ISSN 0031-0301, Paleontological Journal, 2010, Vol. 44, No. 10, pp. 1231–1239. © Pleiades Publishing, Ltd., 2010

Fossil Wood of *Sequoioxylon burejense* sp. nov. (Taxodiaceae) from the Upper Cretaceous of the Zeya-Bureya Basin (Russian Far East)

N. I. Blokhina[a], M. A. Afonin[a], and T.M. Kodrul[b]

[a]*Institute of Biology and Soil Science, Far East Branch, Russian Academy of Sciences, pr. Stoletiya Vladivostoka 159, Vladivostok, 690022 Russia*

e-mail: blokhina@biosoil.ru

[b]*Geological Institute, Russian Academy of Sciences, Pyzhevsky lane 7, Moscow 119017 Russia*

Received February 2, 2009

Abstract—A new species *Sequoioxylon burejense* Blokhina et M. Afonin (Taxodiaceae), identified on the basis of anatomical features of fossil wood from the Middle Maastrichtian (Upper Cretaceous) of the Zeya-Bureya Basin, Amur Region, Russian Far East, is described. The new species is characterized by mixed anatomical features of the modern representatives of the tribe Sequoieae. Cretaceous wood of Taxodiaceae was found in the Amur Region for the first time.

Key words: fossil wood, Sequoioxylon, Sequoieae, Taxodiaceae, Upper Cretaceous, Zeya-Bureya Basin, Amur Region, Russia.

DOI: 10.1134/S0031030110100011

INTRODUCTION

This paper presents the first investigation of fossil woods from the Cretaceous of Amur Region. Until now, fossil woods were studied only from the Cenozoic deposits of the area. *Piceoxylon* sp. (cf. *Picea obovata* Ledeb.), *Laricioxylon priamurensis* Blokh. et Snezhk., and *Populoxylon priamurensis* Blokh. et Snezhk. were described (Blokhina and Snezhkova, 2003) on the basis of fossil wood anatomical characters from deposits of the Sazanka Formation (upper Middle Miocene–Upper Miocene), Erkovets brown-coal field, Amur Region. Fossil woods *Taxodioxylon sequoianum* (Mercklin) Gothan and cf. *Hamamelidoxylon* sp. were reported from the Upper Tsagayan Subformation (Danian) of Zeya-Bureya Basin (Nishida et al., 2006).

Nevertheless, fossil woods were studied from the Cretaceous deposits on the left bank of the Amur River (Heilongjiang Province, North-Eastern China). *Cupressinoxylon baomiqiaoense* Zheng et Zhang, *Glyptostroboxylon xidapoense* Zheng et Zhang, *Phoroxylon qiezihense* Zheng et Zhang, *Protocupressinoxylon mishanense* Zheng et Zhang, *Protopodocarpoxylon arnatum* Zheng et Zhang and *Xenoxylon peidense* Zheng et Zhang (Zheng and Zhang, 1982), *Phoroxylon scalariforme* Sze (Sze, 1951), *Protopiceoxylon mohense* Ding (Ding, 2000) and *Taxodioxylon szei* Yang et Zheng (Yang and Zheng, 2003) were described on the basis of fossil wood anatomical characters from the Lower Cretaceous deposits, and *Cupressinoxylon jiayinense* Wang, Wang et Chen (Wang et al., 1996), *Piceoxylon manchuricum* Sze (Sze, 1951), *Protopiceoxylon amurense* Du, *Xenoxylon latiporosum* (Cramer) Gothan (Du, 1982), and *Taxodioxylon cryptomerioides* Schönfeld (Wang et al., 1997) were described from the Upper Cretaceous deposits.

The new species *Sequoioxylon burejense* Blokhina et M. Afonin is erected on the basis of anatomical structure of fossil wood from the Middle Maastrichtian of Zeya-Bureya Basin. The species is characterized by combination of characters of modern members of the tribe Sequoieae J. Buchh. (monotypic genera *Sequoia* Endl., *Sequoiadendron* J. Buchh., and *Metasequoia* Hu et W.C. Cheng), family Taxodiaceae. Evergreen *Sequoia sempervirense* (D. Don) Endl. and *Sequoiadendron giganteum* (Lindl.) J. Buch. are widespread on the Pacific Coast of the United States: *Sequoia* grows on western slopes of the Cascade Range, Coast Mountains, and Sierra Nevada, and *Sequoiadendron* grows only on western slopes of Sierra Nevada (*Flora of North America North of Mexico,* 1993). Deciduous *Metasequoia glyptostroboides* Hu et W.C. Cheng, shedding of its leafy branches, is survived only in the Chinese provinces Sichuan and Hubei (*Flora of China*, 1999).

Until now, fossil woods with anatomical features of Sequoieae were described on the Russian Far East (RFE) only from Cenozoic deposits, where *Sequoiox-*

