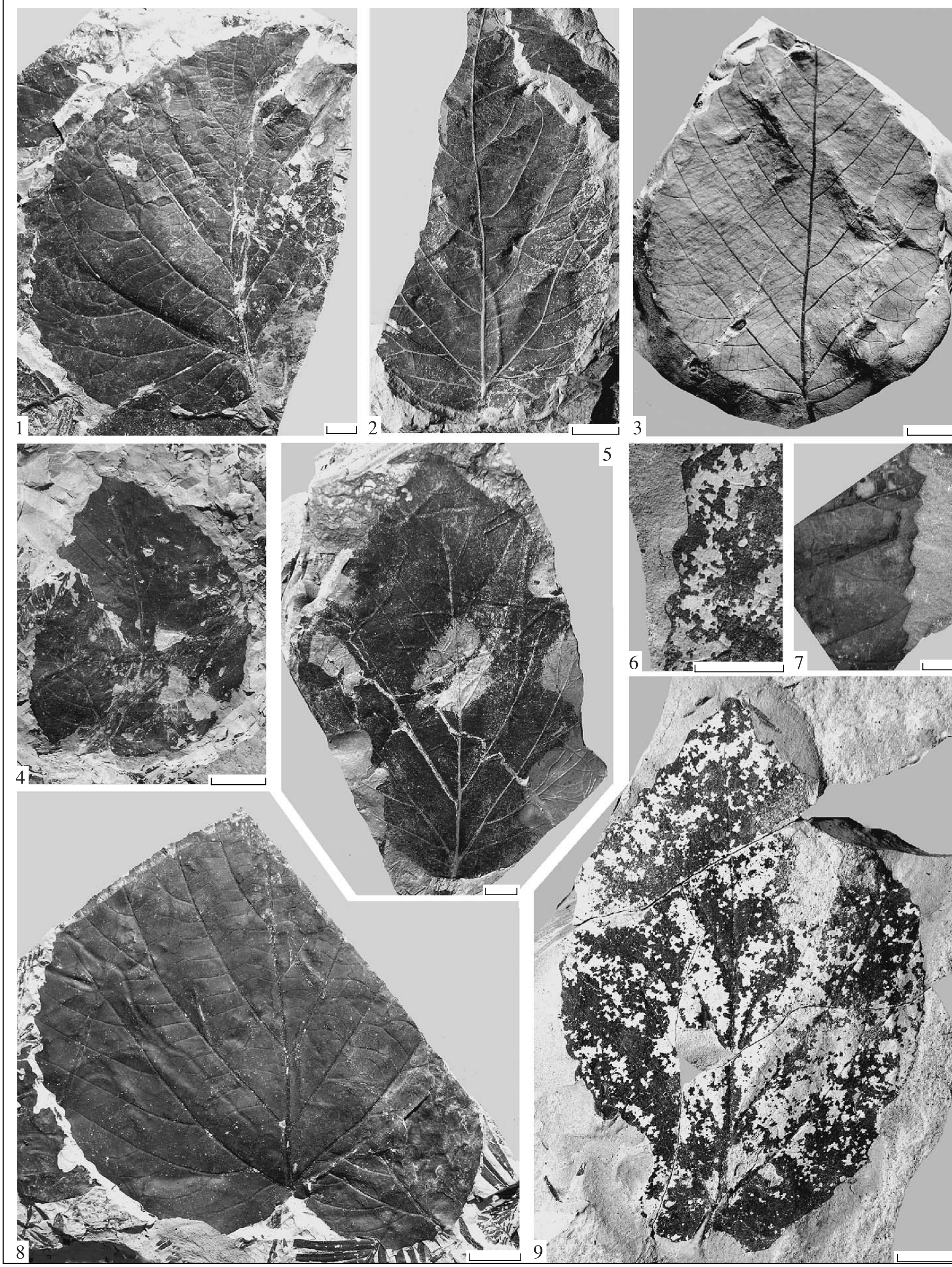
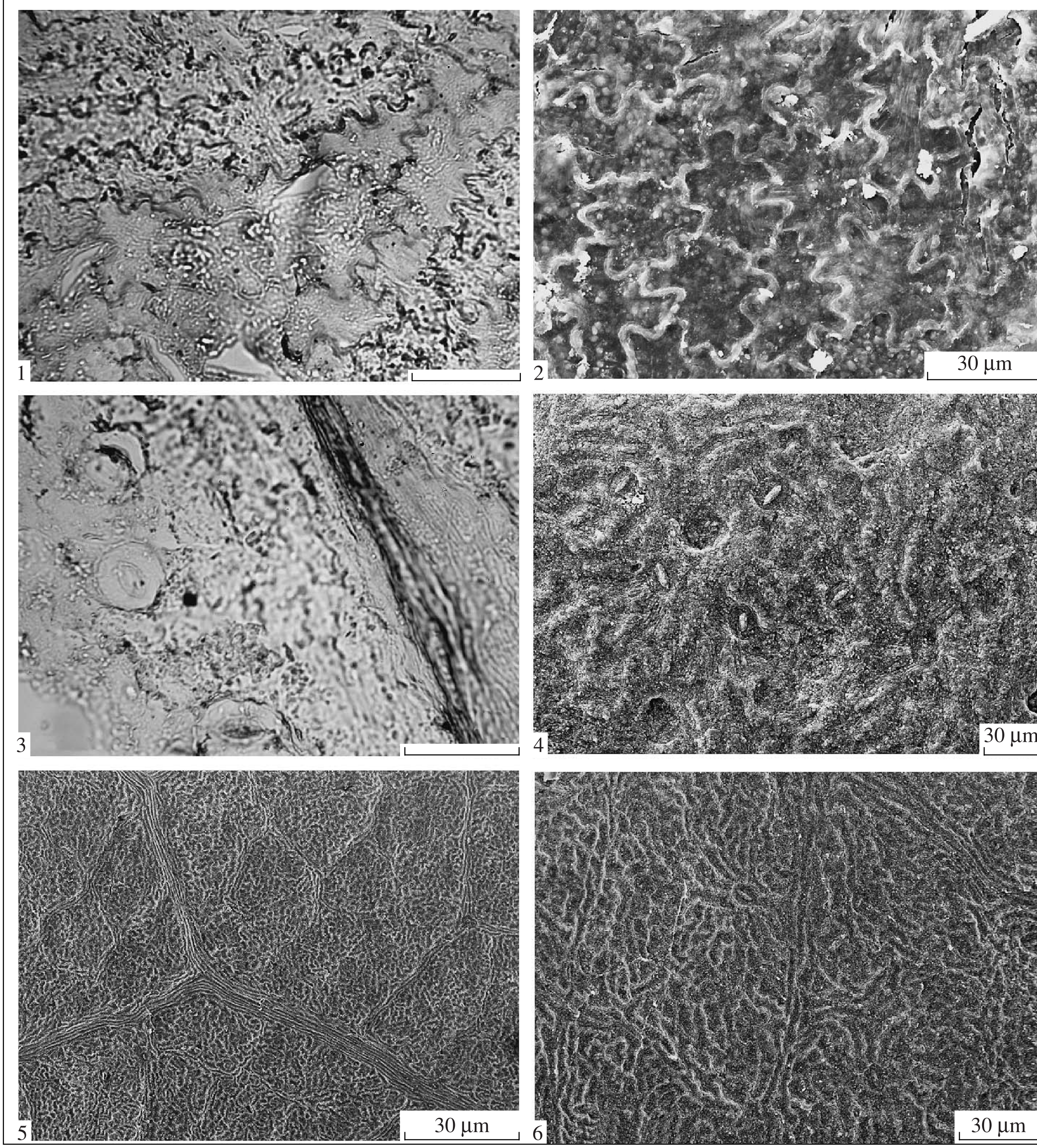


