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Pliocene Wood of *Larix* from Southern Primorye (Russian Far East)

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Abstract—A new fossil larch species, *Laricioxylon blokhinae*, showing the wood anatomy of modern *Larix olgensis* A. Henry and *L. leptolepis* (Siebold et Succ.) Gord. is described. The taxonomic and structural diversity of larch species is reviewed, based on fossil wood remains from the Pliocene of southern Primorye.

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Key words: *Larix*, Pinaceae, wood anatomy, Pliocene, southern Primorye.

INTRODUCTION

Fossil wood is often the only paleobotanical macrofossil known from the Pliocene of the Russian Far East, since remains of leaves and reproductive structures are not usually preserved in the coarse alluvial deposits of this age.

At present, a single, but extremely rich locality for Pliocene wood is known in southern Primorye: Pavlovka lignite field. It is restricted to the Pavlovka group of depressions, situated 35 km northeast of the town of Ussuriisk. The locality contains numerous and often large (branches, stumps with butts, and even complete trunks) wood remains with well-preserved anatomy. The fossil wood comes from small-pebble conglomerates of the upper part of the cross-bedded sandstones and pebble gravels of the Suifun Formation. The formation is either Pliocene (*Resolutions*…, 1994) or Eopleistocene in age (Pavlyutkin, 1998). Fossil leaves are lacking in the beds. However, siltstone lenses have yielded spores, pollen grains, and plant debris composed of fossil fruits, seeds, and unidentifiable needles. Pollen grains of the Pinaceae, including larch, are prominent in the palynological assemblage (Pavlyutkin et al., 1988; *Resolutions*…, 1994).

MATERIALS AND METHODS

The fossil wood of the new species was found in the Pavlovka lignite field, Pavlovskii-2 open-cast coal mine. The remains are dark brown and slightly lignitic, 6–23 cm in length and 3–18 cm in diameter. The growth rings are 0.5–1.7 (3–5) mm wide and are readily distinguishable to the naked eye. The fossil wood remains are housed at the Institute of Biology and Soil Science (Far Eastern Division of the Russian Academy of Sciences), collection IBSS, no. 20a.

In view of the heterogeneous nature of wood anatomy, entailed by diverse functions of the tissue, the anatomical sections were made in three mutually perpendicular planes (transverse, radial, and tangential). We used the technique of preparing sections of fossilized wood that was slightly carbonized and fossilized (Gammerman et al., 1946). After preliminary treatment of the wood specimens (softening and consolidation), transparent thin sections were produced by hand, using a razor blade. In total, 730 thin sections were made and studied. The sections were studied microscopically and microphotographs of anatomical structures were taken by using "Mikmed" LOMO biological light microscopes.

TAXONOMIC AND STRUCTURAL DIVERSITY OF LARCHES ESTABLISHED ON THE BASIS OF FOSSIL WOOD

On the basis of anatomical characters, 35 taxa of fossil wood have been determined. They belong to 18 modern genera (*Abies* Mill., *Keteleeria* Carr., *Picea* A. Dietr., *Larix* Mill., *Microbiota* Kom., *Biota* (D. Don) Endl., *Ulmus* L., *Quercus* L., *Betula* L., *Micromeles* Decne., *Malus* Mill., *Pyrus* L., *Padus* Mill., *Cerasus* Mill., *Acer* L., *Eleutherococcus* Maxim., *Fraxinus* L., and *Sambucus* L.) and four fossil genera (*Pseudotsugoxylon* Blokh. et Bondar., *Piceoxylon* Gothan, *Laricioxylon* Greguss, and *Populoxylon* Mädel-Angeliewa) of 11 families (Pinaceae Lindl., Cupressaceae Gray, Ulmaceae Mirb., Fagaceae Dumort., Betulaceae Gray, Salicaceae Mirb., Rosaceae Adans., Aceraceae Juss., Araliaceae Juss., Oleaceae Hoffmanns. et Link, and Caprifoliaceae Adans.) (Bondarenko, 2006).