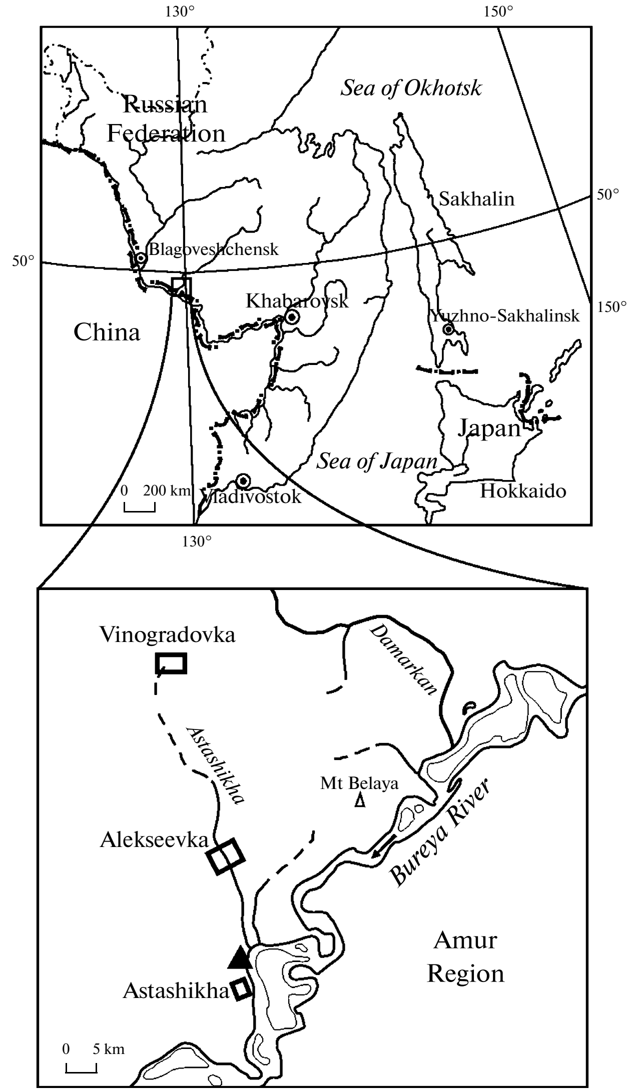


Fig. 1. The map of locality, where fossil wood *Sequoioxylon burejense* Blokhina et M. Afonin, sp. nov. was found. ▲ point of sampling.

ylon chemrylicum Blokh. (Blokhina, 1997) was reported from the Paleocene–Lower Eocene of the Chemryl Cape, North-Western Kamchatka Peninsula; *Sequoioxylon sachalinicum* Blokh. (Blokhina, 2004a) from Paleocene–Eocene of Agnevo River, Alexandrovsk District, and Lower Eocene of Avgustovka River, Uglegorsk District, Sakhalin; *Metasequoia klerkiana* Blokh. (Blokhina, 1977, 1982) from Eocene–Oligocene of Klerk Peninsula (Khasansky District, Primorye Region); *Sequoioxylon sizimanicum* Blokh. (Blokhina, 1986) from Upper Oligocene of Siziman Bay, Khabarovsk Region; and *Metasequoia korfiense* Blokh. (Blokhina, 1995) from Middle Miocene of Korf Bay, North-Eastern Kamchatka Peninsula.

MATERIAL AND METHOD

The wood of the new fossil species *Sequoioxylon burejense* Blokhina et M. Afonin described was found in 2004, during field work, which had placed in Zeya-Bureya Basin, Amur Region (RFE) by workers of the Geological Institute RAS A.B. Herman, T.M. Kodrul, G.V. Kurkin, and M.G. Moiseeva. The wood remains were collected from the lower parts of stratotype section of Tsagayan Formation, the area of Astashikha village, on the right bank of the Bureya River, 9.8 km upstream from the river mouth (Fig. 1). The fossil wood originates from gravel-pebble deposits in the upper part of Lower Tsagayan Subformation, dated by Middle Maastrichtian (*Flora and dinosaurs*..., 2001).

Up to the present time, macroremains of Sequoieae were not described from deposits of the Lower Tsagayan Subformation of Early-Middle Maastrichtian age. However, macroremains of *Sequoia* and *Metasequoia* were reported, from the Middle Tsagayan (Upper Maastrichtian–Danian) and Upper Tsagayan (Danian) subformations of the both Archara-Boguchan brown-coal field and open cast on the eastern slope of Archara hill in the vicinity of Archara village (Akhmetiev et al., 2002), as well as from the Upper Tsagayan Subformation (Danian) of Bureya Belogorye (Krassilov, 1976; *Flora and dinosaurs*..., 2001; Akhmetiev et al., 2002) and Progress area of Raychikhinsk brown-coal field (Akhmetiev et al., 2002).

Fossil wood studied (sample no. 36/2) is dark gray, solid, mineralized, with growth rings, well distinguishable by naked eye; size of sample is 8 × 4 × 10 cm; probably, it is a fragment of large branch or trunk. Collection no. 36 is kept in the Institute of Biology and Soil Science (IBSS) FEB RAS (Vladivostok).

In view of the heterogeneous wood anatomical structure, preparations for investigations of wood anatomy are prepared in three mutually perpendicular planes: transverse, radial, and tangential (at least three transparent thin sections for each wood sample). We used the method of preparing transparent thin sections for solid mineralized wood by standard petrographic technique (Gammerman et al., 1946). In total, 17 transparent thin sections were prepared of sample no. 36/2 (four sections–in transverse, eight–in radial, and five–in tangential plane). The sections were studied microscopically and microphotographs of anatomical structures were taken by using Mikmed biological light microscopes (LOMO) and "Micrat-Izopan" photographic film. The description of wood anatomical structure was done using a terminology, stated in the work of Yatsenko-Khmelevskii (1954a) and adapted to "IAWA List of Microscopic Features for Softwood Identification" (Baas et al., 2004).

SYSTEMATIC PALEOBOTANY

Family Taxodiaceae Saporta, 1865

Genus *Sequoioxylon* Torrey, 1923

Sequoioxylon burejense **Blokhina et M. Afonin, sp. nov.**

Plate 1, figs. 1–21

E t y m o l o g y. From the Bureya River.

H o l o t y p e. IBSS, collection no. 36, sample no. 36/2, fossil wood; the Amur Region (RFE), Zeya-Bureya Basin, right bank of the Bureya River, 9.8 km upstream from its mouth; Tsagayan Formation, upper part of Lower Tsagayan Subformation, Middle Maastrichtian, Upper Cretaceous (Pl. 1, figs. 1–21).