Plate 11



Explanation of Plate 11

Figs. 1–6. *Platimeliphyllum valentinii* sp. nov., leaf epidermal morphology: (1) GIN, no. AB3-116, cuticle of the adaxial leaf surface, LM; (2) GIN, no. AB3-116, note striae and granular layer, SEM; (3) GIN, no. AB3-116, cuticle of the abaxial leaf surface with stomata, LM; (4–6) GIN, no. AB1-109, incrustations with impressions of the abaxial leaf surface, SEM. Arkhara-Boguchan brown coal field, Amur Region; Tsagayan Formation, Lower Paleocene. Scale bar (1, 3) 40 μm.

part of the Tkaprovayam Formation, Upper Paleocene–Lower Eocene; section between Capes Rebro and Getkilnin, Tkaprovayam Formation, Upper Paleocene–Lower Eocene; Evravavayam River, Tkaprovayam Formation, Lower Eocene) allowed us to hypothesize their affinity to the same parent plant.

The new species of *Platimeliphyllum* that is described in this paper includes entire polymorphic leaves from the Paleocene of the Amur Region combining morphologies of leaf blades of the Platanaceae and Hamamelidaceae. In the type locality, they associate with two fundamentally different reproductive structures: platanaceous *Archaranthus* N. Maslova et Kodrul (Maslova and Kodrul, 2003) and *Bogutchanthus* N. Maslova, Kodrul et Tekleva, which combines characters of the Platanaceae and Hamamelidaceae (Maslova et al., 2007).