Of all gymnosperms in the wood remains of the Pavlovka group of depressions, the Pinaceae is the most representative family both at the generic and specific levels. Quantitatively, members of the family constitute 72.5% of all determined specimens of fossil wood. Figure 1 shows the proportions of pinaceous genera in the Pliocene dendroflora of the Pavlovka group of depressions by the number of species (Fig. 1a) and specimens of fossil wood (Fig. 1b): *Larix* and *Laricioxylon* taken together are the most representative genera both at the specific level (seven species, Table 1) and in numbers.

There is no consensus on the number of species of larches currently occurring in Primorye. Koropachinskii (1989) mentioned only two species: *Larix cajanderii* Mayr and *L. olgensis* A. Henry, the latter with a very limited range (Table 1). Other authors have referred to three (Kolesnikov, 1946), two (Dylis, 1961), and four (Gukov, 1976) species present in the same region.

All Pliocene wood showing the anatomy of larch is relatively easily differentiated from each other by a combination of structural elements (Table 2).

The wood anatomy of fossil wood remains of *Larix gmelinii* (Rupr.) Rupr. is identical (even in finest detail) to that of modern *L. gmelinii* and differs from other larches in the presence of triseriate pitting on radial walls of tracheids and in the number and type of pits (both piceoid and taxodioid pits are present) on cross-fields.

All anatomical characters of the fossil wood of *L. olgensis* completely coincide with those of modern *L. olgensis.* The characteristic features are large pits on radial and tangential walls of tracheids, high uniseriate rays, and numerous pits on cross-fields.

Laricioxylon pavlovskiense Blokh. et Bondar. is characterized by a peculiar combination of characters of three modern species: *Larix occidentalis* Nutt., *L. gmelinii,* and *L. olgensis.* Among numerous bi- and uniseriate pits, triseriate pits also occur on radial walls of tracheids; the maximum number of pits occurs on cross-fields (up to 10).

The fossil wood described below, *Laricioxylon blokhinae* sp. nov., combines the wood anatomical characters of modern *Larix olgensis* and *L. leptolepis* (Siebold et Zucc.) Gord. It differs from other fossil wood showing the anatomy of larch from the Pliocene of the Pavlovka group of depressions in the larger pits (30–36 μm) on radial walls of tracheids, large pits on tangential walls of tracheids, very high uniseriate rays, and numerous pits on cross-fields.

Several kinds of fossil wood from the Pliocene of the Pavlovka group of depressions show a considerable similarity to wood from older deposits (Table 1). Thus, Pliocene *Laricioxylon* aff. *chelebaevae* Blokh., *L.* aff. *korfiense* Blokh., and *L.* aff. *sichotealinense* Blokh. are similar to *L. chelebaevae* Blokh. (Blokhina, 1996b) and *L. korfiense* Blokh. (Blokhina, 1996a) from the Middle Miocene of the Korfa Bay of the Kamchatka Peninsula and *L. sichotealinense* Blokh. from the Upper Oligocene of the Siziman Bay of the Khabarovsk Region (Blokhina, 1985), respectively.