D i a g n o s i s. Growth rings distinct. Pitting in the radial walls of tracheids abundant, uni-, bi- or sometimes triseriate, opposite. Circular pits 11-16 μm in diameter, elliptic pits—11–13 × 14–17 μm in size. Crassulae present between multiseriate pits. Pitting in the tangential walls of tracheids abundant, uni- or biseriate; pits circular, 7–11 μm in diameter. Axial parenchyma abundant; transverse walls smooth or with 1–5 nodules, both radial and tangential walls pitted. Rays 1–30 (50–70) cells high; uniseriate, sometimes with 1–7 (13) biseriate layers. Horizontal and tangential walls of ray cells smooth. Ray tracheids smooth-walled, peripheral. Pits of taxodioid type, 1–5 (6) per cross-field, 4–7 (8) μm in diameter, arranged in a single or two horizontal rows. Vertical resin canals traumatic.

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

Growth rings are distinct, 0.3–2 mm wide, consist mainly of early wood tracheids. The early wood often strongly crushed in transverse section, therefore growth rings were, supposedly, wider (Pl. 1, figs. 1, 2). In the transverse section, the early wood tracheids are large, thin-walled, with large lumina, rectangular, occasionally polygonal, and radially elongated. The early/late wood transition is gradual to distinct and even abrupt. Late wood takes an insufficient part of growth ring. Late wood tracheids are square and rectangular, compressed in radial direction at the growth ring boundary, with nearly slit-like lumina. Tracheid ends in radial section are rounded, oblique, stocking-shaped, or tapered.

Pitting in the early wood tracheid radial walls is abundant, uniseriate (Pl. 1, figs. 4–6) and biseriate (Pl. 1, figs. 6, 7), occasionally triseriate pits are also present (Pl. 1, figs. 8, 9); multiseriate pits are opposite. Pits are circular and slightly elliptic, horizontally elongated, with included circular aperture. Uniseriate circular pits are 13-16 μm, elliptic—11–13 ×14–17 μm in diameter; aperture diameter is (3)4–5 μm. Biseriate circular pits are 11–15(16) μm in diameter, elliptic pits are 11–13 ×14, 15 μm in size. Triseriate circular pits are 12–14 μm in diameter, elliptic pits are 12 ×14 μm in size. Aperture diameter in multiseriate pits is 3, 4 μm. Uniseriate pits are scattered along the tracheid wall or in close arrangement, rarely crowded.

Biseriate opposite pits are in a close arrangement with vertical, rarely horizontal contact line or with both lines: vertical and horizontal. Triseriate opposite pits are in a close or in crowded arrangement with vertical and horizontal contact lines. Crassulae are arranged between multiseriate pits (Pl. 1, figs. 7–9). Pits in the early wood radial tracheid walls are circular, 8–11 μm in diameter, uniseriate, mainly scattered along the tracheid length; in the last late wood tracheid layers, pits are absent.

The tracheid tangential wall pitting is abundant; pits are circular, 7–11 μm in diameter, scattered, uniseriate, or biseriate, in more or less opposite arrangement (Pl. 1, figs. 10, 13).

Axial parenchyma (including traumatic one) is abundant, with resin content, diffuse, dedicated to vertical traumatic resin canals (Pl. 1, figs. 11–14) and visible in all three sections. In the tangential section, parenchyma strand includes up to 30(60) cells; width of the cells is (30)50–60(115) μm, their length is 15–35 μm. Transversal axial parenchyma walls are thin and smooth (Pl. 1, figs. 11–13), occasionally they are slightly thickened, or with 1–5 nodules (Pl. 1, figs. 14, 15); radial and tangential walls are often with circular pits, which are 5–8 μm in diameter, with included circular aperture (Pl. 1, fig. 14). Large damage sits, filled with traumatic axial parenchyma, with dentate transversal and pitted walls both radial and tangential, are visible in the tangential section.