MATERIALS AND METHODS

The leaf impressions, with coaly compressions, come from the Tsagayan Formation of the Amur Region (Russia). Most plant remains were found in temporary open-cast coal mines of the Arkhara-Boguchan brown coal field, 15 km southeast of Arkhara (49°18′45.1″ N, 130°12′45.4″ E; 49°18′52.3″ N, 130°12′42.7″ E; and 49°18′59.2″ N, 130°12′44.5″ E). Plant remains occur in gray clays 6–8 m thick between the Nizhnii and Dvoinoi coal seams, in the upper part of the Middle Tsagayan Subformation (Akhmetiev et al., 2002). These deposits are dated to the Early Paleocene based on macrofossil plant remains and palynology (Kodrul, 2004; Markevich et al., 2004). About 20 leaf remains were found in lenses of gray clays at the base of the Upper Tsagayan Subformation, in the stratotype of the formation in Bureinskoe Belogor'e, northeastern slope of Mount Belaya and southern slope of Mount Ploskaya, which are situated on the right bank of the Bureya River, in the mouth of its right tributary, Darmakan Creek (Akhmetiev et al., 2002). Earlier, these fossil leaves were reported as morphotype 2 of "*Platanus*" *raynoldsii* Newberry (Moiseeva et al., 2004). Data on plant macrofossil remains and pollen and spores also date the flora-bearing beds of the Bureinskoe Belogor'e to the Early Paleocene (Krassilov, 1976; *Flora*…, 2001).

The leaf epidermal morphology was studied in cuticle specimens and incrustations. Incrustations are thin mineral films that envelop plant remains during fossilization (Krishtofovich, 1945; Krassilov and Makulbekov, 1996). The leaves under study retain incrustations on the surface of the impression and its counterpart when the coaly compression is removed. The epidermal morphology of the lower leaf surface, which has a thin cuticle, is usually expressed in the incrustations in relief. Impressions of the upper leaf surface allow one to observe a thicker upper cuticle and the topography of the upper epidermis. Cuticles obtained by maceration of coaly compressions with Schulze solution and alkali were studied under the light microscope and scanning electron microscope (SEM). Intact incrustations were mounted on SEM stubs and covered with gold. Leaf impressions were photographed with a Nikon Coolpix 8700 digital camera; micrographs were prepared using a Jenamed light microscope with a Canon EOS-300D digital camera and in a CamScan SEM.

SYSTEMATIC PALEOBOTANY

Family Platanaceae

Genus *Platimeliphyllum* N. Maslova.

Platimeliphyllum valentinii **Kodrul et N. Maslova, sp. nov.**

Plate 10, figs. 1–9; Plate 11, figs. 1–6

E t y m o l o g y. In honor of the paleobotanist Prof. Valentin Krassilov.

H o l o t y p e. GIN, no. AB3-115; leaf impression; Amur Region, Arkhara-Boguchan coal field, 15 km northeast of the village of Arkhara; Tsagayan Formation, between the Nizhnii and Dvoinoi coal seams; Lower Paleocene (Pl. 10, fig. 9).

D i a g n o s i s. Leaf blade entire, rounded, rounded-ovate, or oval, variously asymmetric. Length/width ratio 1.1–1.7. Leaf base cordate and rounded, or wedge-shaped, often asymmetric and peltate. Leaf blade apex acuminate, occasionally elongated mucronate. Leaf margin toothed, teeth from small concave-concave to larger convex-concave or rounded, often with pointed apex. Venation actinodromous, basal veins usually deviate suprabasally, reach at least half of leaf blade length, give five to eight basiscopic deviations, looping or ending craspedodromously. Secondary veins weakly arching, five to eight pairs, three lower pairs give up to three basiscopic deviations. Tertiary veins thin, weakly arching or sinuous, opposite percurrent, and alternate percurrent. Finer venation includes system of polygonal meshes with dichotomizing vein. Epidermis of upper leaf surface consists of polygonal cells with undulating anticlinal walls. Epidermal cells of lower leaf surface predominantly tetragonal, with equal sides, usually in rows radiating from stomata. Stomata anomocytic, with five to seven subsidiary cells.