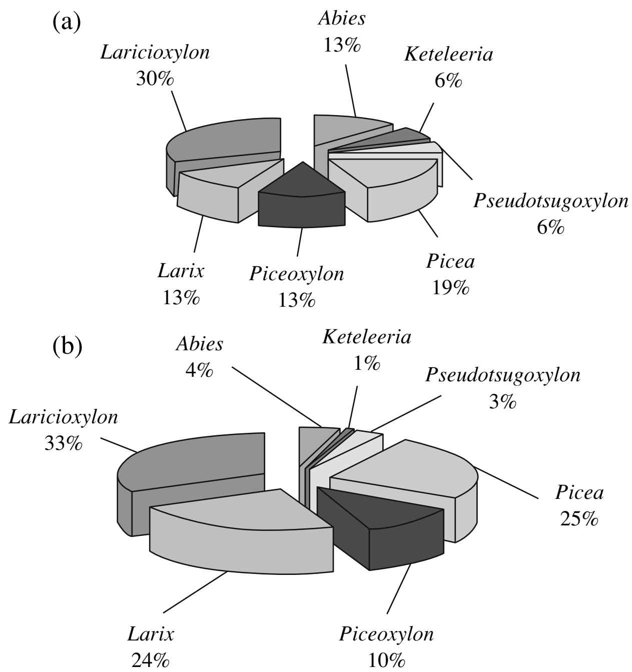


Fig. 1. Proportions of genera of the Pinaceae in the Pliocene dendroflora of the Pavlovka group of depressions: (a) number of species; (b) number of specimens of fossil wood.

The fossil wood of *L.* aff. *chelebaevae* is distinct from other Pliocene larch wood remains by the occasional occurrence of helical thickenings on walls of vertical tracheids, the highest (up to 8 cells) biseriate regions in uniseriate rays, and smaller pits on radial walls of tracheids.

The fossil wood of *L.* aff. *korfiense* is characterized by smaller pits on radial walls of tracheids, less numerous pits on cross-fields, large pits on tangential walls of tracheids, and high uniseriate rays.

L. aff. *sichotealinense* has the smallest (merely 6–7.5 μm) pits on tangential walls of tracheids, not numerous pits on cross-fields, and very high uniseriate rays.

All fossil larch wood from the Pliocene of the Pavlovka group of depressions are characterized by (1) numerous, predominantly biseriate, pits on radial walls of tracheids, (2) large pits on radial (27–30 (36) μm in diameter) and tangential (7–12 μm) walls of tracheids, (3) numerous (6–10) piceoid pits on cross-fields (taxodioid pits are found only in *Larix gmelinii*), and (4) high uniseriate pits (up to 30–40 (47) cells).

Among similar modern larches (Table 1), *Larix occidentalis* and *L. lyallii* Parl. currently have a North American range, *L. gmelinii* and *L. sibirica* Ledeb. have a Siberian range, *L. leptolepis* has a Japanese range, and

Table 1. Fossil wood of larches from the Pliocene of the Pavlovka group of depressions and related fossil and modern species. Geological and geographical ranges

