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Cretaceous Deposits and Flora of the Muravyov-Amurskii Peninsula (Amur Bay, Sea of Japan)

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Abstract—The Cretaceous sections and plant macrofossils are investigated in detail near Vladivostok on the Muravyov-Amurskii Peninsula of southern Primorye. It is established that the Ussuri and Lipovtsy formations in the reference section of the Markovskii Peninsula rest with unconformity upon Upper Triassic strata. The continuous Cretaceous succession is revealed in the Peschanka River area of the northern Muravyov-Amurskii Peninsula, where plant remains were first sampled from the lower and upper parts of the Korkino Group, which are determined to be the late Albian–late Cenmanian in age. The taxonomic composition of floral assemblages from the Ussuri, Lipovtsy, and Galenki formations is widened owing to additional finds of plant remains. The Korkino Group received floral characteristics for the first time. The Cretaceous flora of the peninsula is represented by 126 taxa. It is established that ferns and conifers are dominant elements of the Ussuri floral assemblage, while the Lipovtsy Assemblage is dominated by ferns, conifers, and cycadphytes. In addition, the latter assemblage is characterized by the highest taxonomic diversity. The Galenki Assemblage is marked by the first appearance of rare flowering plants against the background of dominant ferns and conifers. The Korkino floral assemblage is subdivided into two subassemblages dominated by different groups: conifers in the early and flowering plants in the late.

Keywords: Cretaceous deposits, floral assemblage, flora, Muravyov-Amurskii Peninsula, Vladivostok

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INTRODUCTION

Vladivostok and its outskirts are located on the Muravyov-Amurskii Peninsula. F.B. Schmidt, who carried out physicogeographical investigations in this region in 1861, was the first to report on the geological structure of the peninsula. The subsequent investigations by M.A. Klykov, P.V. Margaritov, and other researchers provided information on the geological structure of some of its areas and collections of mollusk and plant remains, which were handed to the Society for the Study of the Amur Region. In 1908–1912, the works by Vittenburg (1910, 1911, 1916) began the new stage in the geological investigation of the Muravyov-Amurskii Peninsula and surrounding islands. He collected diverse phytofossils from coastal sections on Cape Firsova (Vladivostok, Vtoraya Rechka area) and in Brazhnikov Bay of the Markovskii Peninsula (Okeanskaya railway station). Kryshtofovich (1910, 1916, 1919, 1921, 1923) defined in this collection two different-age floras: Montugai (Triassic) and Nikan (Jurassic–Cretaceous). In 1922, M.K. Elishevich gathered a representative collection of the Cretaceous flora on the Muravyov-Amurskii Peninsula, which at present is stored at the Arseniev State Museum of Primorsky Region (Vladivostok). Most plants from this collection are described in (Kryshtofovich, 1932; Kryshtofovich and Prynada, 1932, 1934).

It should be noted that the age of these plant remains was determined in a wide range: Jurassic–Early Cretaceous (Kryshtofovich, 1916, 1921, 1923). Prynada (Kryshtofovich and Prynada, 1932; Prynada, 1937, 1939, 1941) and Shtempel' (1924, 1926) continued geological and phytostratigraphic investigations in the Muravyov-Amurskii Peninsula area.

Krassilov (1967) contributed much to the study of Cretaceous sections and their plant remains. This researcher and Evlanov (1962) investigated and described Lower Cretaceous sections in the Bogataya, Peschanka, and Saperka river basins. Simultaneously, Burde (1961) conducted geological mapping in the Vladivostok area. Krassilov (1967) developed the stratigraphic scale for the Cretaceous deposits of the Razdol'naya Depression, which is subdivided into the Ussuri (Barremian), Lipovtsy (Aptian), and Galenki (Albian) formations and undivided Korkino Group (Cenomanian). Such a subdivision of Cretaceous sections in Primorye has remained unchanged for almost half a century. Subsequently, N.G. Melnikov (1991) investigated the geological structure of the Vladivostok industrial cluster, which was continued by T.K. Kutub-Zade (Kutub-Zade et al., 2002), A.F. Lysyuk, and

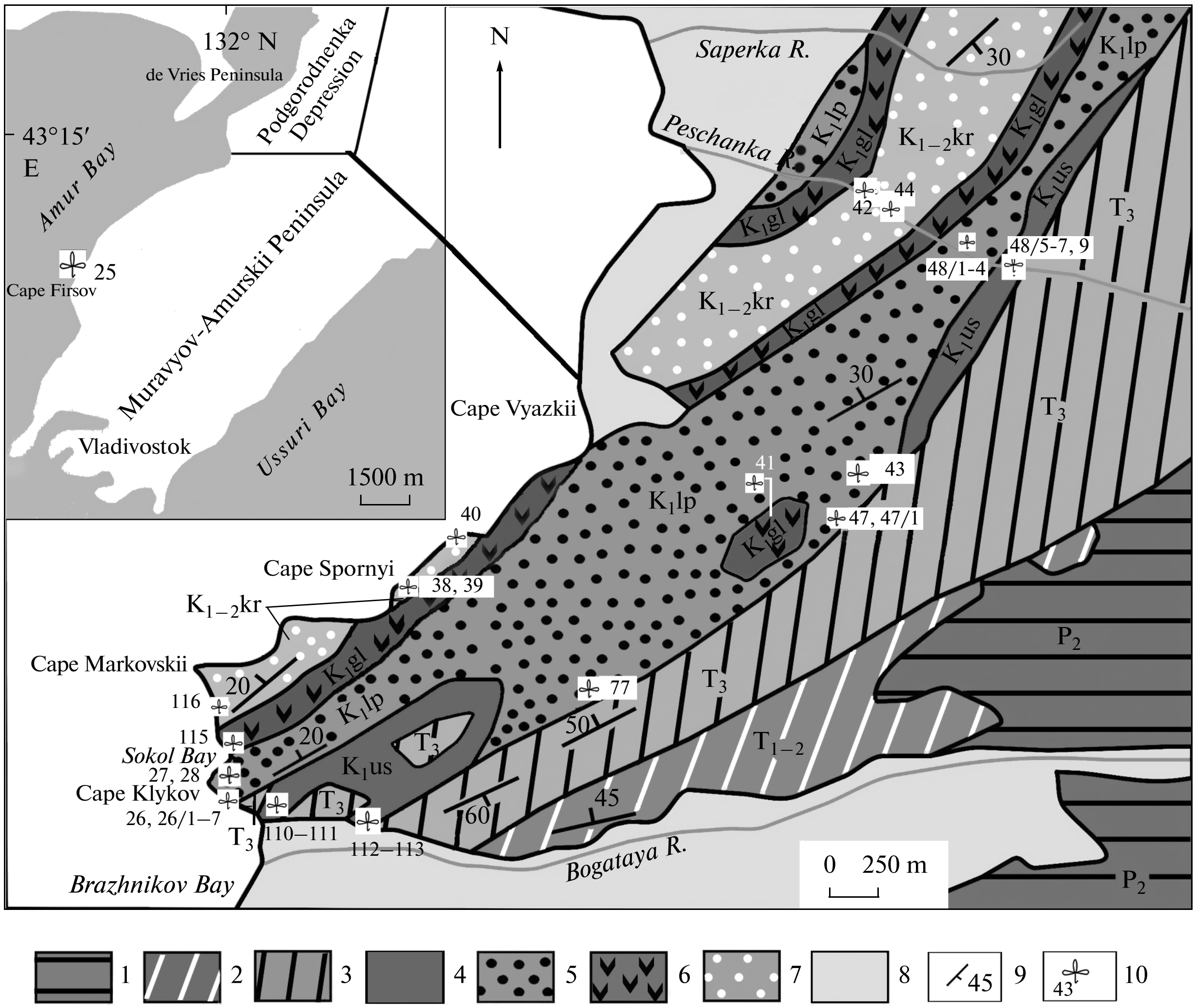

Fig. 1. Schematic geological map of the Podgorodnenka Depression of the Muravyov-Amurskii Peninsula (Evlanov, 1962; Kutub-Zade et al., 2002; this work). Rocks: (1) Upper Permian (P_2); (2) Lower–Middle Triassic (T_{1-2}); (3) Upper Triassic (T3); (4) Lower Cretaceous, Ussuri Formation (K_1us); (5) Lower Cretaceous, Lipovtsy Formation (K_1lp); (6) Lower Cretaceous, Galenki Formation (K_1gl); (7) Lower–Upper Cretaceous, Korkino Group (K_{1-2}kr); (8) Cenozoic; (9) attitude elements; (10) locality number.

E.B. Volynets (2005, 2006, 2009). They collected abundant plant remains and additionally examined Cretaceous sections on the Muravyov-Amurskii Peninsula. Lysyuk was the first to find impressions of shoots with *Nilssonia* leaves. Isolated leaves of these cycadaleans are frequent in many localities, whereas impressions of their shoots with leaves are rare. Japanese paleobotanists Kimura and Sekido (1975) were the first to describe such shoots from the Lower Cretaceous section of Japan, attributing them to a new genus *Nilssoniocladus.* Spicer and Herman (1996) also described new species of this genus from the Albian of Alaska and Albian–Cenomanian of northeastern Russia. Takimoto et al. (1997) described two new species from Jurassic strata of Honshu Island. The impressions of shoots from the Lipovtsy Formation in the outskirts of Vladivostok were described as a new species *Nilssoniocladus anatolii* Volynets (Volynets, 2010).

The purpose of this work is to summarize the extensive geological and paleobotanic data obtained in the course of investigations on the Muravyov-Amurskii Peninsula since the beginning of the 1980s.