D e s c r i p t i o n (Figs. 1–4). Leaves are simple, entire, and petiolate. The petiole is up to 4.5 cm long, basally widened (Fig. 1b). The leaf blade is rounded, rounded-ovate, or oval, often asymmetric. In the largest specimens, the length of the leaf blade reaches 16 cm and the width 13.5 cm. The length/width ratio of the leaf blade ranges from 1.1 to 1.7. This feature allows us to differentiate between two groups of morphotypes that are connected by transitions: virtually rounded leaf blades with the length/width ratio 1.1–1.3 and oval leaf blades with the ratio 1.6–1.7. The outline of the leaf base varies considerably. Specimens with rounded, wedge-shaped, cordate, emarginate (up to notched), and asymmetric bases occur; peltate forms are also common (Figs. 1a–1j). The leaf apex is gradually narrowing, acuminate, or, more rarely, elongated mucronate. The leaf blade margin is variously toothed. There are specimens with teeth starting from the base of the leaf blade (Figs. 2a–2d, 3a, 3h) and specimens with an entire-margined lower third of the leaf blade (Figs. 2g–2i, 3b, 3f, 3g, 3i). The number of teeth per 1 cm of the leaf margin varies from one to five. The teeth are different in height and outline. There are low teeth (=short cusps) and relatively high teeth with unequal apical and basal

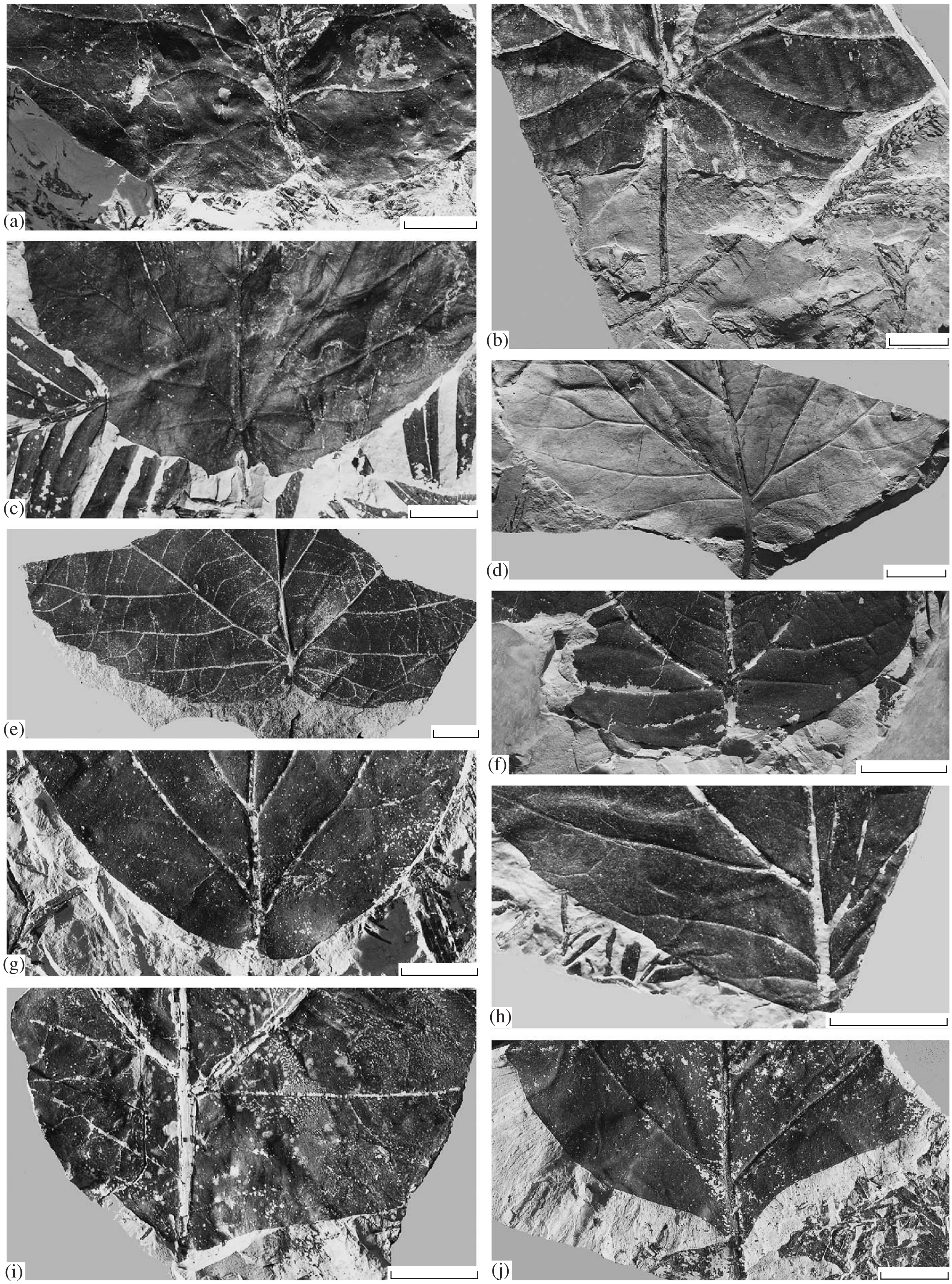

(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)

Fig. 1. Variability in the leaf base outline of *Platimeliphyllum valentinii* sp. nov.: (a) GIN, no. AB1-205; (b) GIN, no. AB1-219; (c) GIN, no. AB1-463; (d) GIN, no. AB1-349; (e) GIN, no AB3-117; (f) GIN, no. AB1-131; (g) GIN, no. AB1-226; (h) GIN, no. AB2-2; (i) GIN, no. AB1-460; (j) GIN, no. AB1-459. Arkhara-Boguchan brown coal field, Amur Region; Tsagayan Formation, Lower Paleocene. Scale bar 10 mm.

