ISSN 0031-0301, Paleontological Journal, 2010, Vol. 44, No. 10, pp. 1348–1352. © Pleiades Publishing, Ltd., 2010

A New Species of *Nilssoniocladus* Kimura et Sekido from the Lower Cretaceous of the Markovsky Peninsula (Southern Primorye)

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Received February 2, 2009

Abstract—An imprint of shoot *Nilssoniocladus* Kimura et Sekido bearing leaves *Nilssonia* Brongniart was found for the first time in the Lower Cretaceous deposits of the Markovsky peninsula near the city of Vladivostok. A new species, *Nilssoniocladus anatolii*, is identified. The finds of such shoots in organic connection with leaves are rare, and new data supplement our knowledge on the diversity, stratigraphic and geographic distribution of the genus *Nilssoniocladus*.

Key words: Early Cretaceous, Lipovtsy Formation, *Nilssoniocladus*, Southern Primorye.

DOI: 10.1134/S0031030110100114

INTRODUCTION

The Cretaceous flora of the Muravyov-Amursky peninsula is widely known due to Kryshtofovich (Kryshtofovich, 1916, 1919; Kryshtofovich and Prynada, 1932) and Krassilov (1967). The Cretaceous deposits of the peninsula are the southern continuation of the Cretaceous deposits of the Razdol'noye Basin and are divided into the Ussuri (Barremian), Lipovtsy (Aptian), and Galenki (Albian) formations and Korkino (Cenomanian) Series (Krassilov, 1967). On the Markovsky peninsula, which is part of the larger Muravyov-Amursky Peninsula, the most complete section of Cretaceous deposits is known in the lower reaches of the Bogataya River in the south; further, it continues to the north along the eastern coast of the Amur Bay . Plant remains were found virtually throughout the section, except for the Korkino Series.

The new species of *Nilssoniocladus* comes from the upper part of the section of the Lipovtsy Formation. This genus was for the first time described by Kimura and Sekido (1975) from the Lower Cretaceous of the Oguchi Formation, Itoshiro Group, in the Tetori Basin of central part of Honshu Island, Japan. It is represented by *N. nipponensis* (Yok.) Kimura et Sekido. According to the authors, this plant might be treelike or, probably, climbing (Kimura and Sekido, 1975, p. 112).

Spicer and Herman (1996) described two other new species of *Nilssoniocladus*: *N. alaskensis* Spicer et Herman and *N. chukotensis* Spicer et Herman from the Upper Albian of Alaska, Lower Killik Tongue, and latest Albian–earliest Cenomanian (Krivorechenskaya Formation) of northeastern Russia (Grebenka River basin). They differ from the Japanese *N. nipponensis* (Kimura and Sekido, 1975) in the morphology of terminal leaves, shape and size of leaf scars and shoots, in the absence of evidence of annual growth of shoots, and also in the presence of scars on the main stem of the plants. They differ from each other in the shape and size of leaf scars, and also in the shape of leaves attached to shoot apexes or associated with them.

Takimoto and co-authors (1997) described two new species of *Nilssoniocladus* from the Jurassic (Oxfordian) of the Tochicubo Formation on the North of Honshu Island: *N. tairae* Takimoto, Ohana et Kimura and *N. japonicus* Takimoto, Ohana et Kimura. They are represented by both long and short shoots, with segmented leaves attached to the apices of the latter.

Peppe with co-authors (2007) gave two new combinations: *Nilssoniocladus yukonensis* (Hollick) Peppe et Hickey and *N. comptula* (Heer) Peppe et Hickey from the Maastrichtian of the Fox Hills Formation in Northern Dakota, United States. Based on their investigation of the leaf morphology in *Nilssonia*, these researchers distinguish two morphotypes: (1) *brevis*-type (from the type species *N. brevis* Brongniart) and (2) *tenuinervis*-type (from *N. tenuinervis* Seward). As far as leaves of the type species *Nilssoniocladus nipponensis* possess all principal characters of the tenuinervis-type, Peppe with co-authors assigned leaves with venation of *tenuinervis*-type to *Nilssoniocladus*; and leaves of *brevis*-type, to *Nilssonia*.