MATERIAL

The geological description of Cretaceous sections of the Muravyov-Amurskii Peninsula and collections of their plant remains served as factual material for this study (Fig. 1). The study of sections and sampling of phytofossils were carried out with my participation in the period of 1986–2012 by many researchers: geologists A.F. Lysyuk, V.F. Lushnikov, A.V. Oleinikov, V.V. Golozubov, paleobotanists E.V. Bugdaeva, V.S. Markevich, M.V. Cherepanova, T.A. Kovaleva, and voluntary assistants Yu.A. Semeikin, I.M. Nikulina, V.R. Meshcheryakov, N.P. Sologub, and V.V. Yuferov. The collection of plant remains numbers approximately 3000 specimens from 40 localities, including 10 localities in the Ussuri Formation (Samples TV-48/5, 6, 7, 9,109–113, 77), 21 localities from the Lipovtsy Formation (Samples TV-25, 26, 26/1-7, 27, 27/1, 28, 47, 47/1, 43, 48/1-4), 7 localities in the Galenki Formation (Samples TV-41, 41/1, 2, 3, 115, 115/1), and 8 localities in the Korkino Group (Samples TV-38, 39, 39/1, 40, 42, 44, 116, 116a). Over 100 samples were taken for palynological analysis, 50 samples from carbonate intercalations for microfaunal investigations, and 40 samples from coal seams for cuticular analysis. All the phytofossils are stored in the Laboratory of Paleobotany of the Institute of Biology and Soil Science (Vladivostok) (collection no. 325). In addition, samples with Cretaceous plant remains from collections by P.V. Wittenburg (no. 612) and M.K. Elishevich (no. 611) stored at the Arseniev State Museum of Primorsky Region (Vladivostok) were used in this study.

GEOLOGICAL DESCRIPTION OF CRETACEOUS DEPOSITS ON THE MURAV'EV-AMURSKII PENINSULA

The Muravyov-Amurskii Peninsula represents a southern continuation of the Razdol'naya basin. In this area, Cretaceous sediments rest with angular unconformity largely upon Upper Triassic strata constitute the Podgorodnenka syncline on the eastern coast of Amur Bay cropping out in the form of a small block at Cape Firsova (Fig. 1). The most representative Cretaceous sections with plant remains were examined in the Peschanka River Basin, in the lower reaches of the Bogataya River, and on the eastern shore of Amur Bay (Evlanov et al., 1962; Kutub-Zade et al., 2002; Volynets, 2009, 2013; Volynets and Kovaleva, 2012; Kovaleva et al., 2012).

The **Ussuri Formation (K_1us)** overlies with an erosional surface and angular unconformity different Upper Triassic layers and is represented by sedimentary rocks, which are dominated by inequigranular sandstones.

In the lower reaches of the Bogataya River, the formation rests upon Upper Triassic massive medium-grained sandstones. Its section comprises (from the base upward) the following beds (Fig. 2, Table 1):

(1) Fine-grained sandstones and silty sandstones with remains of *Lycopodites prynadae, Coniopteris (Dicksonia) burejensis, Coniopteris* sp., and *Onychiopsis psilotoides* (Sample TV-113). The thickness is 2.5 m.

(2) Medium-pebbled conglomerates. The thickness is 6.0 m.

(3) Massive coarse-grained sandstones with rare pebble and gravel intercalations. The thickness is 5.0 m.

(4) Massive medium-grained sandstones. The thickness is 8.0 m.

(5) Massive fine-grained sandstones with remains of *Equsetites* sp., *Coniopteris (Dicksonia) burejensis, Onychiopsis psilotoides, Adiantopteris yuasensis, Podocarpus nicanicus*, and *Pseudolarix dorofeevi* (Sample TV-112). The thickness is 0.5 m.

(6) Massive medium-grained sandstones. The thickness is 2.0 m.

(7) Coaly siltstone. The thickness is 0.4 m.

(8) Alternating medium-grained cross-bedded sandstones and thin-bedded siltstones with plant detritus, thin coal intercalations (0.1 m) with rare remains of *Coniopteris* sp. and *Onychiopsis psilotoides* (Sample TV-111). The thickness is 15.0 m.

(9) Compact massive greenish gray medium- to coarse-grained sandstones (2.0 m) grading into siltstones with rare plant remains *Gleichenites* sp., *Onychiopsis psilotoides, Podozamites* ex gr. *lanceolatus* (Sample TV-110). The thickness is 3.0 m.

(10) Alternating fine-grained sandstones and thin-bedded siltstones with plant remains: *Lycopodites prynadae, Coniopteris* sp., *Onychiopsis psilotoides, Ruffordia goeppertii, Adiantopteris yuasensis, A. sewardii, Cladophlebis denticulata, Sagenopteris* sp. *Nilssoniopteris* sp., *Podozamites* ex gr. *lanceolatus, P. tenuinervis, Pagiophyllum orientalis* (Sample TV-109). The thickness is 8.0 m.

The total thickness of the section is 50.4 m.

It was established that beds 11–14 of the Ussuri Formation section in the lower reaches of the Bogataya River described by Krassilov (1967) as the upper part of the formation belong to the Upper Triassic on the basis of finds of Late Triassic plants.

At the watershed between the Bogataya River and Otradnyi Spring, the Ussuri Formation contains *Neocalamites* cf. *nathorstii, Polypodites ussuriensis, Nilssonia* ex gr. *orientalis*, and other plants in addition to the aforementioned phytofossils (Fig. 1, observation point 77) (Krassilov, 1967; identifications by B.M. Shtempel' in (Evlanov, 1962); Table 1).

In the Peschanka River basin, the section of the Ussuri Formation includes the following beds (Fig. 2, Table 1):

(1) Medium- to small-pebbled conglomerate. The thickness is 1.0 m.

(2) Weakly consolidated fine- to medium-grained sandstone with rare plant remains: *Acrostichopteris* cf. *pluripartita, Podozamites* sp. (Sample TC-48/9). The thickness is 16.5 m.

(3) Fine-grained sandstones represented by alternating finer and coarser varieties, with thin (up to 0.5 m) intercalations of carbonaceous siltstones and plant remains: *Lycopodites* sp., *Equisetum* ex gr. *burejensis, Onychiopsis psilotoides, Adiantopteris yuasensis, Ginkgo* sp., *Podozamites* ex gr. *lanceolatus, Pityophyllum* ex gr. *nordenskoldii, Pityophyllum* sp. (Sample TV-48/6-7). The thickness is 21.0 m.

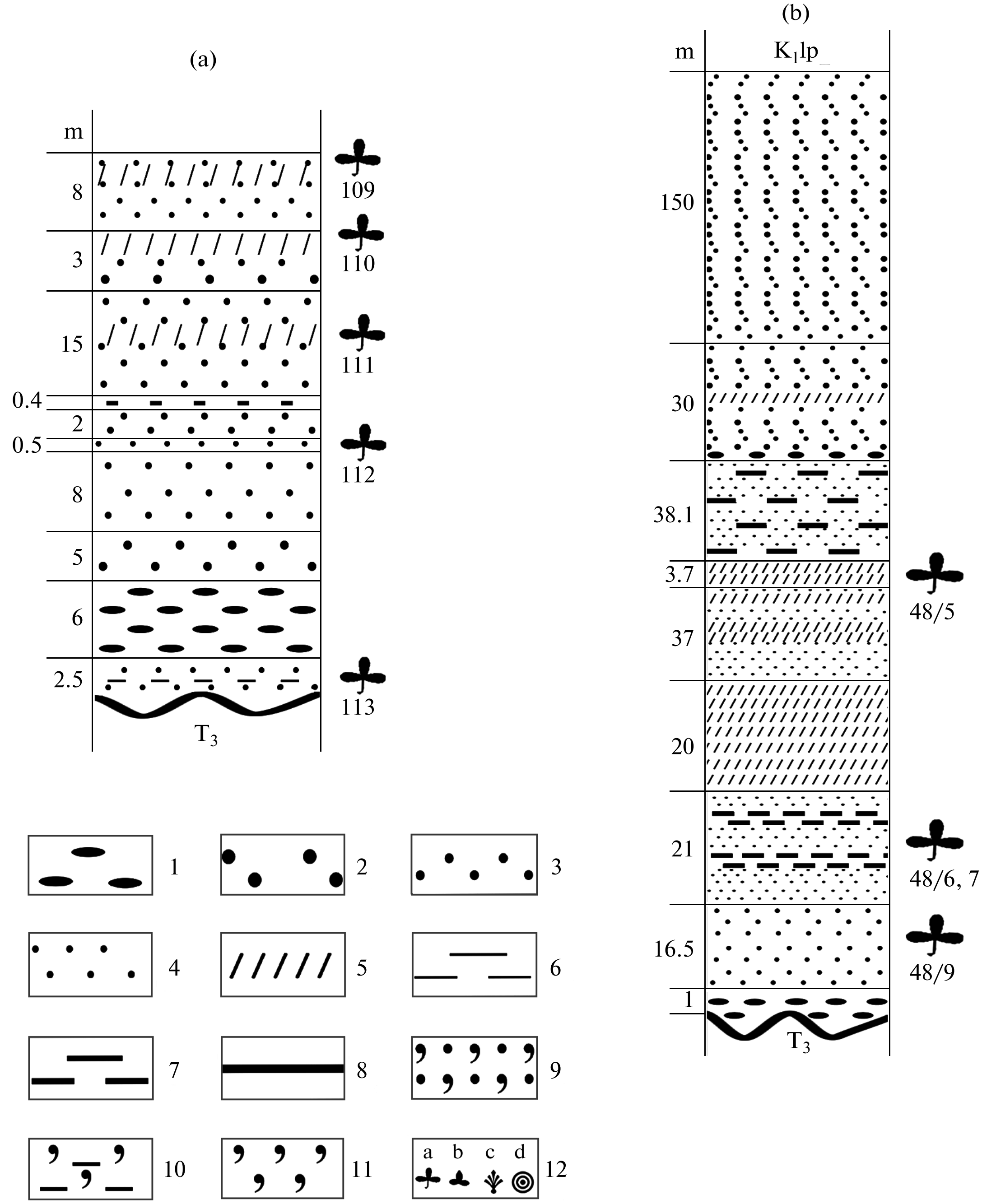

Fig. 2. Sections of the Ussuri Formation in the (a) Bogataya and (b) Peschanka river basins (Evlanov, 1962; Krassilov, 1967; Kutub-Zade et al., 2002; this work). (1) Conglomerates and gravelites; (2) coarse-grained sandstones; (3) medium-grained sandstones; (4) fine-grained sandstones; (5) siltstones; (6) mudstones; (7) coaly siltstones and mudstones; (8) coal; (9) tuffaceous sandstones; (10) tuffaceous siltstones; (11) tuffites; (12) localities of fossil plants (a) and wood (c), palynological (b) and carbonate rock (d) samples.