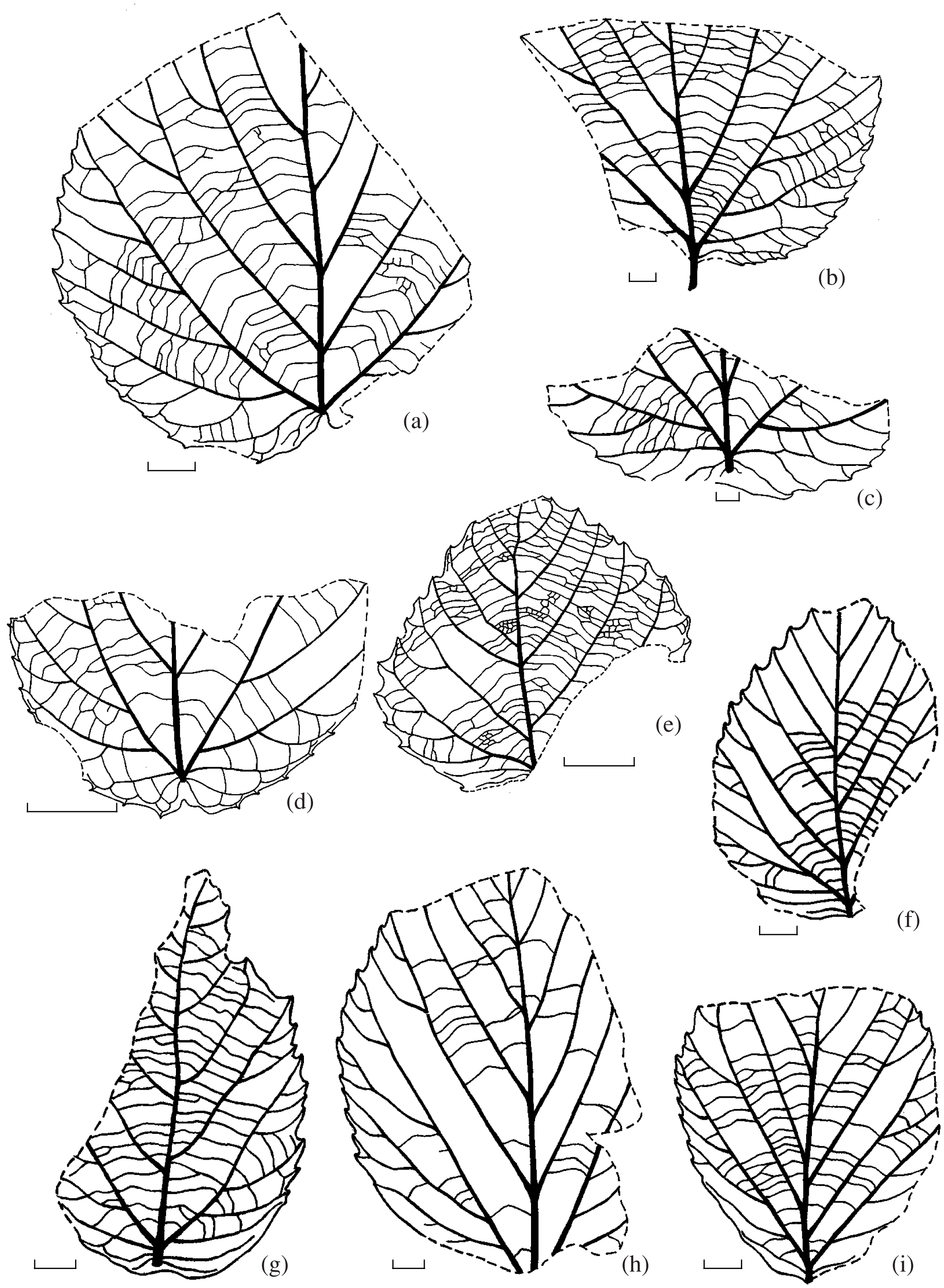


Fig. 2. Morphological variability of leaves of *Platimeliphyllum valentinii* sp. nov.: (a) GIN, no. AB1-463; (b) GIN, no. AB3-91; (c) GIN, no. AB3-66; (d) GIN, no. AB1-463; (e) GIN, no. AB1-1888; (f) GIN, no. AB2-29; (g) GIN, no. AB3-44; (h) GIN, no. AB3-69; (i) GIN, no. AB3-7. Arkhara-Boguchan brown coal field, Amur Region; Tsagayan Formation, Lower Paleocene. Scale bar 10 mm.