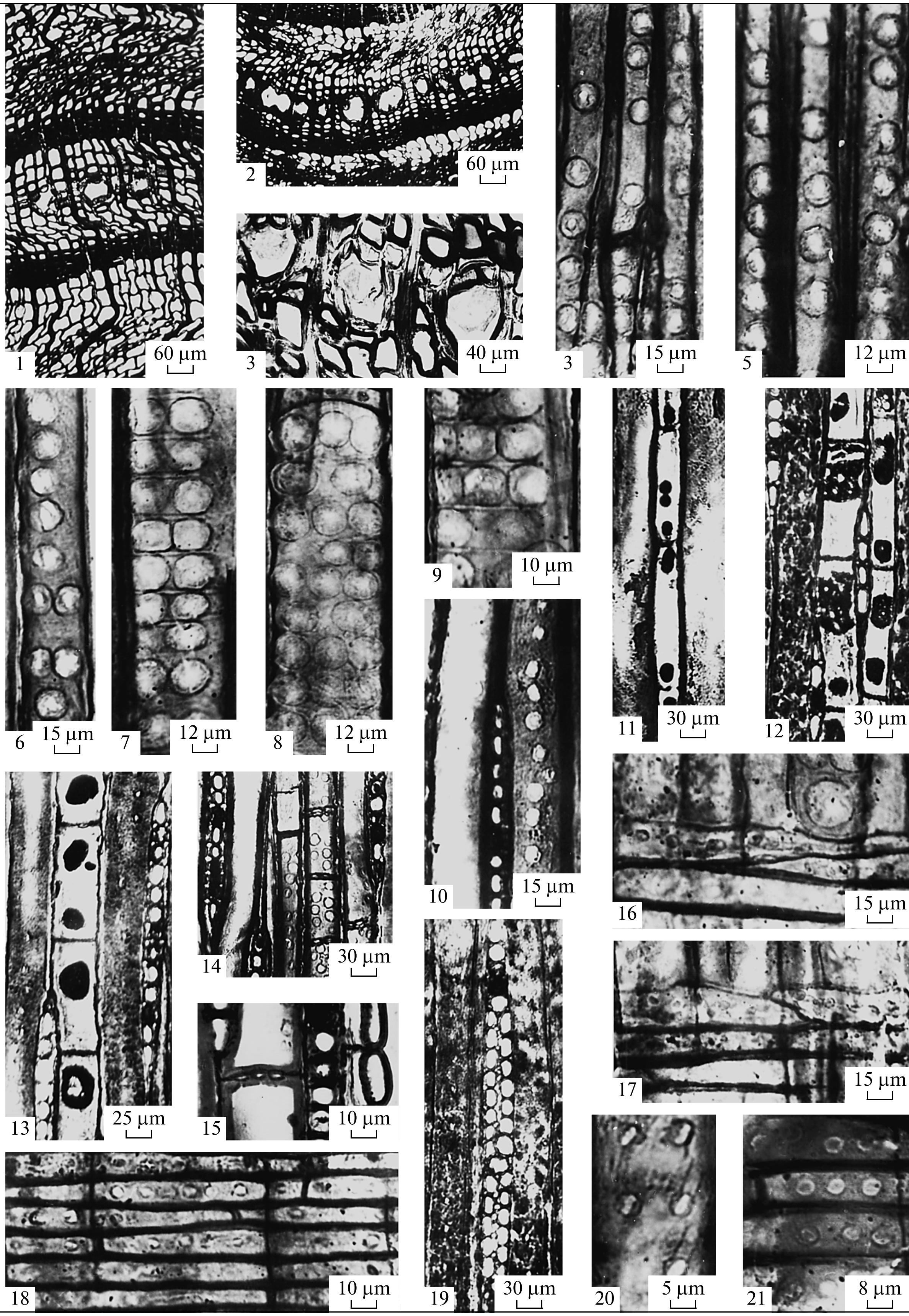
Rays are numerous, 1–30(50) cells in height; one ray, 70 cells in height, was found. Rays are uniseriate (Pl. 1, figs. 10, 13, 14), occasionally with biseriate ranges, which are 1–7(13) cells long (Pl. 1, fig. 19). The median ray cells are elliptic, elongated along the ray, more rarely rounded and rounded-rectangular; marginal ray cells are rounded-triangular and approximately of the same size as the median ones, but often the marginal cells are larger than the latter. Height of the ray cells in tangential section is 12–22 μm and width is 6–11 μm. The horizontal and tangential walls of rays are smooth (Pl. 1, figs. 16–18, 21). Ray cells are often filled with resin content.

In the tangential section, there are well-marked intercellular spaces located between ray cells (Pl. 1, figs. 10, 13, 14, 19). Ray tracheids are peripheral, with smooth inner walls; pits, 5–6.5 μm in diameter, are visible in the radial walls (Pl. 1, figs. 16, 17).

Cross-fields with 1–5(6) taxodioid pits, 4–7(8) μm in diameter (Pl. 1, figs. 18, 20, 21). In the early wood, two–six pits per cross-field are arranged in single horizontal row, rarer two–six pits are in two horizontal rows; nearer to the late wood, three pits are in single horizontal row. In the late wood, one–two (rarely three) pits per cross-field are arranged in single horizontal row.

Normal resin canals are absent, but numerous traumatic vertical resin canals are present (Pl. 1, figs. 1–3). The canals are rounded or elliptic, 20–125 μm in

Plate I


1
60 μm
2
60 μm
3
40 μm
3
15 μm
5
12 μm
6
15 μm
7
12 μm
8
12 μm
9
10 μm
10
15 μm
11
30 μm
12
30 μm
13
25 μm
14
30 μm
15
10 μm
16
15 μm
17
15 μm
18
10 μm
19
30 μm
20
5 μm
21
8 μm

diameter, lined with 4–12 thick-walled epithelial cells, which not always form continuous layer. Cells of accompanying parenchyma, enclosing resin canals, also do not form continuous lining. Traumatic resin canals are arranged in long chains in the late, and more rarely in early wood or early/late wood transition zone.

Comparison. Among fossil woods, *Sequoioxylon burejense* Blokhina et M. Afonin, sp. nov. show the most similarity to the woods of *Taxodioxylon szei* (Yang and Zheng, 2003) from Barremian–Early Aptian of Heilongjiang Province, China; *T. gypsaceum* (Göppert) Kräusel (Ramanujam and Stewart, 1969) from Maastrichtian of Alberta Province, Canada, and *Sequoioxylon sizimanicum* (Brokhina, 1986) from Upper Oligocene of Siziman Bay, Khabarovsk Region (Table 1).

The fossil wood studied differs from the wood of *Taxodioxylon szei* in the presence of ray tracheids, nodules in the tangential walls of axial parenchyma cells, only taxodioid pits in cross-fields, as well as the larger number of the pits arranged in one horizontal row in cross-fields, and higher rays. Moreover, the length of biseriate ranges in uniseriate rays and diameter of pits in cross-fields were not given in the description of *T. szei* (Table 1).

The fossil wood studied differs from the wood of *T. gypsaceum* in the presence of vertical traumatic resin canals, ray tracheids, nodules in the transversal walls of axial parenchyma cells, only taxodioid pits in cross-fields, higher rays, lesser sizes and number of pits in cross-fields, and smaller pits in radial tracheid walls (Table 1).

The fossil wood described differs from the wood of *Sequoioxylon sizimanicum* in the presence of vertical traumatic resin canals, triseriate pits in the radial tracheid walls, only taxodioid pits in cross-fields and larger number of the pits, as well as by the absence of completely biseriate rays (Table 1).