(4) Gray compact fractured siltstone. The thickness is 20.0 m.

(5) Alternating fine- and medium-grained compact sandstones with thin (up to 0.5 m) siltstone intercalations. The thickness is 37.0 m.

(6) Thin-bedded siltstones with remains of *Podozamites* ex gr. *lanceolatus, Pityophyllum* ex gr. nordenskioldii, and *Carpolithes* sp. (Sample TV-48/5). The thickness is 3.7 m.

(7) Fine-grained sandstone with thin (0.3–0.8 m) intercalations of carbonaceous mudstones. The thickness is 38.1 m.

(8) Coarse- to medium-grained sandstone with gravel intercalations (up to 1.0 m) in the lower part of

Table 1. Taxonomic composition of the Ussuri floral assemblage

Taxon \ Locality	113	111+112	109	110	48/5-7,9	B.M. Shtempel'[1]	Krassilov, 1967
Bryophyta							
Marchantites cf. *yabei* Krysht. et Prynada						*	
Lycopodiales							
Lycopodites prynadae Krassilov	*			*			
Lycopodites sp.					*		
Equisetales							
Equisetites ex gr. *burejensis* (Heer) Kryshtofovich					*		
Equisetites sp.		*					
Neocalamites cf. *nathorstii* Erdtman							*
Filicales							
Gleichenites sp.			*				
Coniopteris (Dicksonia) *burejensis* (Zal.) Seward	*	*					*
Coniopteris sp.	*			*	*		
Onychiopsis psilotoides (Stok. et Webb) Ward	*	*	*	*	*		
Ruffordia goeppertii (Dunk.) Seward				*			
Adiantopteris yuasensis (Yok.) Krassilov		*		*	*		
Adiantopteris sewardii (Yabe) Vassilevskaya				*			
Polypodites ussuriensis Krysht. et Prynada							*
Acrostichopteris cf. *pluripartita* (Font.) Berry					*		
Lobifolia novopokrovskii (Pryn.) Rasskaz. et E. Lebedev						*	
Teilhardia tenella (Pryn.) Krassilov							*
Cladophlebis denticulata (Brongn.) Fontaine				*		*	
Cladophlebis sp.							*
Caytoniales							
Sagenopteris sp.				*			*
Bennettitales							
Nilssoniopteris sp.				*			
Cycadales							
Nilssonia ex gr. *orientalis* Heer							*
Ginkgoales							
Ginkgo sp.						*	
Pseudotorellia sp.							*
Coniferales							
Podozamites ex gr. *lanceolatus* (Lindl. et Hutt.) Schenk			*	*	*		*
Podozamites tenuinervis Heer				*			
Podozamites sp.					*		*
Pagiophyllum orientalis Heer				*			
Podocarpus nicanicus Krassilov		*					*
Pseudolarix dorofeevii Samylina		*					*
Pityophyllum sp. + P. ex gr. *nordenskioldii* Heer					*		
Pityostrobus sp.							*
Elatides asiatica (Yok.) Krassilov					*	*	
Brachyphyllum sp.						*	
Cyparissidium gracile Heer						*	
Plants Incertae sedis							
Carpolithes sp.					*		

[1] Identifications by B.M. Shtempel' in (Evlanov, 1962).

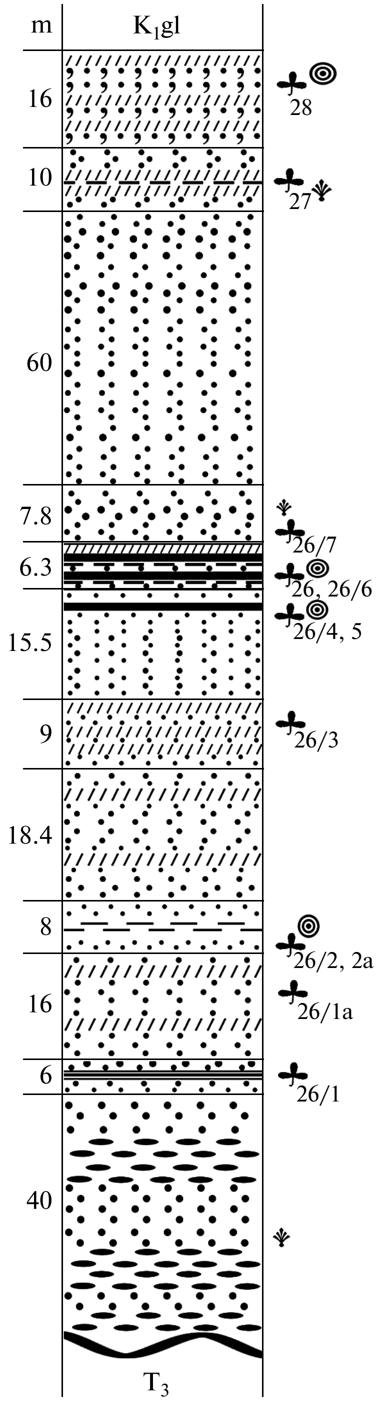

Fig. 3. Section of the Lipovtsy Formation on the Markovskii Peninsula (Evlanov, 1962; Krassilov, 1967; Kutub-Zade et al., 2002; this work). For legend, see Fig. 2.

the bed and intercalations of dark gray siltstones (2.7 m) in its middle part. The thickness is 30.0 m.

(9) Alternating compact fine-, medium-, and coarse-grained sandstones. The thickness is 150.0 m.

The integral apparent thickness of the section is 317.3 m; according to exploration drilling, it is up to 400 m thick (Evlanov, 1962; Kutub-Zade et al., 2002).

The **Lipovtsy Formation (K_1lp)** is widespread in the Peschanka River basin, where it rests conformably upon the Ussuri Formation (Fig. 1). The lower part of the Lipovtsy Formation is composed of coarse-grained sandstones and gravelites with rare intercalations of fine-grained rocks; its upper part is mostly represented by alternating medium- and fine-grained sandstones, siltstones with mudstone intercalations, and coal seams. In the Podgorodnenka mine area, the formation includes 26 coal seams and its thickness amounts to approximately 350.0 m (Kutub-Zade et al., 2002).

On the Markovskii Peninsula (Brazhnikov Bay) and Cape Firsov (Vladivostok), coaliferous sections of the Lipovtsy Formation are investigated in outcrops. Its apparent thickness is 213.0 in the first of them (Kovaleva et al., 2012) and 120.0–150.0 m in the second one (Burde, 1961; Krassilov, 1967).

The most complete section of the formation is observed in Brazhnikov Bay (Markovskii Peninsula), where Upper Triassic strata are overlain by the following members (Fig. 3, Table 2);

(1) Small- and medium-pebbled conglomerates alternating with coarse-grained sandstones enclosing remains of tree trunks. The thickness is 40.0 m.

(2) Inequigranular sandstones and thin-bedded siltstones with thin (up to 0.2 m) intercalations of coals and coaly mudstones with plant remains: *Thallites* sp., *Isoetites* sp., *Equisetites* ex gr. *burejensis, Coniopteris* sp., *Onychiopsis psilotoides, Lobifolia novopokrovskii, Cladophlebis frigida, Nilssonia* ex gr. *brongniartii, Podozamites* sp., *Elatides asiatica, Athrotaxopsis expansa* (Sample TV-26/1). The thickness is 6.0 m.

(3) Alternating medium-grained sandstones and thin-bedded siltstones with plant remains: *Equisetites ramosus, Alsophilites nipponensis, Coniopteris (Dicksonia) burejensis, Coniopteris* sp., *Nilssonia* ex gr. *brongniartii, Podozamites* sp., *Elatides asiatica, Athrotaxopsis expansa* (Sample TV-26/1a). The thickness is 16.0 m.

(4) Alternating fine-grained sandstones, coal seams, and coaly mudstone (0.5 m each) with lenses of carbonate concretions and plant remains: *Lycopodites nicanicus, Alsophilites nipponensis, Gleichenites* sp., *Coniopteris* sp., *Lobifolia novopokrovskii, Cladophlebis* sp., *Sagenopteris* sp., *Nilssonia nicanica, Pityophyllum* sp. (Samples TV-26/2, TV-26/2a). The thickness is 8.0 m.

(5) Massive medium-grained sandstones with intercalations (up to 0.2 m) of sandstones and siltstones. The thickness is 18.4 m.

(6) Alternating fine-grained sandstones and thin-bedded siltstones with plant remains *Ruffordia* sp., *Gleichenites* sp., *Coniopteris (Dicksonia) burejensis, Coniopteris* sp., *Cladophlebis frigida, Sphenopteris* sp., *Nilssonia* ex gr. *brongniartii, Athrotaxopsis expansa* (Sample TV-26/3). The thickness is 9.0 m.