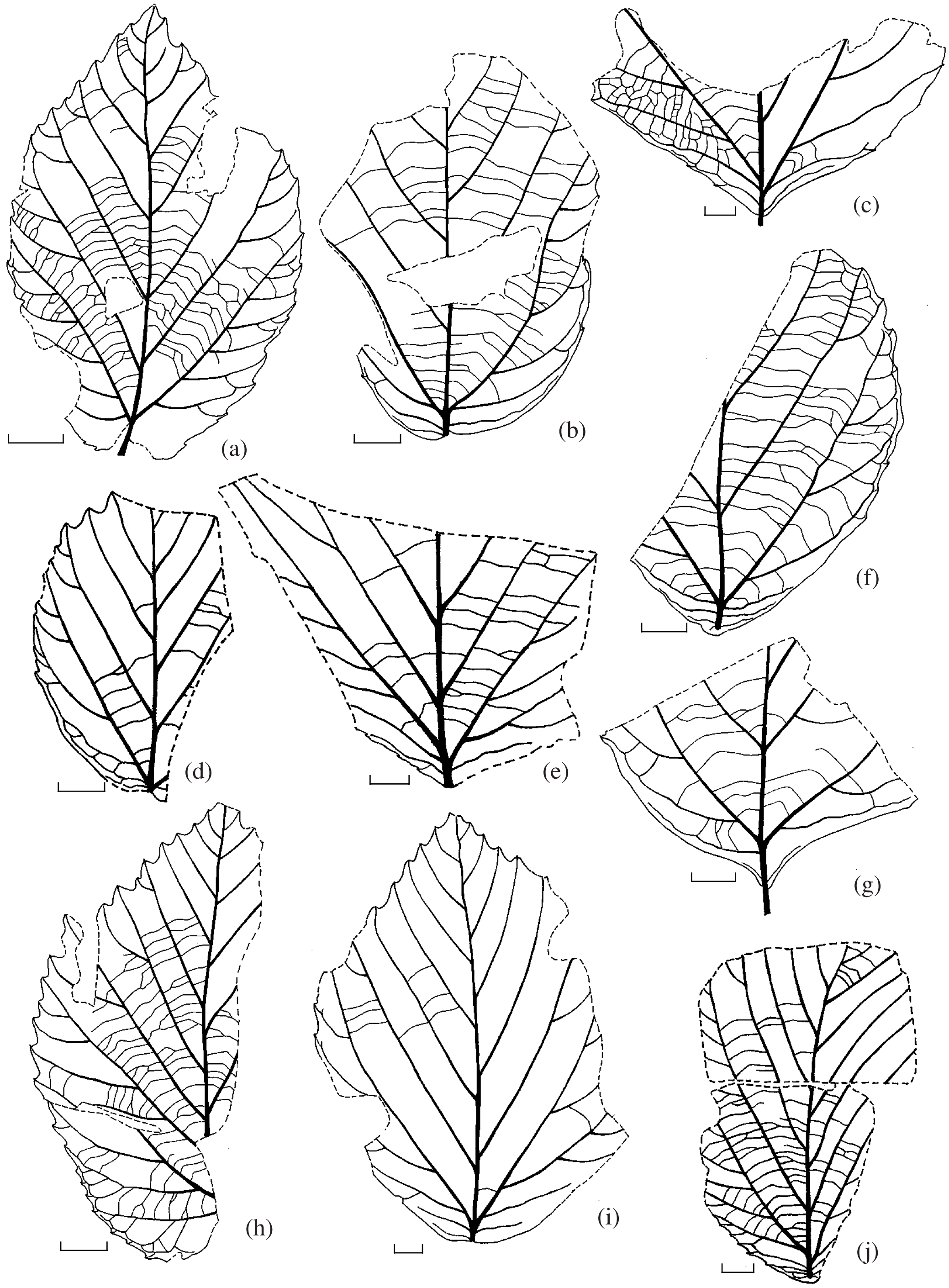


Fig. 3. Morphological variability of leaves of *Platimeliphyllum valentinii* sp. nov.: (a) GIN, no. AB3-115; (b) GIN, no. AB3-90; (c) GIN, no. AB1-225; (d) GIN, no. AB3-64; (e) GIN, no. AB1-41; (f) GIN, no. AB1-432; (g) GIN, no. AB1-459; (h) GIN, no. AB3-114; (i) GIN, no. AB3-92; (j) GIN, no. AB2-2. Arkhara-Boguchan brown coal field, Amur Region; Tsagayan Formation, Lower Paleocene. Scale bar 10 mm.

sides. Convex-concave and concave-concave teeth prevail; teeth with cusps are also common.