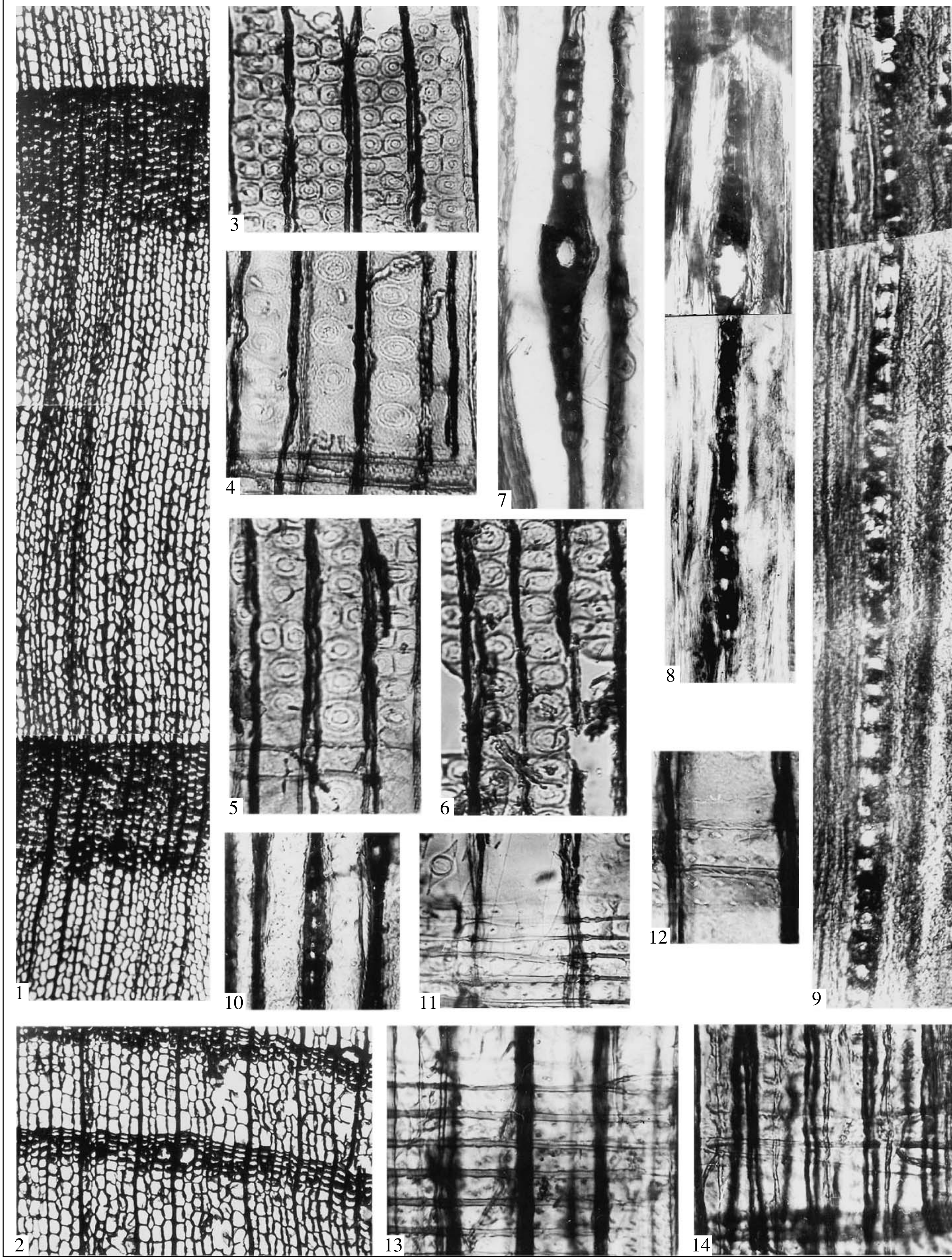
No.	Fossil wood species	Number of specimens in the collection	Related fossil species		Related modern species	
			species name	occurrence	species name	geographical range
1	*Larix gmelinii* (Rupr.) Rupr.	1	–	–	*Larix gmelinii* (Rupr.) Rupr.	Central and eastern Siberia, northern Inner Mongolia, northeastern China
2	*Larix olgensis* A. Henry	31	–	–	*Larix olgensis* A. Henry	Marine coast and eastern slopes of the Sikhote-Alin, between the Valentin and Vladimir bays
3	*Laricioxylon blokhinae* O.V. Bondarenko sp. nov.	24	–	–	*Larix olgensis* A. Henry	As number 2
					Larix leptolepis (Siebold et Zucc.) Gord.	Central Honshu (Japan)
4	*Laricioxylon pavlovskiense* Blokh. et Bondar.	6	–	–	*Larix occidentalis* Nutt.	Washington, Montana, Idaho (United States) and British Columbia (Canada)
					Larix gmelinii (Rupr.) Rupr.	As number 1
					Larix olgensis A. Henry	As number 2
5	*Laricioxylon* aff. *chelebaevae* Blokh.	2	*Laricioxylon chelebaevae* Blokh.	Middle Miocene, Korfa Bay, Kamchatka Peninsula	*Larix lyallii* Parl.	Rocky Mountains and Cascade Range (United States)
6	*Laricioxylon* aff. *korfiense* Blokh.	3	*Laricioxylon korfiense* Blokh.	As *Laricioxylon chelebaevae*	*Larix leptolepis* (Siebold et Zucc.) Gord.	As number 3
					Larix occidentalis Nutt.	As number 4
7	*Laricioxylon* aff. *sichotealinense* Blokh.	10	*Laricioxylon sichotealinense* Blokh.	Upper Oligocene, Siziman Bay, Khabarovsk Region	*Larix gmelinii* (Rupr.) Rupr.	As number 1
					Larix sibirica Ledeb.	Western and central Siberia