The wood of new species differs from the fossil woods of *Sequoioxylon* (*S. montanense* Torrey, *S. dakotense* Torrey, *S. laramense* Torrey, and *S.* (*Sequoia*) *burgessii* (Penhallow) Torrey) described from the Cretaceous of the United States (Torrey, 1923) in the presence of ray tracheids, nodules in transversal walls of axial parenchyma cells, very high rays with continuous biseriate ranges, larger number of pits in cross-fields (including pits, arranged in single horizontal row) and, in the whole, by somewhat lesser pit rows in the radial tracheids walls, as well as by the absence of traumatic horizontal resin canals.

The peculiar feature of the wood *Sequoioxylon burejense* Blokhina et M. Afonin, sp. nov., which distinguishes it from all other described taxodiaceous fossil woods, is the presence of six pits, arranged in single row, per cross-field.

Remarks. The presence of taxodioid cross-field pitting alongside with axial parenchyma, smooth horizontal and tangential walls of ray cells, and the absence of normal resin canals (canals of traumatic origin occur occasionally) testifies that the described fossil wood belongs to representatives of the family Taxodiaceae.

The modern Taxodiaceae are hardly distinguishable by their wood anatomy characters. But members of the tribe Sequoieae (genera *Sequoia*, *Sequoiadendron*, and *Metasequoia*) differ from the other Taxodiaceae in the presence of only smooth (or slightly nodular, but never dentate or pitted, as in *Taxodium* Rich. and *Glyptostrobus* Endl., the tribe Taxodieae J. Buchh.) transversal walls of axial parenchyma cells, and by the presence of ray tracheids and traumatic resin canals or cysts (Basinger, 1981; Blokhina, 1999, 2002, 2004b). Sometimes, it is difficult to identify the woods, because smooth transversal walls of axial parenchyma cells are also present in representatives of the tribe Cunninghamieae J. Buchh. (genera *Cryptomeria* D. Don, *Cunninghamia* R. Br., *Taiwania* Hayata, and *Athrotaxis* D. Don); moreover, schyzogenous cavities may occur in *Athrotaxis* and *Cryptomeria*. However, given the additional characters (type of radial tracheid walls pitting and cross-field pitting, alongside with sizes of the pits), the mature wood of Sequoieae may be distinguished from the mature wood of other members of Taxodiaceae (Blokhina, 1999, 2002, 2004b; Afonin and Blokhina, 2008).

Explanation of Plate 1

Figs. 1–21. *Sequoioxylon burejense* Blokhina et M. Afonin, sp. nov., holotype no. 36/2: (1, 2) transverse section, growth rings, and traumatic vertical resin canals; (3) transverse section, traumatic vertical resin canals; (4, 5) radial section, uniseriate pits in the tracheid walls; (6) radial section, occasional pairs of biseriate opposite pits among uniseriate pits in the tracheid wall; (7) radial section, biseriate pits in the tracheid wall and crassulae; (8, 9) radial section, triseriate pits in the tangential tracheid wall and crassulae; (10) tangential section, pits in the tracheid wall, uniseriate ray, and intercellular spaces; (11) tangential section, the axial parenchyma with smooth transverse walls and resin content; (12) tangential section, the axial parenchyma with smooth transverse walls and resin content, uniseriate rays, and intercellular spaces; (13) tangential section, the axial parenchyma with smooth transverse walls and resin content, uniseriate rays, intercellular spaces, and pits in tangential tracheid walls; (14) tangential section, the axial parenchyma with pitted tangential walls, each transverse wall with two small nodules, uniseriate rays with pronounced intercellular spaces; (15) tangential section, axial parenchyma with three small nodules in the tangential wall; (16, 17) radial section, smooth tangential and horizontal walls of ray cells, and marginal ray tracheids; (18) radial section, six pits in one horizontal row in a cross-field, smooth tangential and horizontal walls of ray cells; (19) tangential section, uniseriate ray with extensive biseriate areas; (20, 21) radial section, taxodioid pits in cross-fields, smooth tangential and horizontal walls of ray cells. The Amur Region (RFE), Zeya-Bureya Basin, right bank of the Bureya River, 9.8 km upstream from the river mouth; Tsagayan Formation, upper part of the Lower Tsagayan Subformation, Middle Maastrichtian, Upper Cretaceous.

Table 1. Comparative wood anatomy of the fossil wood *Sequoioxylon burejense* Blokhina et M. Afonin, sp. nov. and related fossil and modern representatives of the family Taxodiaceae

Anatomical characters	*Sequoioxylon burejense* Blokhina et M. Afonin, sp. nov.	*Taxodioxylon szei* Yang et Zheng, 2003	*Taxodioxylon gypsaceum* (Göppert) Kräusel (Ramanujam and Stewart, 1969)	*Sequoioxylon sizimanicum* Blokhina, 1986	*Sequoia* Endl. (Bailey and Faull, 1934; Yatsenko-Khmelevskii, 1954 b; Greguss, 1955, 1963; Vikhrov, 1959; Chavchavadze, 1979; Atlas of wood…, 1992)	*Sequoiadendron* J. Buchh. (Yatsenko-Khmelevskii, 1954 b; Greguss, 1955, 1963)	*Metasequoia* Hu et W.C. Cheng (Greguss, 1955, 1963; Chavchavadze, 1979)
Pits in the radial walls of tracheids:							
uniseriate	+	+	+	+	+	++	+
biseriate	+	+	++	++	++	–	++
triseriate	+–	+–	+	–	++	–	+–
tetraseriate	–	–	–	–	+–	–	–
pentaseriate	–	–	–	–	+––	–	–
pit diameters, μm	11–17	16–19	16–21	?	15–17(14–16)	14–17	18–20(20–22)
Pit diameters in the tangential walls of tracheids, μm	7–11	+	+	+	12–14(16)	11–13	9–11(13)
Crassulae	+	+	+	+	+	+	+
Transverse walls of the axial parenchyma cells:							
smooth	+	+	+	+	+	+	+
number of nodules	1–5	–	–	1–3	1–3	?	1–5
Uniseriate rays:							
height (in cells)	1–30(50–70)	1–15(50)	1–20(35)	1–40(50–80)	1–30(75)	1–20(30–50)	1–23(30)
number of biseriate layers	1–7(13)	+	+	1–4(9)	1–15(20–30)	1–6(7)	1–3(8)
triseriate layers	–	–	–	–	+	+	–
tetraseriate layers	–	–	–	–	+–	+––	–
Biserate rays	–	–	–	1–10	+–	+–	–
Triserate rays	–	–	–	–	+––	+––	–
Ray tracheids:							
marginal	+	–	–	+	+	+	+
medial	–	–	–	–	+–	?	–
Cross-fields:							
number of pits	1–5(6)	1–6	1–8	1–3	1–6(8–10)	1–6	1–4
pit diameters, μm	4–7(8)	?	8–12	?	5–6(12)	4.5–8	10–13
number of pits in a single horizontal row	2–6	2(3)	2–4	2–3	2–5	2–3	2–3
type of pits–							
cupressoid	–	+–	+–	+–	+	+	+
taxodioid	+	+	+	+	++	++	++
pinoid	–	–	–	–	+	+	+–
Traumatic resin canals:							
vertical	+	+	–	–	+	+	+
horizontal	–	–	–	–	+	+	–