(7) Compact massive fine- to medium-grained sandstone with two coaly intercalations (0.1 m), coal seam (0.4 m) in the upper part of the member, and diverse plant remains: *Foliosites* sp., *Equisetites ramo-*

sus, Osmunda sp., *Coniopteris (Dicksonia) burejensis, Onychiopsis psilotoides, Asplenium samylinae, Ruffordia goeppertii, Arctopteris* sp., *Teilhardia tenella, Pterophyllum burejense, Cycadites sulcatus, Nilssonia densinervis, N.* ex gr. *orientalis, N. nicanica, Ginkgo pluripartita, Podozamites* ex gr. *lanceolatus, Torreya nicanica, Elatides asiatica, Athrotaxopsis expansa*, and others (Samples TV-26/4, 26/5; Table 2). The thickness is 15.5 m.

(8) Alternating compact fine- and medium-grained sandstones with lenses of carbonate concretions and siltstones intercalated by thin (0.1 m) laminae of coaly mudstone, two coal seams (0.5 m), and abundant phytofossils *Lycopodites nicanicus, Coniopteris (Dicksonia) burejensis,* Nathorstia *pectinata, Adiantopteris yuasensis, Lobifolia novopokrovskii, Cladophlebis frigida, C. denticulata, Dictyozamites cordatus, Nilssonia densinervis, N.* ex gr. *orientalis, Ginkgo* ex gr. *adiantoides, G. concinna, G. pluripartita, Czekanowskia* ex gr. *rigida, Podozamites* ex gr. *lanceolatus, Elatides asiatica, Athrotaxopsis expansa*, and others (Samples TV-26, 26/6; Table 2). The thickness is 6.3 m.

(9) Medium-grained sandstone with intercalations (0.4 m) of its coarser varieties, remains of *Xenoxylon* trunks, and rare impressions of leaves belonging to *Onychiopsis psilotoides, Podozamites* ex gr. *lanceolatus, Pityophyllum* sp., and *Coniferites* sp. (Sample TV-26/7). The thickness is 7.8 m.

(10) Compact massive coarse- to medium-grained sandstone. The thickness is 60.0 m.

(11) Alternating medium-grained sandstones, siltstones, and carbonaceous mudstones with plant remains *Lycopodites prynadae, Equisetites* sp., *Osmunda* sp., *Gleichenites* sp., *Coniopteris (Dicksonia) burejensis, Coniopteris* sp., *Onychiopsis psilotoides, Asplenium samylinae, Arctopteris* sp., *Lobifolia novopokrovskii, Sagenopteris mantellii, Nilssoniopteris* sp., *Cycadites sulcatus, Nilssonia densinervis, Ginkgo pluripartita, Podozamites* ex gr. *lanceolatus, Pseudolarix dorofeevii*, and others (Samples TV-27, 27/1; Table 2). The thickness is 10.0 m.

(12) Frequent alternation of tuffstones and siltstones, which yielded *Marchantites* ex gr. *yabei, Osmunda denticulata, Ruffordia goeppertii, Gleichenites porsildii, G. zippei, Adiantopteris sewardii, A. yuasensis, Polypodites polysorus, Arctopteris* aff. *kolymensis, Pterophyllum burejense, P. manchurense, Nilssoniocladus anatolii, Araucariodendron* cf. *heterophyllum, Elatides asiatica, Taxites brevifolius* (Font.) Samyl., and others (Sample TV-28, Table 2). The thickness is 16.0 m.

The total thickness of this section is 213.0 m.

O.L. Smirnova (Pacific Oceanological Institute, Far East Branch, Russian Academy of Sciences) identified rare multichamber foraminifers and radiolarian casts from outcrops on Cape Klykov and in Sokol Bay (Volynets, 2010). On Cape Klykov, they yielded fragments of *Xenoxylon latiporosum* (Cramer) Gothan and *Xenoxylon hopeiense* Chang trunks (Afonin, 2008).

In the Cape Firsov area, the fragment of the Lipovtsy Formation section is represented by alternating fine- to medium-grained sandstones and siltstones with intercalations of coaly mudstones and coals (Krassilov, 1967), which contain the following plant remains (Sample TV-25): *Thallites* sp., *Foliosites* sp., *Lycopodites prynadae, L. nicanicus, L. obtusus, Equisetites* ex gr. *burejensis, Alsophillites nipponensis, Nathorstia pectinata, Osmunda denticulata, Ruffordia goeppertii, Gleichenites zippei, Birisia onychioides, Onychiopsis psilotoides, Adiantopteris sewardii, Arctopteris* aff. *kolymensis, Polypodites polysorus, Lobifolia novopokrovskii, Teilhardia tenella, Cladophlebis virginiensis, Sagenopteris variabilis, S. petiolata, Dictyozamites cordatus, D. reniformis, Pterophyllum burejense, Williamsonia* cf. *pacifica, Pseudoctenis eathiensis, Cycadites sulcatus, Nilssonia densinervis, N. mediana, N. prynadae, Ginkgo* ex gr. *adiantoides, Czekanowskia* ex. gr. *rigida, Podozamites* ex gr. *lanceolatus, P. subreinii, Pseudolarix dorofeevii, Torreya nicanica, Elatides asiatica*, and others (Table 2). In addition, these rocks yielded remains of tree trunks: *Protocedroxylon primoryense* M. Afonin and *Xenoxylon latiporosum* (Cramer) Gothan (Afonin, 2008, 2012).

Additional previously unknown localities with plant remains from local sections of the Lipovtsy Formation are examined in the upper reaches of Dachnyi Creek and in the watershed between Dachnyi and Ugol'nyi creeks, which flow into Amur Bay (Fig. 1). Their plant remains include *Equisetites* ex gr. *burejensis, Alsophillites nipponensis, Nathorstia pectinata, Onychiopsis psilotoides, Dictyozamites cordatus, Nilssonia densinervis, N. nicanica, Ginkgo* ex gr. *adiantoides, Podozamites* ex gr. *lanceolatus*, and *Elatides asiatica* (Samples TV-43, 47, 47/1). In the Peschanka River basin, coeval strata (Fig. 1) yielded remains of *Thallites* sp., *Lycopodites nicanicus, L. prynadae, Isoetites* sp., *Equisetites* ex gr. *burejensis, Osmunda denticulata, Ruffordia goeppertii, Gleichenites porsildii, Onychiopsis psilotoides, Dicksonia concinna, Coniopteris* sp., *Lobifolia novopokrovskii, Ginkgo concinna, G. pluripartita, Pterophyllum burejense, Nilssonia nicanica, N.* ex gr. *orientalis, Podozamites* ex gr. *lanceolatus, Elatides asiatica, Athrotaxopsis expansa, Pityophyllum* sp., *Pityostrobus* sp., and *Carpolithes* sp. (Sample TV-4/1-4).

The **Galenki Formation (K_1gl)** is developed in the Podgorodnenka Depression on the left shore of Amur Bay from Sokol Bay in the south (Sadgorod railway station) to the Saperka River basin (Uglovoe settlement) in the north (Fig. 1). It is composed of sandstones, siltstones, conglomerates, carbonaceous mudstones, and tuffites. Its relationships with the Lipovtsy Formation are unobservable. The sections of the Galenki Formation are examined on the Markovskii Peninsula, in the upper reaches of Dachnyi Creek, and on the right bank of the Peschanka River. According to exploration drilling, the thickness of the formation in the Peschanka

Table 2. Taxonomic composition of the Lipovtsy floral assemblage

Taxon \ Locality	26	26(1)	26(1a)	26(2)	26(2a)	26(3)	26(4)	26(5)	26(6)	26(7)	27	27(1)	28	25	Krassilov, 1967
Bryophyta															
Marchantites ex gr. *yabei* Krysht. et Prynada													*		
Thallites sp.		*												*	
Foliosites sp.								*					*	*	
Lycopodiales															
Lycopodites prynadae Krassilov											*			*	*
Lycopodites nicanicus Krassilov	*			*									*	*	*
Lycopodites nosikovii (Krysht. et Pryn.) Krassilov															*
Lycopodites obatus Deng														*	
Lycopodites ussuriensis Krysht. et Prynada															*
Lycopodites sp.	*								*					*	*
Lycopodiostrobus sp.														*	
Isoetites sp.		*													
Equisetales															
Equisetites ex gr. *burejensis* (Heer) Kryshtofovich		*							*					*	
Equisetites sp.	*										*		*	*	*
Equisetites ramosus Samylina			*				*	*							
Equisetostrobus sp.														*	
Filicales															
Alsophilites nipponensis (Oishi) Krassilov			*	*										*	
Nathorstia pectinata (Goepp.) Krassilov	*													*	
Osmunda denticulata Samylina													*	*	
Osmunda sp.	*							*				*	*		
Ruffordia goeppertii (Dunk.) Seward							*						*	*	
Ruffordia sp.						*		*						*	
Gleichenites porsildii Seward	*							*					*		
Gleichenites zippei (Corda) Seward	*							*					*	*	
Gleichenites sp.				*		*						*			*
Dicksonia concinna Heer	*														
Coniopteris (Dicksonia) *burejensis* (Zal.) Seward			*			*		*			*		*		*
Coniopteris sp.		*	*	*		*					*	*		*	*
Birisia onychioides (Vassilevsk. et Kara-Mursa) Samylina								*	*				*	*	
Onychiopsis psilotoides (Stok. et Webb) Ward		*					*	*		*	*	*	*	*	*
Adiantopteris yuasensis (Yok.) Krassilov									*				*		
Adiantopteris sewardii (Yabe) Vassilevskaya													*	*	
Arctopteris aff. *kolymensis* Samylina	*								*				*	*	
Arctopteris sp.								*				*	*	*	
Asplenium samylinae Krassilov								*			*		*		*
Hausmannia sp. 1													*		
"*Polypodites*" *polysorus* Prynada													*	*	
Lobifolia novopokrovskii (Pryn.) Rasskaz. et E. Lebedev	*	*			*						*		*	*	*
Teilhardia tenella (Pryn.) Krassilov								*					*	*	
Cladophlebis frigida (Heer) Seward	*	*				*			*					*	*
Cladophlebis denticulata (Brongn.) Fontaine	*												*		
Cladophlebis opposita Prynada													*		

Table 2. (Contd.)