MATERIAL

The material for study is represented by plant remains collected on the Markovsky Peninsula. Plant imprints originate from locality T.V.-28l, coordinate

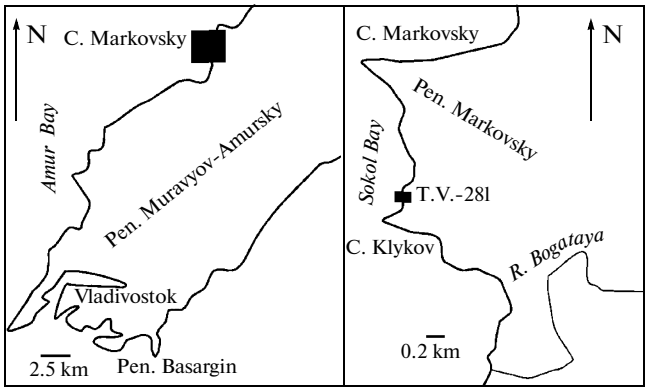


Fig. 1. The fossil flora locality in the Sokol Bay, Markovsky Peninsula.

position is 43°15′06.58″ N, 132°00′22.74″ E (Fig. 1) and concentrated in the upper part of the Lipovtsy Formation section. Earlier, Krassilov (1967) identified in layer no. 18 of this part of section only rare remains of *Elatocladus* Halle. The investigation of new plant remains allowed us to detect 45 additional taxa.

The collection contains one well-preserved specimen of the new species of *Nilssoniocladus*, which is represented by imprint and counter-imprint of shoot; phytoleim is not preserved. The collection no. T.V.-28l is kept in the Institute of Biology and Soil Science, Far Eastern Branch, Russian Academy of Sciences (IBSS).

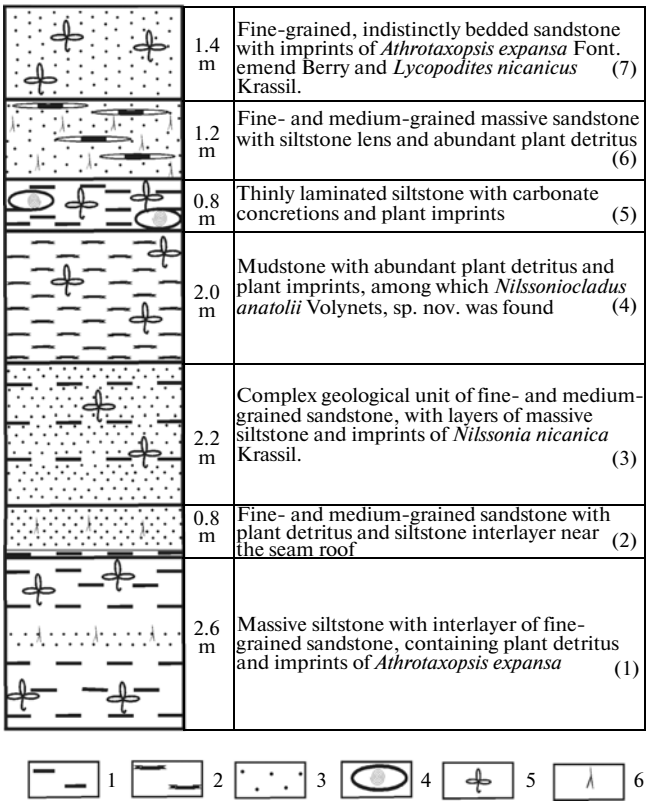


Fig. 2. The upper part of the Lipovtsy Formation section in Sokol Bay. Legend: (1) siltstone, (2) mudstone, (3) sandstone, (4) carbonate concretion, (5) plant imprints, (6) plant detritus.

TAXONOMIC COMPOSITION OF FOSSILS FROM THE SOKOL BAY IN THE MARKOVSKY PENINSULA

Locality T.V.-28l is situated on the southern coast of the Markovsky Peninsula, southern part of Sokol Bay, and is confined to the upper part of the Lipovtsy Formation section (Fig. 2). Plant remains were found in layers 1, 3–5, and 7.