Note: (+) character is present, (–) character is absent, (++) character dominates, (+–) character is occasionally present, (+––) character is uncommon, (?) data are absent.

The presence in fossil wood studied of predominantly smooth transversal walls of axial parenchyma cells (occasionally thickened or with small nodules), ray tracheids, traumatic resin canals, as well as the occurrence in cross-fields of large number of the pits (six pits), arranged in a single horizontal row, testifies that this fossil wood belongs to the wood of representatives of the tribe Sequoieae. However, it is nearly impossible to distinguish modern representatives of the tribe (*Sequoia*, *Sequoiadendron*, and *Metasequoia*) by their wood anatomy characters (Table 1). The difficulties of fossil Sequoieae woods diagnostics are complicated by incomplete preservation of anatomical characters in fossil condition. In addition, fossil woods often show a combination of features that is not characteristic of modern woods and differs from the latter in the taxonomic, age-related, or evolutional features, as well as in the specific growth conditions, distinguishing from the modern. The data on variability of wood structure characters in modern species in relation to the age and grows conditions of tree would be a great help for identification of fossil woods and interpretation of paleoxylotomic data.

Nevertheless, the presence in fossil wood studied of very high (up to 70 cells) rays with long biseriate ranges (up to 13 cells), as well as the occurrence in cross-fields of large number of the pits in a single horizontal row (up to six pits), allows to suppose its somewhat greater similarity with the wood of modern *Sequoia* (Table 1). According to Greguss (1955, 1963), among modern Taxodiaceae, only *Sequoia* and *Taxodium* may have in cross-fields up to four pits in a single horizontal row, and *Sequoia* even up to five pits.

Torrey (1923) proposed the formal genus *Sequoioxylon* for fossil woods of the Taxodiaceae with traumatic resin canals. Kräusel (1949) analyzed fossil woods of the Taxodiaceae and recommended to use *Sequoioxylon* only for undoubtful fossil woods of Sequoieae, and assign all other woods of Cretaceous and Cenozoic Taxodiaceae to formal genus *Taxodioxylon* Hartig emend. Gothan. *Taxodioxylon*, erected by Hartig (1848) and emended by Gothan (1905), was proposed for fossil woods characterized by the abietoid pitting (opposite, if multiseriate) in the radial tracheid walls, crassulae, axial parenchyma, traumatic resin canals or schyzogenous cavities, smooth horizontal and tangential walls of ray cells, and taxodioid cross-field pitting in the early wood. Therefore, *Taxodioxylon* unites fossil woods showing anatomical characters similar to those in woods of the modern *Sequoia*, *Sequoiadendron*, *Metasequoia* (tribe Sequoieae), *Taxodium* (tribe Taxodieae), and *Athrotaxis* (tribe Cunninghamieae). Schönfeld (1955), Süss (Süss and Velitzelos, 1997), and some other authors assign all taxodiaceous woods to the genus *Taxodioxylon*. However, Greguss (1967), Basinger (1981), Blokhina (Blokhina, 1986, 1997a, 1997b; 2004a; Blokhina and Nassichuk, 2000), and S. Iamandei and E. Iamandei (1999) use formal genus *Sequoioxylon* for fossil woods showing anatomical characters of the modern representatives of Sequoieae. On the contrary, the legitimacy of using formal genus *Metasequoioxylon*, proposed by Greguss (1967) for fossil woods of *Metasequoia*, is doubtful, as far as diagnosis of the genus includes woods of all representatives of Sequoieae.

In the present work we use the formal genus *Sequoioxylon* for naming fossil woods belonging to Sequoieae. As far as the wood under study does not show the complete identity to the wood of any modern or fossil representative of the tribe Sequoieae, it is described here as a wood of the new fossil species *Sequoioxylon burejense* Blokhina et M. Afonin, which is characterized by the combination of modern *Sequoieae* wood anatomical characters.

M a t e r i a l. Collection no. 36, sample no. 36/2 (holotype).

ACKNOWLEDGEMENTS

We are grateful to Presidium of the Far East Branch of the Russian Academy of Sciences (project no. 09-1-P15–02, Program "The Origin of the Biosphere and Evolution of Geobiosystems") and Russian Foundation for Basic Research, project no. 08-04-00419, for financial support of the work, K.P. Novikova (IBSS FEB RAS) for photographic work, and technicians of grinding workroom (FEGI FEB RAS) for preparing of thin sections.