Table 2. Comparative anatomy of fossil larch wood from the Pliocene of southern Primorye

Anatomical characters	*Larix gmelinii* (Rupr.) Rupr.	*Larix olgensis* A. Henry	*Laricioxylon blokhinae* sp. nov.	*Laricioxylon pavlovskiense* Blokh. et Bondar.	*Laricioxylon* aff. *chelebaevae* Blokh.	*Laricioxylon* aff. *korfiense* Blokh.	*Laricioxylon* aff. *sichotealinense* Blokh.
Pits on radial walls of tracheids:							
uniseriate	+	+	+	+	+	+	+
biseriate	++	++	++	++	++	++	++
triseriate	+––	–	–	+–	–	–	–
pit diameter, μm	18–27(30)	(14)18–28(30)	(12)18–28 (30–36)	(14)17–24(30)	15–24(27)	15–24(30)	(15)18–21(27)
Pit diameter on tangential walls of tracheids, μm	9–12	6–8(10)	7–10(12)	12	6–7.5(9)	9–12	6–7.5
Helical thickenings on walls of vertical tracheids	–	–	–	–	+––	–	–
Uniseriate rays:							
height (number of cells)	1–26	1–35(42)	1–35(47)	1–25(30)	1–27	1–30(46)	1–35(44)
number of biseriate regions	1–3	1–3(6)	1–6	–	1–8	1–7	1–6
Vertical resin canals:							
number of epithelial cells	8–10(12)	8–10(12)	7–10(13)	7–9(10)	8–11	7–12	8–12
Horizontal resin canals:							
number of epithelial cells	8–9(11)	7–10	(5)6–9	5–7	6–9	6–8	6–10
arrangement in rays							
biseriate	+	+	+	+	+	+	+
bi- or triseriate	+	+	–	+–	+	–	+
triseriate	+	+	–	–	+	–	+
uniseriate ends:							
short	1–3	1–12	2–5	1–10	1–5	1–6	1–19
long	11	4–25	11–20	5–26	2–14	10–24	10–28
Pits on cross-fields:							
number of pits	1–6(7)	1–6(7–8)	1–6(7–8)	1–6(7–10)	1–6	1–6	1–6
pit diameter, μm	(4.5)6–8(9)	4.5–6	5–8	5–7	4.5–6	6–7.5	5–7
type of pits							
piceoid	+	+	+	+	+	+	+
taxodioid	+–	–	–	–	–	–	–

Note: (+) character is present, (–) character is absent, (++) character prevails, (+–) character is occasionally present, (+––) character occurs very rarely; (?) no data.

Plate 1



L. olgensis is an endemic of the Sikhote-Alin. Pliocene finds of *Laricioxylon pavlovskiense, L.* aff. *chelebaevae*, and *L.* aff. *korfiense*, resembling the modern *Larix occidentalis* and *L. lyallii* in wood anatomy, confirm the supposition made by Blokhina (1984) that larches related to modern North American species possibly grew in the Russian Far East during the Neogene, but disappeared in the post-Pliocene time.

In addition, the majority of Pliocene wood remains of larch show the anatomical wood characters of the modern *Larix olgensis* and/or *L. gmelinii* (Table 1). This fact, along with finds of fossil wood of *L. olgensis* and *L. gmelinii*, testifies to the probable presence of these species in southern Primorye in the Pliocene and the possibility of their introgressive hybridization with other ancient larches (Bondarenko and Blokhina, 2003). Dylis (1961), Bobrov (1972, 1978), and Gukov (1976) found in Primorye hybrids with the participation of *L. olgensis*: *L. lubarskii* Suk. and *L. komarovii* B. Kolesn. Unfortunately, so far the wood anatomy of hybrid larches has not been studied.