Taxon / Locality	26	26(1)	26(1a)	26(2)	26(2a)	26(3)	26(4)	26(5)	26(6)	26(7)	27	27(1)	28	25	Krassilov, 1967
Cladophlebis virginiensis Fontaine														*	
Cladophlebis sp.				*								*		*	
Sphenopteris sp.						*						*		*	*
Caytoniales															
Sagenopteris variabilis (Velen.) Velenovsky													*	*	
Sagenopteris mantellii (Dunk.) Schenk											*				*
Sagenopteris petiolata Oishi														*	
Sagenopteris sp.				*							*		*	*	
Bennettitales															
Dictyozamites cordatus (Krysht.) Prynada									*					*	*
Dictyozamites reniformis (Font.) Oishi														*	
Pterophyllum burejense Prynada							*						*	*	
Pterophyllum manchurense (Oishi) Krassilov													*		
Pterophyllum sutschanense Prynada														*	*
Nilssoniopteris sp.											*				
Williamsonia pacifica Kryshtofovich															*
Williamsonia cf. *pacifica* Kryshtofovich														*	
Cycadites sulcatus Krysht. et Prynada							*				*		*	*	*
Cycadolepis sp.															*
Cycadales															
Ctenis sp.														*	
Pseudoctenis eathiensis (Rich.) Seward														*	
Nilssonia densinervis (Font.) Berry	*						*		*		*		*	*	*
Nilssonia mediana (Leck.) Fox-Strangways														*	
Nilssonia ex gr. *orientalis* Heer	*						*		*		*		*		*
Nilssonia nicanica Prynada	*			*			*						*		
Nilssonia prynadii Vachrameev														*	
Nilssonia ex gr. *brongniartii* (Mant.) Dunker		*	*			*						*		*	*
Nilssoniocladus anatolii Volynets													*		
Taeniopteris kryshtofovichii (Pryn.) Prynada														*	*
Ginkgoales															
Ginkgo ex gr. *adiantoides* Heer									*					*	
Ginkgo concinna Heer	*								*						
Ginkgo pluripartita (Schimp.) Heer							*		*		*				*
Ginkgo sp.									*					*	
Desmiophyllum sp.														*	
Czekanowskiales															
Czekanowskia ex gr. *rigida* Heer	*													*	
Coniferales															
Podozamites angustifolius (Eichw.) Heer															*
Podozamites ex gr. *lanceolatus* (Lindl. et Hutt.) Schenk							*	*	*	*	*		*	*	*
Podozamites subreinii Krysht. et Prynada														*	*
Podozamites tenuinervis Heer													*	*	
Podozamites sp.		*	*								*	*			*

Table 2. (Contd.)

Taxon \ Locality	26	26(1)	26(1a)	26(2)	26(2a)	26(3)	26(4)	26(5)	26(6)	26(7)	27	27(1)	28	25	Krassilov, 1967
Araucariodendron cf. *heterophyllum* Krassilov											*		*	*	*
Araucariodendron sp.													*		
Podocarpus sp.													*		
Pseudolarix dorofeevii Samylina											*			*	*
Pityophyllum ex gr. *nordenskioldii* Heer									*		*		*	*	
Pityophyllum sp.					*		*	*		*	*	*			*
Pityostrobus sp.	*														
Pityolepis sp.								*							
Pityospermum sp.	*							*					*	*	
Torreya nicanica Krassilov							*							*	
Taxites brevifolius (Font.) Samylina	*								*				*		*
Taxites sp.													*	*	
Elatides asiatica (Yok.) Krassilov	*	*	*		*		*				*	*	*	*	*
Elatides sp.	*														
Sequoia ex gr. *reichenbachii* (Gein.) Heer	*								*				*	*	
Sequoia sp.												*	*		
Athrotaxites berryi Bell											*			*	
Athrotaxopsis expansa Fontaine emend. Berry	*	*	*			*		*	*		*		*	*	*
Elatocladus sp.	*								*				*	*	
Brachyphyllum japonicum (Yok.) Oishi													*		
Brachyphyllum ex gr. *obesum* Heer	*												*	*	
Brachyphyllum sp.								*					*	*	
Plants Incertae sedis															
Carpolithes sp.							*	*					*		
Coniferites sp.										*					
Hydropterangium sp.														*	*
Zamiopsis insignis Fontaine														*	
Ctenozamites sp.													*		

River basin is approximately 100.0 m (Kutub-Zade et al., 2002).

In the upper reaches of Dachnyi Creek, the Galenki Formation rests unconformably the Upper Triassic strata and is represented by the following rocks (from the base upward, Fig. 4):

(1) Weakly consolidated coarse-grained gravely sandstone. The thickness is 12.0 m.

(2) Compact fine-grained sandstone. The thickness is 5.0 m.

(3) Alternating carbonaceous mudstones, bedded fine- to medium-grained sandstones, and siltstones with phytofossils (Sample TV-41). The thickness is 3.4 m.

(4) Rhythmically alternating fine- to medium-grained sandstones (0.1–0.5 m), siltstones, and thin-bedded coaly mudstones (up to ashy coals) with plant remains (Sample TV-41/1). The thickness is 12.0 m.

(5) Alternating fine-grained sandstones and thin-bedded siltstones with plant remains (Sample TV-41/2). The thickness is 14.0 m.

(6) Tuffites. The thickness is 3.6 m.

(7) Alternating fine-grained sandstones and tuffites. The thickness is 3.0 m.

(8) Compact silicified siltstone with plant remains and mineralized wood (Sample TV-41/3). The thickness is 3.0 m.

The apparent thickness of the section is 56.0 m.

In this section, phytofossils include *Lycopodites nicanicus, L. prynadae, Osmunda* sp., *Ruffordia goeppertii, Anemia dicksoniana, Gleichenites* cf. *gieseckianus, Dicksonia concinna, Coniopteris* ex gr. *arctica, Birisia onychioides, Adiantopteris yuasensis, Neozamites denticulatus, Nilssonia densinervis, Podozamites* ex gr. *lanceolatus, Sequoia* ex gr. *reichenbachii, Elatides asiatica, Sapindopsis variabilis*, and mineralized wood (Table 3).

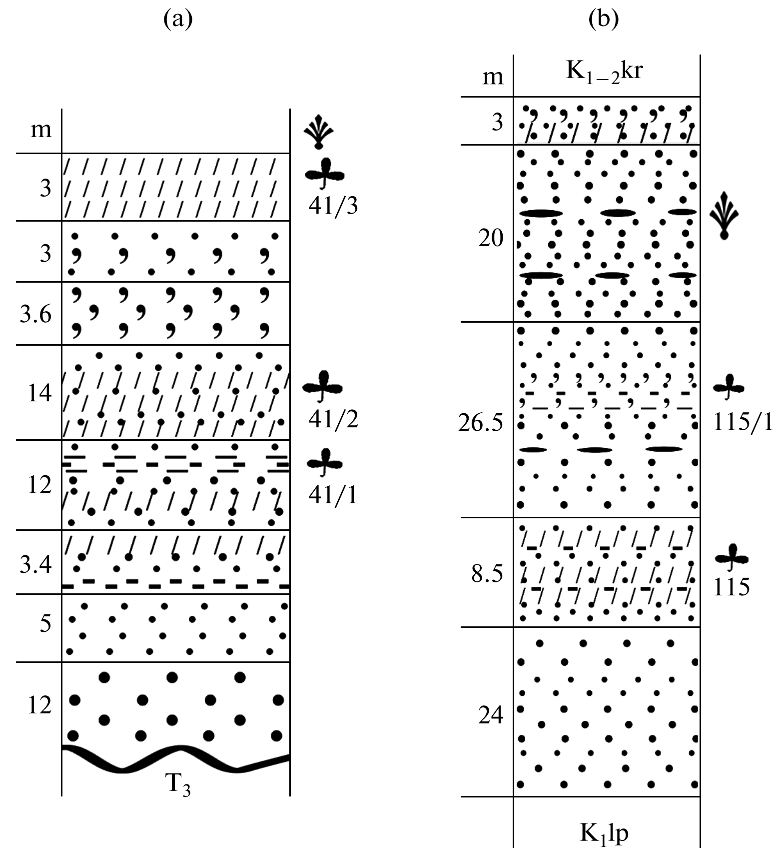

Fig. 4. Sections of the Galenki Formation along Dachnyi Creek (a) and on the Markovskii Peninsula (b) (Evlanov, 1962; Krassilov, 1967; Kutub-Zade et al., 2002; this work). For legend, see Fig. 2.

On the Markovskii Peninsula, the section of the Galenki Formation is composed of the following beds (Fig. 4):

(1) Cross-bedded coarse-grained sandstone with intercalations (1.0–1.5 m) of compact medium-grained sandstone. The thickness is 24.0 m.

(2) Medium-grained sandstone with intercalations of gray siltstones and carbonaceous mudstone containing plant remains *Equisetites* sp., *Osmunda* sp., *Anemia dicksoniana, Athrotaxopsis expansa*, and *Sequoia* ex gr. *reichenbachii* (Sample TV-115). The thickness is 8.5 m.

(3) Alternating inequigranular (coarse- to fine-grained) sandstones, conglomerates, compact tuffaceous siltstones, and thin (up to 0.4 m) carbonaceous mudstones with plant remains *Anemia dicksoniana, Coniopteris burejensis, Onychiopsis psilotoides, Adiantopteris sewardii, Cladophlebis* sp., *Nilssonia* ex gr. *brongniartii*, *Ginkgo pluripartita, Athrotaxopsis expansa, Sequoia* ex gr. *reichenbachii, Elatides asiatica*, and others (Sample TV-115/1; observation point 60 in (Krassilov, 1967)). The thickness is 26.5 m.

(4) Coarse-grained sandstone varieties with two conglomerate intercalations (1.0 m), plant detritus, and fragments of mineralized wood. The thickness is 20.0 m.