REFERENCES

1. M. A. Afonin and N. I. Blokhina, "Fossil Woods of Some Representatives of Sequoioideae (Cupressaceae) from the Cretaceous and Tertiary Deposits of the Russian Far East," in *Fundamental and Applied Aspects in Botany of XXI Century. Part 3: Proceedings of the All-Russia Conference Part 3: Molecular Systematics and Biosystematics, Flora and Systematics of Higher Plants, Paleobotany, Cultivated and Weed Plants, Botanical Resources and Pharmacognosy, Plant Life Protection, Petrozavodsk, September 22–27, 2008* (Petrozavodsk, Karel. Nauchn. Tsentr Ross. Akad. Nauk, 2008) pp. 201–203 [in Russian].
2. M. A. Akhmetiev, T. V. Kezina, T. M. Kodrul, and S. R. Manchester, "Stratigraphy and Flora of the Cretaceous–Paleogene Boundary Beds in the Southeastern Part of the Zeya–Bureya Sedimentary Basin," in *Collection of Papers in Memory of Corresponding Member of the Russian Academy of Sciences Prof. V.A. Vachrameev on Occasion of His 90th Birthday*, Ed. by M. A. Akhmetiev, A. B. Herman, M. P. Doludenko, and I. A. Ignatiev (GEOS, Moscow, 2002), pp. 275–315 [in Russian].
3. *Atlas of Wood and Wood Fibers for Paper*, Ed. by E. S. Chavchavadze (Klyuch, Moscow, 1992) [in Russian].
4. P. Baas, N. Blokhina, T. Fujii, et al., "IAWA List of Microscopic Features for Softwood Identification," Ed. by H. G. Richter, D. Grosser, I. Heinz, and P. E. Gasson IAWA J. **25** (1), 1–70 (2004).

5. I. W. Bailey and A. F. Faull, "The Cambium and Its Derivative Tissues. IX. Structural Variability in the Redwood, Sequoia sempervirens, and Its Significance in the Identification of Fossil Woods," J. Arnold Arb. **15**, 233–254 (1934).

6. J. F. Basinger, "The Vegetative Body of *Metasequoia milleri* from the Middle Eocene of Southern British Columbia," Can. J. Bot. **59** (12), 2379–2410 (1981).

7. N. I. Blokhina, "Wood *Metasequoia sp. nov. from the Paleogene Deposits of Southwestern Primorye," in Paleobotany on the Russian Far East* (Dal'nevost. Nauchn. Tsentr Akad. Nauk SSSR, Vladivostok, 1977), pp. 18–21.

8. N. I. Blokhina, "Additional Data on the Paleogene Species *Metasequoia klerkiana* (Taxodiaceae)," Bot. Zh. **67** (7), 988–990 (1982).

9. N. I. Blokhina, "*Sequoia* Wood from the Late Oligocene of Siziman Bay (Khabarovsk Region)," Paleontol. Zh., No. 3, 131–135 (1986).

10. N. I. Blokhina, "Petrified Wood of *Metasequoia* from the Miocene of Kamchatka (Korfa Bay)," Paleontol. Zh. **29** (1a), 103–112 (1995) [Paleontol. J. **29** (1a), 103–112 (1995)].

11. N. I. Blokhina, "Fossil Wood of *Sequoioxylon chemrylicum* sp. nov. (Taxodiaceae) from the Paleogene of Chemurnaut Bay, Kamchatka," Paleontol. J. **31** (2), 235–238 (1997) [Paleontol. J. **31** (2), 235–238 (1997)].

12. N. I. Blokhina, "Some Problems in Systematics of Fossil Plants of the Redwood Plants Based on Wood Anatomical Characters," in *Proceedings of X Moscow Conference on Phylogeny of Plants, Commemorating V.N. Tikhomirov* (Mosk. ob-vo Estestvoispyt., Mosk. Gos. Univ., Moscow, 1999), pp. 31–33 [in Russian].

13. N. I. Blokhina, "On Some Aspects of Systematics, Evolution, and Phylogeny of the Redwood Plants by Wood Anatomy," in *Abstracts of the 6th European Paleobotany–Palynology Conference, Athens (Greece), 29 August–2 September, 2002* (Univ. Athens, Athens, 2002), pp. 59–60.

14. N. I. Blokhina, "Fossil Wood *Sequoioxylon sachalinicum* sp. nov. (Taxodiaceae) from the Tertiary Deposits of Western Sakhalin Island," Bot. Zh. **89** (5), 139–147 (2004a).

15. N. I. Blokhina, "On Some Wood Anatomical Features of the Modern and Fossil Taxodiaceae," in *Wood Structure, Properties, and Quality-2004. Proceedings of IV International Symposium, St. Petersburg, SPbGLTA, October 13–16, 2004*, Ed. by B. N. Ugolev (SPbGLTA, St. Petersburg, 2004b), Vol. 1, pp. 44–47 [in Russian].

16. N. I. Blokhina and W. W. Nassichuk, "Lower Tertiary Wood of *Sequoioxylon canadense* sp. nov. (Taxodiaceae) from a Kimberlite Pipe (Northern Canada)," Bot. Zh. **85** (4), 122–132 (2000).

17. N. I. Blokhina and S. A. Snezhkova, "Fossil Woods from the Upper Miocene of the Erkovetskii Brown Coal Field (Amur River Region)," Paleontol. Zh., No. 5, 97–102 (2003) [Paleontol. J. **37** (5), 545–551 (2003)].

18. E. S. Chavchavadze, *Wood of Pinaceae* (Nauka, Leningrad, 1979) [in Russian].

19. Ding Q.-H., "*Protopiceoxylon mohense* sp. nov. from the Jiufengshan Formation in Heilongjiang Province," Chinese Bull. Bot. (Sp. Issue) **17**, 206–209 (2000) [in Chinese with English summary].