In layer 1, only remains of conifer *Athrotaxopsis expansa* Font. emend. Berry, represented by numerous shoot fragments and isolated cones, were found. In layer 3, numerous compressions of *Nilssonia nicanica* Krassil. were found. In layer 4, abundant imprints of leaves *N. densinervis* (Font.) Berry and numerous fragments of shoots and cones of *Elatides asiatica* (Yok.) Krassil., shoots of *Taxites brevifolius* (Font.) Samyl. and *Araucariodendron* cf. *heterophyllum* Krassil., leaves of *Pityophyllum* ex gr. *nordenskioldii* Heer, and a shoot of *Nilssoniocladus anatolii* sp. nov., were found. Layer 5 is the most abundant in plant remains. The layer contains numerous imprints of leaves of *Nilssonia* ex gr. *orientalis* Heer and *Cycadites sulcatus* Krysht. et Pryn., shoots and cones of *Elatides asiatica* and *Athrotaxopsis expansa*, as well as numerous remains of ferns *Osmunda denticulata* Samyl., *Adiantopteris sewardii* (Yabe) Vassilevsk., *Arctopteris* aff. *kolymensis* Samyl., *Polypodites polysorus* Pryn., rare Eqisetales (*Equisetum* sp.), Caytoniales (*Sagenopteris variabilis* (Velen.) Velen.), etc. In layer 7, remains of conifer *Athrotaxopsis expansa* and lycopods *Lycopodites nicanicus* Krassil. were found.

In locality T.V.-28l, the remains of *Athrotaxopsis expansa* are the most numerous among conifers, *Cycadites sulcatus*, among bennettites, *Nilssonia densinervis* and *N.* ex gr. *orientalis*, among cycads, *Osmunda denticulata* and *Onychiopsis psilotoides* (St. et W.) Ward, among ferns. In addition, the following plant remains were found here: *Marchantites yabei* Krysht., *Lycopodites nicanicus*, *Equisetum* sp., *Eogonocormus cretaceum* Deng, *Osmunda cretacea* Samyl., *Ruffordia goeppertii* (Dunk.) Sew., *Gleichenites porsildii* Sew., *G. zippei* (Corda) Sew., *Coniopteris burejensis* (Zal.) Sew., *Adiantopteris sewardii*, *A. yuasensis* (Oishi) Krassil., *Asplenium samylinae* Krassil., *Hausmannia* sp., *Polypodites polysorus*, *Arctopteris* aff. *kolymensis*, *Arctopteris* sp. 1, *Lobifolia novopokrovskii* (Pryn.) Rasskaz. et E. Lebedev, *Cladophlebis* ex gr. *denticulata* (Brongn.) Font., *C. opposita* Pryn., *Sagenopteris variabilis*, *Sagenopteris* sp., *Ctenozamites* sp., *Pterophyllum burejense* Pryn., *P. manchurense* (Oishi) Krassil., *Pseudocycas* sp., *Nilssonia nicanica*, *Nilssoniocladus anatolii* sp. nov., *Podozamites* ex gr. *lanceolatus*