(5) Alternating compact fine- and medium-grained tuffstones with fractured silicified siltstones. The thickness is 3.0 m.

The integral apparent thickness of the section is 82.0 m.

It should be noted that the section cropping out on the Markovskii Peninsula corresponds to layers 1–8 in the section described in (Krassilov, 1967), while layer 9 begins the section of the Korkino Group.

The **Korkino Group ($K_{1-2}kr$)** is spread on the shore of Amur Bay from Cape Markovskii in the south (Sokol Bay) to the Saperka River basin (Uglovoe settlement) in the north (Fig. 1). It rests conformably on the Galenki Formation, being composed of conglomerates, sandstones, siltstones, and mudstones with spotty (figured) cherry and reddish brown coloration (Evlanov, 1962; Krassilov, 1967).

The sections of this group are thoroughly examined on Capes Markovskii and Spornyi and in the lower reaches of the Peschanka River (Kutub-Zade et al., 2002; Volynets, 2009, 2013). In these sections, the group is subdivided into two sequences: lower, composed mostly of conglomerates and sandstones (layers 1 and 2 in the above section), and upper, repre-

Table 3. Taxonomic composition of the Galenki floral assemblage

Taxon / Locality	115, 115/1	41	Krassilov, 1967
Lycopodiales			
Lycopodites prynadae Krassilov		*	
Lycopodites nicanicus Krassilov		*	
Equisetales			
Equisetites sp.	*		*
Filicales			
Osmunda sp.		*	
Ruffordia goeppertii (Dunk.) Seward		*	
Anemia dicksoniana (Heer) Krassilov	*	*	
Anemia sp.		*	
Gleichenites cf. *gieseckianus* (Heer) Seward		*	
Dicksonia concinna Heer		*	
Coniopteris (Dicksonia) *burejensis* (Zal.) Seward	*		*
Coniopteris ex gr. *arctica* (Pryn.) Samylina		*	
Coniopteris sp.	*		
Birisia onychioides (Vassilevsk. et Kara-Mursa) Samylina		*	
Onychiopsis psilotoides (Stok. et Webb) Ward	*		*
Adiantopteris yuasensis (Yok.) Krassilov		*	
Adiantopteris sewardii (Yabe) Vassilevskaya	*		*
Lobifolia novopokrovskii (Pryn.) Rasskaz. et E. Lebedev			*
Cladophlebis sp.	*		*
Bennettitales			
Neozamites denticulatus (Krysht. et Pryn.) Vachrameev		*	
Neozamites sp.		*	
Cycadites sulcatus Krysht. et Prynada			*
Cycadales			
Nilssonia densinervis (Font.) Berry		*	
Nilssonia ex gr. *brongniartii* (Mant.) Dunker	*		
Ginkgoales			
Ginkgo pluripartita (Schimp.) Heer	*		*
Coniferales			
Podozamites ex gr. *lanceolatus* (Lindl. et Hutt.) Schenk		*	
Podozamites sp.	*		
Pityophyllum sp.	*	*	
Pityospermum prynadae Krassilov			*
Taxites sp.		*	
Elatides asiatica (Yok.) Krassilov	*	*	*
Sequoia ex gr. *reichenbachii* (Gein.) Heer	*	*	
Athrotaxopsis expansa Font. emend. Berry	*	*	
Elatocladus sp.	*		
Angiospermae			
Sapindopsis variabilis Fontaine		*	
Sapindopsis sp.		*	
Menispermites sp.		*	
Dicotylophyllum sp.		*	

sented by siltstones and figured mudstones (layers 3–5; Fig. 5).

On the Markovskii Peninsula (Cape Markovskii) and in the Peschanka River Basin, yellowish tuffites of the Galenki Formation are conformably (without apparent erosion) overlain by the following succession (Fig. 5, Table 4).

(1) Small- to medium-pebbled conglomerate with rare intercalations (0.2–0.4 m) of dark gray sandy siltstones with plant remains: *Onychiopsis psilotoides, Nilssonia* ex gr. *orientalis, Podozamites* sp., *Elatides asiatica, Athrotaxopsis expansa* (specimen TV-116). Previously, Krassilov (1967) found in this layer *Coniopteris burejensis, Onychiopsis psilotoides, Cladophlebis* sp., *Podozamites* sp., *Pityophyllum* sp., *Pityospermum prynadae, Taxites brevifolius, Elatides asiatica, Elatocladus obtusifolius, Hudropterangium* sp. A, and *Carpolithes* sp. The thickness is 54.0 m.

(2) Alternating fine- and medium-grained sandstones with intercalations of sandy siltstones, which yielded remains of *Equisetites* sp., *Anemia dicksoniana, Coniopteris burejensis, Onychiopsis psilotoides, Cladophlebis* sp., *Podozamites* ex gr. *lanceolatus, Pityophillum* sp., *Pityospermum prynadae, Taxites brevifolius, Elatides asiatica, Athrotaxopsis expansa, Sequoia* ex gr. *reichenbachii, Elatocladus obtusifolius, Brachyphyllum* sp., *Hudropterangium* sp., and *Carpolithes* sp. (specimen TV-44) and intercalations of compact gray limonitized siltstones with phytofossils *Gleichenites* aff. *porsildii, Anemia dicksoniana, Birisia onychiodes, Nilssonia* ex gr. *orientalis, Elatides asiatica, Athrotaxopsis expansa*, and *Sequoia reichenbachii* (specimen TV-116a). The thickness is 52.0 m.

(3) Rhythmically alternating small- to medium-pebbled conglomerates, siltstones, and gray and reddish brown mudstones. The thickness s is 45.0 m.

(4) Small- and medium-pebbled conglomerates. The thickness is 15.0 m.

(5) Alternating fine-grained sandstones and siltstones, coaly mudstones, and figured cherry, chocolate, and gray mudstones with impressions of *Equisetites* sp., *Osmunda* sp., *Gleichenites* sp., *Cladophlebis* sp., *Sphenopteris* sp., *Podozamites* sp., *Parataxodium* sp. 1, *Parataxodium* sp. 2, *Sapindopsis* sp., *Platanophyllum* sp., *Platanophyllum* sp. 1, *Platanophyllum* sp. 2, *Dicotylophyllum* sp., and *Carpolithes* sp. (specimen TV-42). The thickness is 24.0 m.

The total thickness of the section is 190.0 m.

The lower part of the Korkino Group cropping out in the Cape Spornyi area is composed of small- to medium-pebbled conglomerates with lenses of dark gray siltstones, which contain plant remains and fragments of mineralized wood. At observation points TV-38, 39, and 39/1, collected *Anemia dicksoniana, Arctopteris* sp., *Nilssonia* ex gr. *brongniartii, N.* ex gr. *orientalis, Podozamites* ex gr. *lanceolatus, P. tenuinervis, Pseudolarix dorofeevii, Taxites brevifolius*, and *Elatides asiatica*. At observation point TV-40, they yielded *Anemia dicksoniana, Dicksonia concinna, Elatides asiatica*, and *Carpolithes* sp. (Table 4).

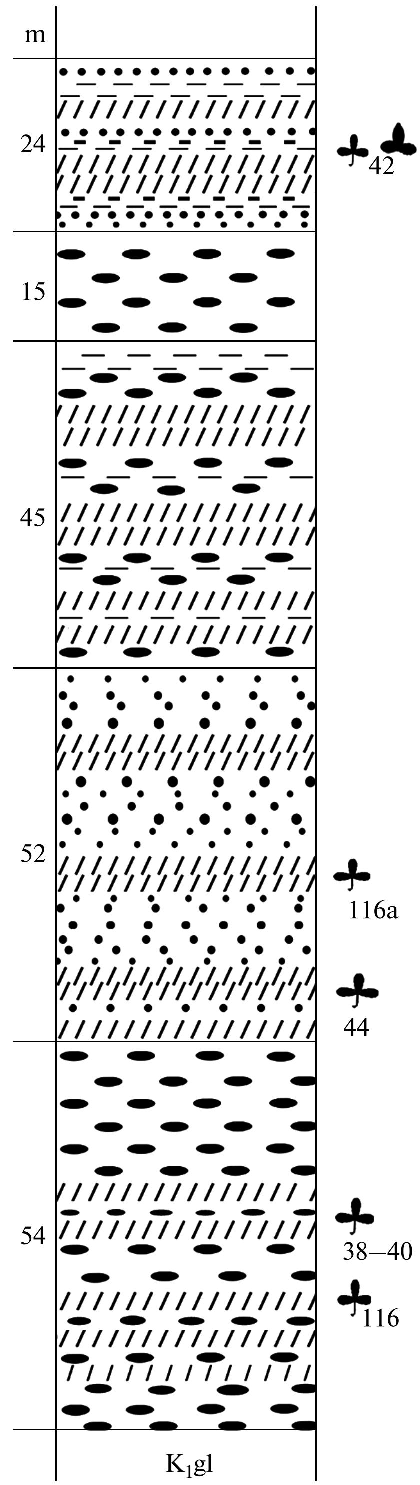

Fig. 5. Section of the Korkino Group in the Podgorodnenka Depression (Evlanov, 1962; Krassilov, 1967; Kutub-Zade et al., 2002; this work). For legend, see Fig. 2.