20. Du N.-Z., "Two Fossil Woods from Heilongjiang Sheng of China," Acta Bot. Sin. **24**, 383–387 (1982) (in Chinese with English summary).

21. *Flora and Dinosaurs at the Cretaceous–Paleogene Boundary in the Zeya-Bureya Basin: Project 434 of the International Program for Geological Correlation*, Ed. by E. V. Bugdaeva (Vladivostok, Dal'nauka, Vladivostok, 2001).

22. *Flora of China*, Vol. 4: *Cycadaceae through Fagaceae*, Ed. by Wu Z.-Y. and P. H. Raven (Sci. Press and Missouri Bot. Garden Press, Beijing and St. Louis, 1999).

23. *Flora of North America North of Mexico*, Vol. 2: *Pteridophytes and Gymnosperms,* Ed. by N. R. Morin (Oxford Univ. Press, Oxford-New York, 1993).

24. A. F. Gammerman, A. A. Nikitin, and G. I. Nikolaeva, *Guide to Wood Identification Based on Characteristic Microscopical Features* (Akad. Nauk SSSR, Moscow-Leningrad, 1946) [in Russian].

25. W. Gothan, "Zur Anatomie lebender und fossiler Gymnospermenhölzer," Abh. Kgl. Preué. Geol. Landesanst., N. F. **44**, 1–108 (1905).

26. P. Greguss, *Xylotomische Bestimmung der heute lebenden Gymnospermen* (Akad. Kiado, Budapest, 1955).

27. P. Greguss, *Guide to Wood Identification of Gymnosperms Based on Microscopical Features* (Mosk. Gos. Univ., Moscow, 1963) [in Russian].

28. P. Greguss, *Fossil Gymnospermen Woods in Hungary from the Permian to the Pliocene* (Akad. Kiado, Budapest, 1967).

29. T. Harting, "Beiträge zur Geschichte der Pflanzen und zur Kenntniss der norddeutschen Braunkohlenflora," Bot. Zeiting (Berlin) **6**, 166–172 (1848).

30. S. Iamandei and E. Iamandei, "Fossil Conifer Wood from Prăvăleni-Ociu, Metalliferous Mts.," Acta Palaeontol. Rom. **2**, 201–212 (1999).

31. R. Kräusel, "Die fossilen Koniferen-Hölzer (unter Ausschlué von *Araucarioxylon* Kraus.). II. Kritische Untersuchungen zur Diagnostik lebender und fossiler Koniferen-Hölzer," Palaeontogr. Abt. B. **89** (4–6), 83–203 (1949).

32. V. A. Krassilov, *Tsagayan Flora of the Amur Region* (Nauka, Moscow, 1976) [in Russian].

33. Nishida H., Terada K., and Sun G., "Fossil Woods from the Late Cretaceous to Palaeocene of the Heilongjiang River Area of China and Russia," i*n Ancient Life and Modern Approaches: Abstracts of the Second International Palaeontological Congress, Beijing (China), June 17–21, 2006* Ed. by Q. Yang, Y. Wang, and E. A. Weldon (Univ. Sci. Technol. China Press, Beijing, 2006), pp. 527–528.

34. C. G. R. Ramanujam and W. N. Stewart, "Fossil Woods of Taxodiaceae from the Edmonton Formation (Upper Cretaceous) of Alberta," Can. J. Bot. **47** (1), 115–124 (1969).

35. H. Süss and E. Velitzelos, "Fossile Hölzer der Familie Taxodiaceae aus tertiären Schichten des Versteinerten Walds von Lesbos, Griechenland," Feddes Repert. **108** (1–2), 1–30 (1997).

36. E. Schönfeld, "*Metasequoia* in der westdeutschen Braunkohle," Senck. Leth. **36** (5/6), 389–399 (1955).

37. H. C. Sze, "Petrified Woods from Northern Manchuria," Sci. Record. **4** (4), 443–457 (1951).

38. R. E. Torrey, "The Comparative Anatomy and Phylogeny of the Coniferales. Part 3. Mesozoic and Tertiary Coniferous Woods," Mem. Boston Soc. Nat. Hist. **6** (2), 39–106 (1923).

39. V. E. Vikhrov, *Diagnostic Characters of the Wood of Major Forest-Forming and Commercial Timber Species of the USSR* (Akad. Nauk SSSR, Moscow, 1959) [in Russian].

40. Wang R.-F., Wang Y.-F., Chen Y.-Z. "*Cupressinoxylon jiayinense*, a New Species of the Late Cretaceous from the Heilongjiang Province, China," IAWA J. **17** (3), 319–326 (1996).

41. Wang R.-F., Wang Y.-F., and Chen Y.-Z., "Fossil Woods from Late Cretaceous of Heilongjiang Province, Northeast China, and Their Palaeoenviromental Implications," Acta Bot. Sin. **39** (10), 972–978 (1997) (in Chinese with English summary).

42. Yang X.-J. and Zheng S.-L., "A New Species of Taxodioxylon from the Lower Cretaceous of the Jixi Basin, Eastern Heilongjiang, China," Cretaceous Res. **24** (6), 653–660 (2003).

43. A. A. Yatsenko-Khmelevskii, *Fundamentals and Methods of Anatomical Examination of Wood* (Akad. Nauk SSSR, Moscow-Leningrad, 1954a) [in Russian].

44. A. A. Yatsenko-Khmelevskii, *Woods of the Caucasus Mountains* (Akad. Nauk Arm. SSR, Yerevan, 1954b) [in Russian].

45. Zheng S.-L. and Zhang W., "Fossil Plants from Longzhaogou and Jixi Groups in Eastern Heilongjiang Province," Bull. Shenyang Inst. Geol. Min. Resour. **5**, 227–348 (1982) (in Chinese with English summary).