SYSTEMATIC PALEOBOTANY

Family Pinaceae Lindley, 1836

Genus *Laricioxylon* Greguss, 1967

Laricioxylon blokhinae O.V. Bondarenko, sp. nov.

Plate 1, figs. 1–14

E t y m o l o g y. In honor of N.I. Blokhina, a fossil wood anatomist.

H o l o t y p e. IBSS, no. 20a/135, fossil wood, Primorye, Mikhailovskii district, Pavlovka lignite field, open-pit coal mine Pavlovskii-2, Suifun Formation, Pliocene; Pl. 1, figs. 1–14.

D i a g n o s i s. Growth rings distinct. Pits on radial walls of tracheids rarely uniseriate, predominantly biseriate, opposite. Crassulae present. Circular pits 18–24(28–30) μm in diameter, and elliptic pits (14)1821 × 24–30(36) μm in size. Pits on tangential walls of tracheids uniseriate and biseriate, 7–10(12) μm in diameter. Uniseriate rays 1–35(47) cells high, occasionally with 1–6 biseriate layers. Inner walls of ray tracheids smooth. Vertical and horizontal resin canals encircled with 7–10(13) and (5)6–9 thick-walled epithelial cells, respectively. Horizontal resin canals occur in biseriate rays; uniseriate ends equal (up to 1–8 cells long) or unequal: short ends of 2–5 cells, and long ends of 11–20 cells. Piceoid pits 1–6(7–8) per cross-field, 5–8 μm in diameter.

D e s c r i p t i o n. The wood consists of tracheids, ray tracheids, ray parenchyma, and epithelial cells of resin canals.

Earlywood tracheids are large, thin-walled, with large lumina, radially elongated, rectangular and polygonal (Pl. 1, figs. 1, 2). Uniseriate pits are circular and slightly oval, horizontally elongated, with included circular and oval apertures, respectively; they are in diffuse or close arrangement, or crowded along the length of the tracheid (Pl. 1, figs. 4–6). Circular pits are 18–24(28–30) μm in diameter, and oval pits are 18–21 × 24–30(36) μm in size. Biseriate pits are opposite, circular and slightly oval, horizontally elongated, with included circular and oval apertures, respectively; they are in diffuse or close arrangement, or crowded along the length of the tracheids (Pl. 1, figs. 3, 5). Circular pits are 18–24(30) μm in diameter, and oval pits are (14)18 × 21(24–28) μm in size. Crassulae are present between biseriate pits. On radial walls of latewood tracheids, only uniseriate pits occur, which are circular, 12–15 μm in diameter, in a very diffuse arrangement along the length of the tracheid. Last latewood tracheids lack pits. Pits on tangential walls of tracheids are abundant, uni- and biseriate, 7–10(12) μm in diameter. Uniseriate pits are in diffuse arrangement along the length of the tracheid; biseriate pits are more or less opposite or alternate (Pl. 1, fig. 10). There are 1–6(7–8) piceoid pits 5–8 μm in diameter per cross-field (Pl. 1, figs. 12, 13).

Growth rings are distinct, 0.5–1.7(3–5) mm wide, mostly consisting of earlywood tracheids. The transition from earlywood to latewood is abrupt; occasionally, it becomes more gradual in the widest rings. Latewood occupies only about one-fourth to -one-fifth of the growth ring. Latewood tracheids are thick-walled, rectangular or strongly flattened in radial direction, with nearly slitlike lumina (Pl. 1, figs. 1, 2).