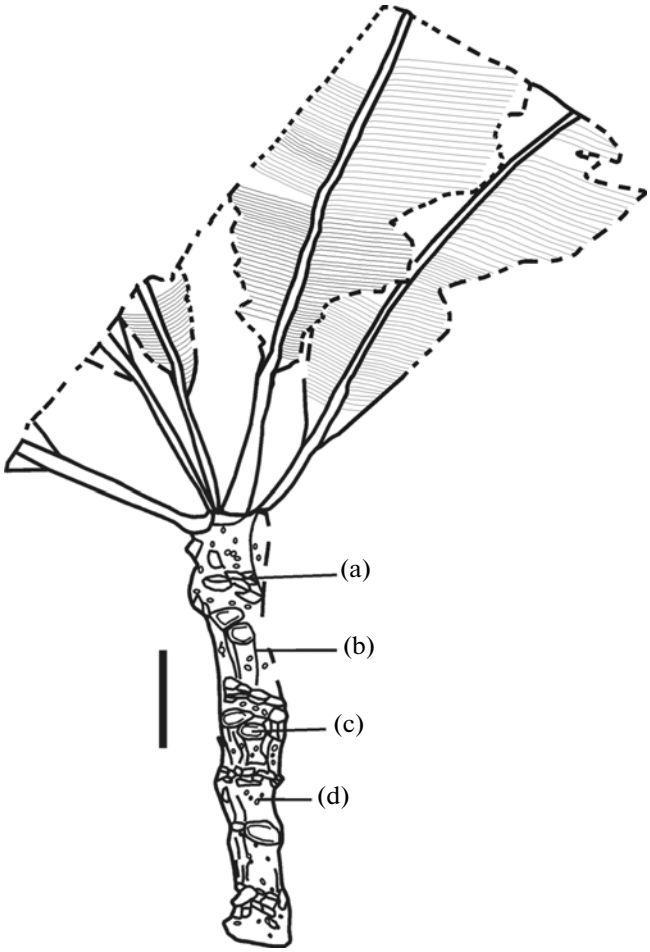


Fig. 3. *Nilssoniocladus anatolii* sp. nov., holotype IBSS no. T.V.-28l/1.: (a) annual/seasonal growth boundary with elliptic-rhomboidal cataphyll scars; (b) transverse folds; (c) large rhomboidal leaf scars; (d) small lenticel-like structures. Scale bar 10 mm.

(L. et H.) Schimp., *P. tenuinervis* Heer, *Araucariodendron* cf. *heterophyllum*, *Araucariodendron* sp., *Podocarpus* sp., *Elatides asiatica*, *Sequoia reichenbachii* (Gein.) Heer, *Sequoia* sp., *Taxites brevifolius*, *Taxites* sp., *Pityophyllum* ex gr. *nordenskioldii*, and *Carpolithes* sp.

These plant-bearing strata are dated as Aptian (Krassilov, 1967); spores and pollen were not found here. In carbonate interlayers in the upper part of the section (Fig. 2, layer 5), solitary ill-preserved radiolarians were found and studied in thin sections. According O.L. Smirnova's personal communication (Pacific Oceanological Institute, FED RAS), the radiolarians are represented predominately by the globular *Spumellaria* Haeckel, and also three- and multi-segmented forms of *Nassellaria* Haeckel. Unidentified on the specific level *Stichocapsa* Haeckel, and representatives of *Tricyrtida* Haeckel were also recognized. The carbonate layer in the middle part of the Lipovtsy Formation section contains, along with *Spumellaria*, representatives of *Nassellaria*, which were identified as Stichocapsidae and Williriedallidae. The presence of remains of radiolarians, stenohaline microorganisms, points to the marine sedimentation environment. All this suggests that the Lipovtsy Formation was formed under coastal marine conditions and that the coal-bearing deposits of the Formation should be assigned to the parallic type.

The description of the new species of *Nilssoniocladus* is given below.

SYSTEMATIC PALEOBOTANY

Order CYCADALES DUMORTIER, 1829

Family Nilssoniaceae kimura et Sekido, 1975

Genus *Nilssoniocladus* Kimura et Sekido

***Nilssoniocladus anatolii* Volynets, sp. nov.**

Plate 35, figs. 1, 2

Etymology. From the name Anatoly, in honor of A.F. Lysyuk, geologist of the Primorsky Exploring and Surveying Expedition.

Holotype. IBSS, no. T.V.-28l/1; imprint and counter-imprint of shoot; Southern Primorye, Markovsky Peninsula, Sokol Bay; upper part of Lipovtsy Formation, Aptian (Pl. 35, fig. 1; Fig. 3).

Diagnosis. Fragment of stem. Leaves attached to its distal part. Stem approximately 6–7 mm wide, 50 mm long, with transverse ridges formed of leaf elliptic-rhomboidal scars, 0.3–0.9 mm high, up to 3 mm wide, large rhomboidal leaf scars, up to 3 mm in diameter, and round small scars, 1 mm in diameter. Leaves simple, oblanceolate, petiolate. The basal parts of leaf blades wedge-shaped.