The venation is actinodromous. The midrib is relatively thick in the lower part of the leaf, gradually becoming thinner at the expense of deviating basal and secondary veins, straight or weakly curved, and usually sinuous in the upper part of the leaf. Basal veins are arching, as thick as the next pair of secondary veins (or slightly thicker), deviating from above the base of the leaf blade (rarely from the base) with a certain dis-

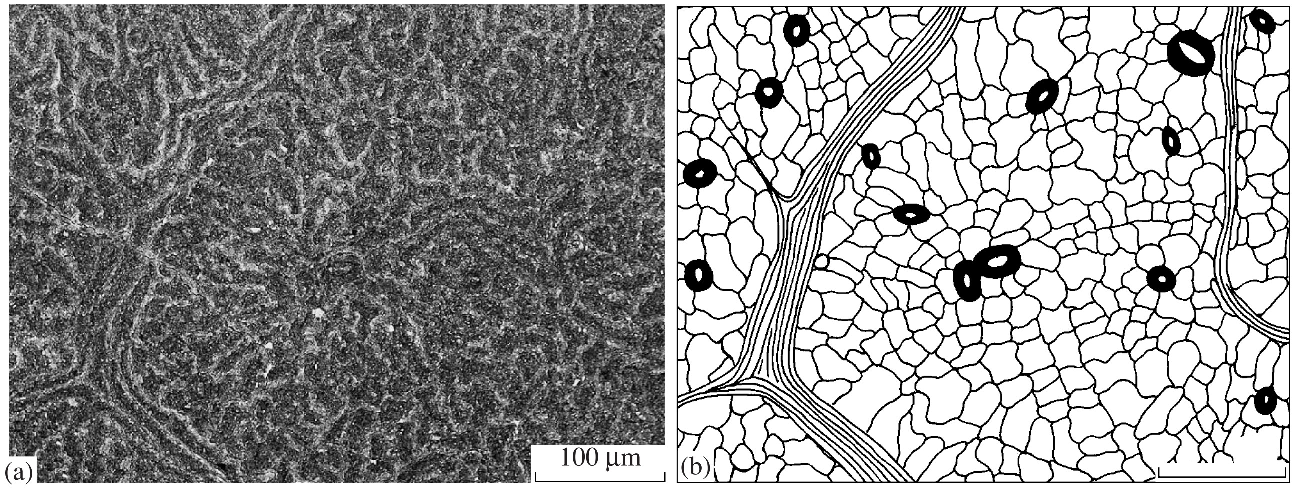


Fig. 4. Leaf epidermal morphology of *Platimeliphyllum valentinii* sp. nov.: (a) GIN, no. AB1-109, incrustation with an impression of the abaxial leaf surface, SEM; (b) GIN, no. AB1-109, idealized drawing of the leaf surface, connivent stomata are shown. Scale bar 100 µm.

placement between each other, reaching at least a half of the leaf blade length. There are five to eight basiscopic deviations of basal veins; they are thin and arching. When the lower region of the leaf blade is devoid of teeth, lower basiscopic deviations of basal veins are looping, and upper deviations end in teeth. Basiscopic deviations of basal veins branch one to five times. Leaves with distinct pomes have up to four infrabasal veins, ending in teeth or looping. There are five to eight pairs of secondary veins. They are thin and weakly arching. The first to third pairs give up to three basiscopic deviations. Tertiary veins are variously developed. They are thin, weakly arching or sinuous, opposite percurrent and alternate percurrent. There are two to four (in small leaves up to seven) tertiary veins per 1 cm of a secondary vein. Finer venation is a system of polygonal meshes with a dichotomizing vein.

The epidermal morphology was studied in cuticle samples (Pl. 11, figs. 1–3) and incrustations (Pl. 11, figs. 4–6; Figs. 4a, 4b). The cuticles of the lower surface of these leaves is thin, the cuticle of the upper surface is thicker, with fine striae on the outer surface (Pl. 11, figs. 1, 2) and a granular inner layer (Pl. 11, fig. 2).