Rays are numerous, of two types: uniseriate and multiseriate, the latter type is with horizontal resin canals. The height of uniseriate rays is 1–35(47) cells (Pl. 1, fig. 9), biseriate regions occasionally present, 1–6 cells long. Ray tracheids are arranged in 1–2(3) rows along ray margins (Pl. 1, figs. 11–13), or, more rarely, in one or two rows in the middle part of the ray. They also form separate rays with 1–3(4) rows (Pl. 1, fig. 14). Ray tracheids are low, with smooth interior and uneven

E x p l a n a t i o n o f P l a t e 1

Figs. 1–14. *Laricioxylon blokhinae* sp. nov., holotype IBBS, no. 20a/135: (1) transverse section, wide growth ring, a gradual earlywood/latewood transition, ×35; (2) transverse section, narrow growth rings, an abrupt earlywood/latewood transition, note vertical resin canals in latewood, ×47; (3) radial section, biseriate pits on tracheid walls, ×206; (4) radial section, large uniseriate pits on tracheid walls, ×206; (5) radial section, uniseriate and biseriate pits on tracheid walls, ×206; (6) radial section, uniseriate pits on tracheid walls, ×206; (7) tangential section, horizontal resin canal in a biseriate ray with short equal uniseriate ends, ×206; (8) tangential section, horizontal resin canal in a biseriate ray with unequal uniseriate ends, ×206; (9) tangential section, long uniseriate ray, ×206; (10) tangential section, pits on tracheid walls, ×206; (11) radial section, marginal ray tracheids, ×206; (12) radial section, eight piceoid pits on cross-fields, ×330; (13) radial section, pits on cross-fields, pitted walls of ray cells, ×206; (14) radial section, ray tracheids in two rows, ×206. Primorye, Pavlovka lignite field, open-cast coal mine Pavlovskii-2, Suifun Formation, Pliocene.

Table 3. Comparative anatomy of fossil wood of *Laricioxylon blokhinae* sp. nov. and wood of related modern and fossil species

Anatomical characters	*Laricioxylon blokhinae* sp. nov.	*Larix olgensis* A. Henry (Budkevich, 1961; Blokhina, 1998; Blokhina and Minkhaidarov, 2000)	*Larix leptolepis* Gord. (Budkevich, 1956, 1961; Greguss, 1955, 1963; *Atlas*…, 1992)	*Laricioxylon primorskiense* Blokh. (Blokhina and Snezhkova, 2003)	*Laricioxylon kofiense* Blokh. (Blokhina, 1996a)
Pits on radial walls of tracheids:					
uniseriate	+	+	+	+	+
biseriate	++	++	+	++	+
pit diameter, μm	(12)18–28(30–36)	(18)21–27(30)	20–24	(15)18–24(30)	15–24
Pit diameter on tangential walls of tracheids, μm	7–10(12)	6–9(12)	(5)6–9(10)	(6)9	?
Helical thickenings on walls of vertical tracheids	–	–	+–	–	–
Uniseriate rays:					
height (number of cells)	1–35(47)	1–36	1–30(37)	1–30(40)	1–30(40)
number of biseriate regions	1–6	1–2(5)	?	–	1–6(11)
Vertical resin canals:					
number of epithelial cells	7–10(13)	8–10(12)	8–12	7–10	8–10(12)
Horizontal resin canals:					
number of epithelial cells	(5)6–9	8–10(12)	6–12	6–10	6–10(12)
arrangement in rays					
biseriate	+	+	+	+	+
bi- or triseriate	–	+	–	–	–
triseriate	–	+	–	–	–
uniseriate ends:					
short	2–5	1–10	1–4	3–8	1–4
long	11–20	17–28	2–13	7–16(25)	4–14
Pits on cross-fields:					
number of pits	1–6(7–8)	1–6(8)	1–6(7)	1–6(8–9)	1–6
pit diameter, μm	5–8	4–5	?	5	5–7
type of pits					
piceoid	+	+	+	+	+
taxodioid	–	–	+–	–	–

Note: (+) character is present, (–) character is absent, (++) character prevails, (+–) character is occasionally present, (?) no data.

and occasionally strongly sinuous external walls. Bordered pits are present on radial walls of ray tracheids.