Description (Fig. 3). There are single specimen, preserved as imprint and counter-imprint of the upper part of shoot fragment. The shoot fragment is unbranched, 6–8 mm wide and about 50 mm long. The stem with four transverse ridges. First transverse ridge is situated 9 mm below apical part of the stem, second is 18 mm below the first, third is 9 mm below second, and fourth is 15 mm below the third. Leaf

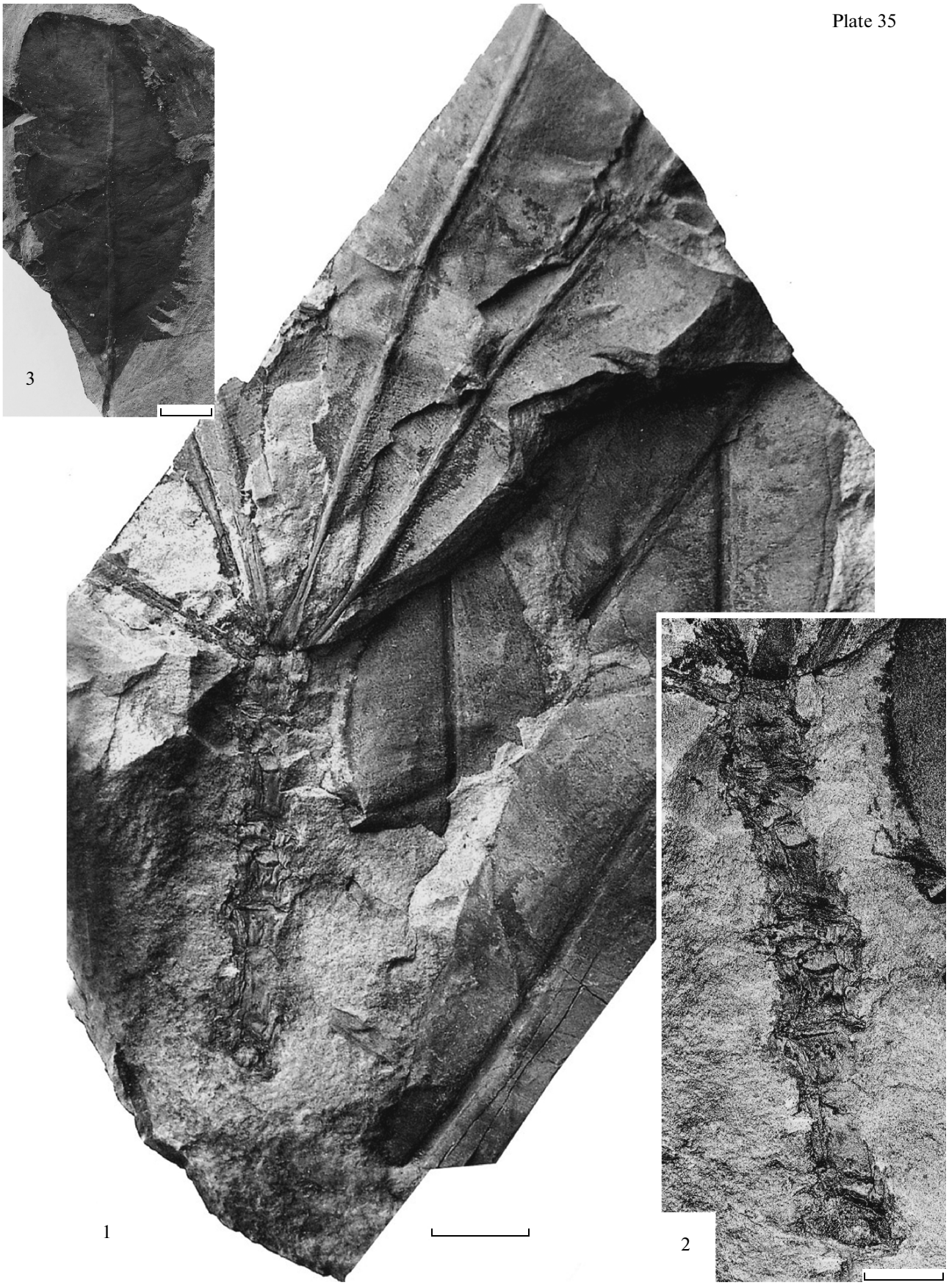
Explanation of Plate 35

Figs. 1 and 2. *Nilssoniocladus anatolii* sp. nov.: (1) holotype IBSS, no. 28/1 T.V.-28l; (2) specimen IBSS, no. 28/1 T.V.-28l, shoot fragment.