Table 4. Taxonomic composition of the Korkino floral assemblage

Taxon \ Locality	116, 116a	38, 39, 39/1	40	44	Krassilov, 1967	42
	early SA					late SA
Equisetales						
Equisetites sp.				*		*
Filicales						
Osmunda sp.						*
Gleichenites aff. *porsildii* Seward	*					
Gleichenites sp.	*					*
Anemia dicksoniana (Heer) Krassilov	*	*	*	*		
Birisia onychioides (Vassilevask. et Kara-Mursa) Samylina	*					
Coniopteris burejensis (Zal.) Seward	*			*	*	
Onychiopsis psilotoides (Stok. et Webb) Ward				*	*	
Dicksonia concinna Heer			*			
Arctopteris sp.		*				
Cladophlebis sp.				*	*	*
Sphenopteris sp.						*
Cycadales						
Nilssonia ex gr. *orientalis* Heer	*	*				
Nilssonia ex gr. *brongniartii* (Mant.) Dunker		*				
Coniferales						
Podozamites ex gr. *lanceolatus* (Lindl. et Hutt.) Schenk		*		*		
Podozamites tenuinervis Heer		*				
Podozamites sp.					*	*
Pityophyllum sp.				*	*	
Pityospermum prynadae Krassilov				*	*	
Pseudolarix dorofeevii Samylina		*				
Parataxodium sp. 1						*
Taxites sp. 1						*
Taxites brevifolius (Font.) Samylina		*		*	*	
Elatides asiatica (Yok.) Krassilov	*	*	*	*	*	
Athrotaxopsis expansa Fontaine emend. Berry	*			*		
Sequoia reichenbachii (Gein.) Heer	*			*	*	
Elatocladus obtusifolius Oishi		*		*	*	
Brachyphyllum sp.				*		
Angiospermae						
Sapindopsis sp.						*
Platanophyllum sp.						*
Platanophyllum sp. 1						*
Platanophyllum sp. 2 + *Platanophyllum* sp. 3						*
Dicotylophyllum sp. + *Dicotylophyllum* sp. 1						*
Plants Incertae sedis						
Hydropterangium sp. A				*	*	
Carpolithes sp.			*	*	*	*

CRETACEOUS FLORAL ASSEMBLAGES OF THE MURAVYOV-AMURSKII PENINSULA AND THEIR AGES

The **Ussuri floral assemblage** originates from the synonymous formation. It includes 35 taxa, among which ferns and conifers are most diverse (Table 1). The first group includes 13 taxa: *Gleichenites* sp., *Coniopteris (Dicksonia) burejensis, Onychiopsis psilotoides, Ruffordia goeppertii, Adiantopteris yuasensis, A. sewardii, Polypodites ussuriensis, Acrostichopteris pluripartita, Lobifolia novopokrovskii, Teilhardia tenella, Cladophlebis denticulata, Cladophlebis* sp. Of them, the most abundant species are *Coniopteris (Dicksonia) burejensis, Onychiopsis psilotoides*, and *Adiantopteris yuasensis*, while other forms are rare. Conifers are represented by *Podozamites* ex gr. *lanceolatus, P. tenuinervis, Podocarpus nicanicus, Pseudolarix dorofeevii, Elatides asiatica, Brachyphyllum* sp., *Cyparissidium gracile, Pagiophyllum orientalis*, and others with *Podozamites tenuinervis* and *Pseudolarix dorofeevii* being most abundant.

The assemblage includes rare Cycadales (*Nilssonopteris* sp., *Nilssonia* ex gr. *orientalis*), Ginkgoales (*Ginkgo* sp., *Pseudotorellia* sp.), Lycopodiales (*Lycopodites prynadae, Lycopodites* sp.), and Equisetales (*Neocalamites* cf. *nathorstii*). There are single Bryophyta (*Marchantites* cf. *yabei*), Caytoniales (*Sagenopteris* sp.), and plants of unclear taxonomic position (*Carpolithes* sp.).

The characteristic feature of the assemblage is the presence of the conifer form *Elatides asiatica*, which was widespread in Lipovtsy time (Volynets, 2013), in addition to typical Early Cretaceous taxa.

The Ussuri floral assemblage is accepted to be the Barremian in age (Fig. 6) on the basis of its taxonomic similarity to the synonymous assemblage from the central part of the Razdolnaya Basin (Krassilov, 1967; *Resheniya...*, 1994; Volynets, 2009). Both of these assemblages include *Coniopteris (Dicksonia) burejensis, Onychiopsis psilotoides, Adiantopteris yuasensis, A. sewardii*, and *Polypodites ussuriensis* among ferns and permanently occurring *Elatides asiatica* among conifers. The palynological data also indicate Barremian age of the assemblage under consideration (Markevich, 1995). By its taxonomic composition, the Ussuri Assemblage is also similar to the early Suchan floral assemblage from the Partizansk Coal Field Basin basin of Primorye (Oleinikov et al., 1990; Volynets, 1998). The species in common for them are *Elatides asiatica* (conifers), *Coniopteris (Dicksonia) burejensis, Onychiopsis psilotoides, Adiantopteris* sp. (ferns), and *Nilssonia* ex gr. *orientalis* (cycadophytes).

The **Lipovtsy floral assemblage** is named after the synonymous formation. It includes 102 taxa (Table 2). The assemblage is characterized by the high share of ferns (29 taxa) with *Alsophillites nipponensis, Cladophlebis frigida*, and *Lobifolia novopokrovskii* being the most abundant. They are accompanied by subordinate *Nathorstia pectinata, Dicksonia concinna, "Polypodites" polysorus*, and *Cladophlebis denticulata*; more rarely, *Osmunda denticulata, Osmunda* sp., *Coniopteris (Dicksonia) burejensis, Ruffordia goeppertii, Birisia onychioides, Adiantopteris yuasensis, Arctopteris* aff. *kolymensis*, and *Teilhardia tenella*, are received; and single *Ruffordia* sp., *Gleichenites* sp., *Coniopteris* sp., *Asplenium samylinae, Hausmannia* sp. 1, *Arctopteris* sp., *Cladophlebis opposita, C. virginiensis, Cladophlebis* sp., and *Sphenopteris* sp. are found.

Conifers (27 taxa) are mostly represented by *Podozamites* ex gr. *lanceolatus, P. tenuinervis, Elatides asiatica*, and *Athrotaxopsis expansa*, accompanied by common *Pityophyllum* ex gr. *nordenskoldii* and *Sequoia* ex gr. *reichenbachii*; rare *Podozamites* sp., *Pseudolarix dorofeevii, Pityophyllum* sp., *Torreya nicanica, Taxites brevifolius, Taxites* sp., *Elatides* sp., *Sequoia* sp., *Elatocladus* sp., and *Brachyphyllum* ex gr. *obesum*, are received, as well as single *Podozamites angustifolius, P. subreinii, Araucariodendron* cf. *heterophyllum, Araucariodendron* sp., *Podocarpus* sp., *Pityolepis* sp., *Pityospermum* sp., *Athrotaxites berryi, Brachyphyllum japonicum*, and *Brachyphyllum* sp.

The significant role in the assemblage belongs to cycadophytes (20 taxa), which are represented in equal proportions (10 taxa each) by Bennettitales and Cycadales. The first group includes abundant *Pterophyllum burejense* and *Cycadites sulcatus*, accompanied by common *Pterophyllum sutschanense* and single *Dictyozamites cordatus, D. reniformis, Pterophyllum manchurense, Nilssoniopteris* sp., *Williamsonia pacifica, W.* cf. *pacifica*, and *Cladophlebis* sp. Among Cycadales plants, the leading role belongs to *Nilssonia densinervis, N.* ex gr. *brongniartii*, and *N.* ex gr. *orientalis*, accompanied by subordinate *Ctenis* sp. *Pseudoctenis eathiensis, Nilssonia mediana, N. nicanica, N. prynadii, Nilssoniocladus anatolii*, and *Taeniopteris kryshtofovichii*.

The Lipovtsy Assemblage includes also diverse Lycopodiales (*Lycopodites nicanicus, L. nosikovii, L. obatus, L. prynadae, L. ussuriensis*, and others), Caytoniales (*Sagenopteris mantellii, S. petiolata, S. variabilis, Sagenopteris* sp.), and Ginkgoales (*Ginkgo* ex gr. *adiantoides, G. concinna, G. pluripartita, Ginkgo* sp.). The plants of unclear taxonomic belonging are represented by *Carpolithes* sp., *Coniferites* sp., *Hydropterangium* sp., *Ctenozamites* sp., and *Zamiopsis insignis*. Equisetales and Bryophyta are rare and Czekanowskiales (*Czekanowskia* ex gr. *rigida*) are single (Table 3).

The unique feature of this assemblage is the highest taxonomic diversity and appearance of evolutionary advanced "young" plants such as *Osmunda denticulata, Birisia onychioides, Arctopteris* aff. *kolymensis, Sequoia* ex gr. *reichenbachii*, and *Taxites brevifolius* (Volynets, 2013).