Vertical resin canals with 7–10(13) thick-walled epithelial cells are predominantly situated in latewood. Resin canals are 40–100 μm in diameter, circular and oval, radially elongated (Pl. 1, fig. 2). Horizontal resin canals are with (5)6–9 thick-walled epithelial cells, oval, elongated along the ray, 36–48 μm in diameter; they are situated in biseriate rays with equal (1–14 cells) or sharply unequal uniseriate ends: the short end consists of 2–5 cells, and the long end consists of 11–20 cells (Pl. 1, figs. 7, 8).

C o m p a r i s o n. The fossil wood under study most closely resembles the wood of modern *Larix olgensis* and *L. leptolepis* (Table 3). It differs from the wood of *L. olgensis* mostly by the absence of triseriate rays with horizontal resin canals. In addition, it has slightly larger pits on radial walls of tracheids and cross-fields, shorter uniseriate ends of multiseriate rays, and smaller number of epithelial cells lining horizontal resin canals.

The fossil wood under study differs from the wood of *L. leptolepis* in the larger pits on radial and tangential walls of tracheids, more numerous pits, and in the absence of taxodioid pits on cross-fields, as well as in the longer uniseriate ends of multiseriate rays and less numerous epithelial cells lining horizontal resin canals.

Among fossil wood, some similarities are found in *Laricioxylon primorskiense* Blokh. from the Upper Miocene of the Erkovetskii brown coal field in the Amur Region (Blokhina and Snezhkova, 2003) and *L. korfiense* from the Middle Miocene of the Korfa Bay of the Kamchatka Peninsula (Blokhina, 1996a).

The wood under study differs from *L. primorskiense* in the larger pits on radial and tangential walls of tracheids, higher uniseriate rays, biseriate regions in uniseriate rays, numerous epithelial cells lining vertical resin canals, slightly smaller number of pits per cross-field, and greater diameter of such pits (Table 3).

The Pliocene wood differs from the wood of *L. korfiense* in the prevalence of biseriate pits on radial walls of tracheids, greater diameter of such pits, higher uniseriate rays, and shorter biseriate regions in uniseriate pits, less numerous epithelial cells lining horizontal resin canals, and more numerous pits on cross-fields (Table 3).

R e m a r k s. The presence of normal vertical and horizontal resin canals with thick-walled epithelial cells testifies to the affinity of the wood under description to the formal genus *Piceoxylon*, which embraces fossil wood remains showing characters of modern *Picea, Larix*, *Pseudotsuga* Carr., and, in part, *Keteleeria* Carr.

However, *Keteleeria* should be excluded because of lacking horizontal resin canals. The wood of *Pseudotsuga* differs in the presence of helical thickenings on walls of both vertical and ray tracheids and penta- or hexagonal outlines of horizontal resin canals with small number of epithelial cells. The wood of *Picea* and *Larix* are often difficult to differentiate. Nonetheless, the presence of predominantly biseriate pits on radial walls of tracheids, smooth internal walls of ray tracheids, numerous pits on cross-fields, abrupt earlywood/latewood transition, and arrangement of horizontal resin canals only in biseriate rays with sharply uneven uniseriate ends allow me to assign the wood under study to the genus *Larix*.

Greguss (1967) proposed to use the generic name *Laricioxylon* for fossil wood remains showing the anatomy of modern larches. Since the wood under study is not identical to any modern or fossil larch, it should be considered as a new fossil species, *Laricioxylon blokhinae* sp. nov., with a certain similarity to the wood of modern *Larix olgensis* and *L. leptolepis.*

M a t e r i a l. IBBS, nos. 20a/3, 20a/4, 20a/6, 20a/9, 20a/29, 20a/30, 20a/31, 20a/33, 20a/40, 20a/44, 20a/48, 20a/50, 20a/52, 20a/54, 20a/55, 20a/57, 20a/101, 20a/135 (holotype), 20a/150 and IBBS, nos. 20b/5, 20b/16, 20b/23, 20b/32, 20b/49. In total, 24 specimens were studied.

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