Fig. 3. Isolated petiolate leaf, specimen IBSS, no. 28/7 T.V.-28l.

Southern Primorye, Markovsky Peninsula, Sokol Bay; upper part of the Lipovtsy Formation section, Aptian. Scale bar is 10 mm for Figs. 1 and 3 and 5 mm for Fig. 2.

Plate 35



scars, arranged in tight spiral, are distinctly viewed on the stem. In the outer annual rings zones, they are elliptic-rhomboidal, small, 0.3–0.9 mm high and up to three mm wide, corresponding to cataphylls (Fig. 3). In the internodes, leaf scars are larger (up to 3 mm in diameter), rhomboidal, corresponding to normally developed leaves. Thin transverse folds are often formed below the leaf scars. Small (up to 1 mm) rounded lenticel-like structures are distributed on the stem surface irregularly.

Leaves are simple, oblanceolate, petiolate, attached to the shoot apex (Pl. 35, fig. 1). Maximal leaf width (up to 38 mm) falls on the middle part of a leaf and gradually decreases towards its base; complete length of leaves is unknown. Petioles are up to 20–25 mm long and 2–3 mm wide. Rachis is about 1.8 mm thick and round. Leaf blades are entire, some of them with slightly sinuous margins. The bases of leaf blades are wedge-shaped; the shape of leaf apices is unknown. Veins in leaf blades are thin, simple, parallel, straight, and slightly curved upward near leaf margins. Venation density is 15–19 veins per 5 mm.

C o m p a r i s o n. The new species differs from *N. nipponensis* (Kimura and Sekido, 1975) in the simple non-segmented leaves, presence of annual/seasonal growth rings on the stem, cataphyll scars, longitudinal grooves, and lenticel-like structures.

The studied species differs from *N. alaskensis* (Spicer and Herman, 1996) in the presence of two types of leaf scars: large rhomboidal scars of normal leaves and small elliptic-rhomboidal scars of cataphylls. In addition, *N. alaskensis* possess large rounded scars of lateral shoots and segmented leaves, assigned to another morphotype.

The Primorsky species differs from *N. chukotensis* (Spicer and Herman, 1996) in the presence of outer annual rings on stem and scars of cataphylls. In the new species, unlike *N. chukotensis*, leaves are simple, non-segmented, sitting on longer petioles.

The studied species differs from *N. tairae* (Takimoto et al., 1997) in the non-segmented leaves, which are sitting on petioles of larger size (up to 25 mm), by larger leaf scars and presence of annual/seasonal growth rings in its stem.

In *N. japonicus* (Takimoto et al., 1997), relative to Primorsky species, leaves are segmented, sitting on long (55 mm) petioles. The Japanese species is characterized by shoots of two types: long shoots (up to 8 cm) with ill-preserved ornamentation on their surface and short shoots with rhomboidal leaf scars.

The Maastrichtian species from Northern Dakota, assigned to *Nilssoniocladus* (Peppe et al., 2007), in fact must be assigned to *Nilssonia* (the American material is presented by only dispersed leaves, whereas the genus *Nilssoniocladus* was established on shoots with leaves of *Nilssonia*-type, attached to their apical parts).

R e m a r k s. Following Spicer and Herman (1996), I regard transverse ridges as annual/seasonal annual growth boundary of stem (outer annual rings).

Fragments of dispersed leaves are found near the shoot (Pl. 35, fig. 1), which I assigned to the new species on the basis of their venation character. In the same layer one isolated leaf was found (Pl. 35, fig. 3). The leaf is petiolate; its blade has wedge-shaped base, sinuate-concave apex, and dense venation pattern. On their whole morphology, these leaves are similar to leaves, attached to the shoot.

M a t e r i a l. One shoot fragment, Lower Cretaceous, Lipovtsy Formation, Markovsky Peninsula, Southern Primorye; collection IBSS no. 28, specimen T.V.-28l/1.

ACKNOWLEDGMENTS

I am grateful to the geologist of the Primorsky Exploring and Surveying Expedition A.F. Lysyuk for collecting of the paleobotanical material. Digital photography was made by Y.A. Semejkin.

This study was supported by the grant of the Presidium of the Russian Academy of Sciences no. 09-1-P1502.

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