The epidermis of the upper surface of the leaf blade is composed of cells that vary in shape and size. Polygonal cells with variously undulated anticlinal walls (up to amoeboid forms) and a maximum size of 50–70 µm definitely prevail. The epidermis of the lower surface of the leaves is mostly formed by tetragonal equilateral cells of 25–40 µm. Usually, these cells form rows that radiate from the stomata (Figs. 4a, 4b). More rarely, polygonal cells with undulated walls and maximum sizes of 50–70 µm occur in the lower epidermis. Stomatal apparatuses are anomocytic, with five to seven subsidiary cells, slightly varying in size (from 15 to 30 µm) and shape (rounded to oval), one or two per 1 mm^2 (Pl. 11, figs. 3, 4, 6; Figs. 4a, 4b). Connivent stomata occur, which share subsidiary cells, and the guard cells of which are in contact (Figs. 4a, 4b).

C o m p a r i s o n. Three species of *Platimeliphyllum, P. palanense, P. snatolense* N. Maslova, and *P. denticulatum* N. Maslova, were described previously (Maslova, 2002a). The new species is distinctive in the much higher polymorphism of the leaf blade: considerable variability in the outline of leaf blades and leaf base and the length/width ratio. The new species most closely resembles *P. palanense* but differs from it in the more variable outline of the leaf blade base (in particular, relatively numerous specimens with peltate bases) and better developed and often branching basal veins. Unlike *P. valentinii* sp. nov., *P. snatolense* is characterized by a symmetrical leaf blade and extremely small acute teeth. *P. denticulatum* differs by prevailing asymmetrical morphotypes of the leaf blade as well as the type of teeth. *P. denticulatum* is dominated by low triangular teeth, whereas *P. valentinii* sp. nov. has teeth varying in outline even within one leaf.

M a t e r i a l. About 100 specimens from the upper part of the Middle Tsagayan Subformation, type locality (Arkhara-Boguchan brown coal field) and from the lower part of the Upper Tsagayan Subformation in Bureinskoe Belogor'e.

DISCUSSION

The traditional assignment of Cretaceous dispersed leaf remains similar in macromorphology to the leaves of the modern plane tree to *Platanus* has been questioned (Wolfe, 1973; Krassilov, 1976, Maslova 2002b), since no relevant reproductive remains confirm the existence of the genus in Cretaceous floras. Based on micromorphology, inflorescences and infructescences that occur in association with such foliage are assignable to the Platanaceae (Krassilov, 1976; Krassilov and

Shilin, 1995; Maslova and Krassilov, 2002; Maslova and Kodrul, 2003; Maslova and Herman, 2006), Hamamelidaceae (Maslova and Herman, 2004), or combine characters of both families (Maslova et al., 2005, 2007). Maslova (2007, this issue) discusses the cooccurrence of leaf remains of the *Platanus morphology*, which are referred to as *Ettinghausenia* Stiehler in the morphological system of dispersed leaf remains (Maslova et al., 2005), and reproductive structures assigned to different families.

The association between entire-margined leaves of *Platimeliphyllum* and staminate inflorescences assignable or similar to different families based on micromorphological characters provides more evidence that it is necessary to use the morphological system for dispersed leaves of fossil angiosperms.

Of the three previously described species of *Platimeliphyllum*, two species (*P. palanense* and *P. snatolense*) are associated with staminate inflorescences of *Chemurnautia*, found in the Chemurnaut Bay, Evravavayam River, and Statol River localities of the northwestern Kamchatka Peninsula, ranging from the Upper Paleocene to Lower Eocene. Inflorescences of *Chemurnautia* have much in common with the modern plane tree (Maslova, 2002a).

Leaves of an Amur member of *Platimeliphyllum*, *P. valentinii* sp. nov., were originally found in the Arkhara-Boguchan brown coal field, in the middle part of the clay beds, between the Nizhnii and Dvoinoi coal seams, in association with staminate inflorescences of *Archaranthus* (Maslova and Kodrul, 2003). The paucity of that material prevented the generic determination of the leaf remains. Only their association with staminate inflorescences of *Archaranthus*, assigned to the Platanaceae on the basis of micromorphology, was mentioned. Later, additional sampling from other sections of temporary open-pit coal mines in the Arkhara-Boguchan coal field supplied the study with more abundant plant material. The study of the distribution of plant fossils revealed a constant association between such leaves and staminate inflorescences of the genus *Bogutchanthus*, which combines platanaceous and hamamelidaceous characters (Maslova et al., 2007).

The genus *Platimeliphyllum*, which is known in the geological record from the Early Paleocene to the Middle Eocene and is associated with *Archaranthus, Bogutchanthus*, and *Chemurnautia* reproductive structures, which are similar in macromorphology, but fundamentally different in micromorphology, supports the idea of Krassilov (1976) that leaves are more evolutionarily stable than reproductive structures.

ACKNOWLEDGMENTS

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