The Lipovtsy floral assemblage is estimated to be the Aptian–earliest Early Albian in age (Fig. 6) on the basis of its taxonomic similarity to the synonymous

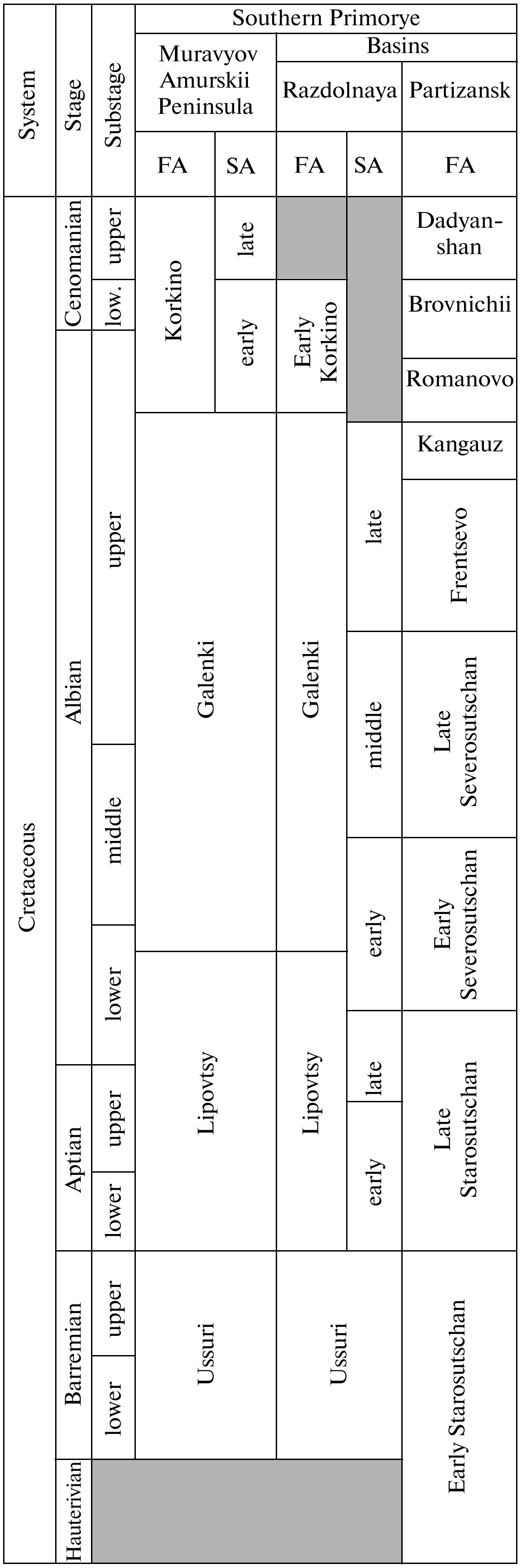

Fig. 6. Correlation of Cretaceous floral assemblages in southern Primorye. (FA) floral assemblage; (SA) subassemblage.

assemblage from the Razdolnaya Basin (Volynets, 2005, 2006, 2009, 2011; Bugdaeva et al., 2006; Volynets and Markevich, 2013). Both of them include Early Cretaceous *Nathorstia pectinata, Coniopteris burejensis, Dictyozamites cordatus* (Krysht.) Pryn., *Cycadites sulcatus*, *Torreya nicanica*, and others and abundant "young" advanced taxa: *Osmunda denticulata, Birisia onychioides, Arctopteris* aff. *kolymensis, Sequoia* ex gr. *reichenbachii*, and *Taxites brevifolius.* The Lipovtsy Assemblage exhibits also some similarity to the late Starosuchan floral assemblage from the Partizansk Basin (Fig. 6), which is dated back to the Aptian–earliest Early Albian (Volynets, 2005, 2006, 2011). According to V.S. Markevich, the early Albian age of the upper part of the Starosutschan Formation is supported by the "appearance of such a young (Albian) palynological spectrum" with the first angiosperms (Oleinikov et al., 1990).

The **Galenki floral assemblage** originates from the synonymous formation. The assemblage numbers 37 taxa (Table 3). The most abundant group in this assemblage is represented by ferns (14 taxa) dominated by *Anemia dicksoniana, Birisia onychioides*, and *Lobifolia novopokrovskii.* They are usually accompanied by common *Onychiopsis psilotoides*; rare *Ruffordia goeppertii, Coniopteris arctica, C. burejensis*, and *Adiantopteris yuasenensis*; and single *Osmunda* sp., *Anemia* sp., *Gleichenites* cf. *gieseckianus, Dicksonia concinna, Coniopteris* sp., and *Adiantopteris sewardii.*

Conifers (11 taxa) include abundant *Podozamites* ex gr. *lanceolatus, Elatides asiatica*, and *Sequoia* ex gr. *reichenbachii*; rare *Athrotaxopsis expansa, Taxites* sp., and *Pityophyllum* sp.; and single *Pityospermum prynadae*, *Elatocladus obtusifolius*, and others.

Cycadophytes are represented by five species belonging to the genera *Neozamites, Cycadites*, and *Nilssonia.* They are dominated by *Nilssonoia densinervis* and *N.* ex gr. *brongniartii*, accompanied by rare *Neozamites denticulatus* and *Cycadites sulcatus.*

Ginkgo pluripartita, Lycopodites nicanicus, L. prynadae, and *Equsetites* sp. occur as single specimens.

The first appearing angiosperms are extremely rare, being represented by *Sapindopsis* sp., *S. variabilis, Menispermites* sp., and *Dicotylophyllum* sp. (Table 3).

The peculiar feature of this assemblage is its reduced taxonomic diversity, the increased share of evolutionarily advanced species (such as *Anemia dicksoniana, Birisia onychioides*, and *Sequoia* ex gr. *reichenbachii*), and the appearance of angiosperms (Volynets, 2013; Volynets and Markevich, 2013).

On the basis of the significant role of evolutionarily advanced taxa and the appearance of angiosperms, the Galenki floral assemblage of the Muravyov-Amurskii

Peninsula is correlated with the middle and upper Galenki Subassemblages from the central part of the Razdolnaya basin of Primorye (Fig. 6), which are attributed to the upper half of the Albian Stage (Volynets, 2006, 2009, 2011; Bugdaeva et al., 2006). In the Partizansk Basin, this stratigraphic level is characterized by two floral assemblages which also include the first angiosperms: late Severosutschan and Frentsevo (Volynets, 2006, 2009). The age of the Frentsevo Assemblage is controlled by marine mollusks (Markevich et al., 2000; Volynets, 2006). V.P. Konovalov, who investigated the mollusk remains, considers them to be the middle Albian in age (Konovalov and Mirolyubov, 1978; Markevich et al., 2000).

The **Korkino floral assemblage** is named after the host group. The heterogeneous taxonomic composition of this assemblage provides grounds for its subdivision into two subassemblages: early and late (Table 4).

The early subassemblage of the Korkino floral assemblage is defined in the lower part of the Korkino Group section (Table 4). It is dominated by conifers (11 taxa), which are accompanied by subordinate ferns (nine taxa), single cycadophytes (two taxa), and plants of unknown taxonomic position (two taxa).

Conifers include abundant *Elatides asiatica* and *Elatocladus obtusifolius*; common *Sequoia* ex gr. *reichenbachii* and *Podozamites* ex gr. *lanceolatus*; rare *Podozamites tenuinervis, Taxites brevifolius, Athrotaxopsis expansa*, and *Brachyphyllum* sp.; and single *Pityophyllum* sp., *Pityospermum prynadae*, and *Pseudolarix dorofeevii.*

Ferns are less diverse with *Gleichenites* aff. *porsildii* and *Anemia dicksoniana* being the most abundant; accompanying species (*Osmunda* sp., *Arctopteris* sp., *Birisia onychioides, Dicksonia concinna*, and others) are extremely rare (Table 4).

The share of cycadophytes in this subassemblage represented by *Nilssonia* ex gr. *brongniartii* and *N.* ex gr. *orientalis* is low.

The specific feature of the subassemblage is the dominant role of conifers against the background of its generally reduced diversity.

By its species composition, this subassemblage is close to the floral assemblage from the terminal Albian strata of Primorye. The corresponding period was marked by a significant decrease in the taxonomic diversity of plant communities (Volynets, 2005, 2011; Bugdaeva et al., 2006).

The late subassemblage of the Korkino floral assemblage originates from the member of siltstones and mudstones in the upper part of the host group. It has a low diversity (16 taxa), dominated by angiosperms (7 taxa), which include relatively abundant *Dictyophyllum* sp., common *Platanophyllum* spp., and rare *Sapindopsis* sp.

Ferns are represented by rare *Osmunda* sp., *Gleichenites* sp., *Anemia dicksoniana* and *Sphenopteris* sp.

Conifers include *Podozamites* sp., *Parataxodium* sp. 1, and *Taxites* sp. 1 with *Paratoxodium* sp. 1 being the most abundant.

Equisetites sp. and *Carpolithes* sp. seeds are rare (Table 4).

The characteristic feature of the subassemblage is the dominant role of angiosperms with diverse taxa of platanaceous type (Volynets, 2013).

V.S. Markevich identified in the upper part of the Korkino Group the late Cenomanian palynological assemblage (Volynets and Markevich, 2013). In Primorye, all the late Cenomanian assemblages are characterized by the dominant role and high diversity of angiosperms with an insignificant share of all other plant groups (Bugdaeva et al., 2006; Volynets, 2011, 2013).

CONCLUSIONS

The presented data allow the following inferences:

(1) In the lower reaches of the Bogataya River, the Ussuri Formations begins with a member of fine-grained sandstones and siltstones.

(2) Beds 11–14 in the reference section of the Ussuri Formation in Brazhnikov Bay of the Markovskii Peninsula (Krassilov, 1967) contain remains of Late Triassic plants.

(3) In Brazhnikov Bay, the Lipovtsy Formation, which was previously thought to overlie conformably the Ussuri Formation (Krassilov, 1967; Kutub-Zade et al., 2002), overlies unconformably the Upper Triassic strata.

(4) Bed 9 of the Galenki Formation section on the Markovskii Peninsula (Krassilov, 1967) is represented by thick inequipebbled conglomerates, which begin a basal rhythm of the Korkino Group.

(5) The section of the Korkino Group consists of two members: the lower one (Beds 1 and 2) is largely composed of conglomerates and sandstones and the upper one (Beds 3–5) is represented by siltstones and figured mudstones.

(6) The section along the Peschanka River which includes the sequence of Barremian to Cenomanian is proposed to represent a reference one for Cretaceous deposits of the Muravyov-Amurskii Peninsula.

(7) The thorough analysis of the taxonomic composition of floral assemblages from the Ussuri, Lipovtsy, and Ussuri formations of the Muravyov-Amurskii Peninsula reveals that the Ussuri floral assemblage is dominated by ferns and conifers; in the Lipovtsy Assemblage, which is characterized by the maximum diversity, the main role belongs to ferns, conifers, and cycadophytes; the Galenki Assemblage is marked by the first appearance of angiosperms against the background of the dominant function of ferns and conifers.

(8) The first studied floral assemblage from the Korkino Group of the Razdolnaya basin is dates from the late Albian–late Cenomanian.

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