Geol. of Pac. Ocean, 2000, Vol. 15, pp. 547-566
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Grebenka Floral Assemblage in the Anadyr River Basin (Chukotka)

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Received June 21, 1997

The Grebenka floral assemblage on the right bank of the Anadyr River (Krivorechenskaya suite) is divided into lower and upper subassemblages. The lower subassemblage originates from the deposits on the Malaya Grebenka, Srednyaya Orlovka and Berezovaya Rivers. Its age is determined as Late Albian-beginning of the Early Cenomanian from the copresence (Malaya Grebenka) of floral and faunal remains. The upper subassemblage of the Grebenka assemblage originates from the deposits along the Grebenka (Eliseevskoe outcrop), Chukotskaya and Bystraya Rivers (right bank of Anadyr River) and Krivaya and Vetvistaya Rivers, right tributaries of the Ubienka River (left bank of Anadyr River).The age of the upper subassemblage is dated as Cenomanian, possibly Cenomanian-beginning of Early Turonian, on the basis of conformable coverage of the flora-bearing layers of the Krivorechenskaya suite by marine sediments of the Dugovskaya suite with Turonian fauna.

The continental and coastal marine deposits assigned to the Krivorechenskaya suite are traced in the form of a narrow band along the northwestern side of the Penzhina downwarp from the headwaters of the Levaya Berezovaya River (a right-hand tributary of the Penzhina River) in the south to the headwaters of the Ubienka River (a left-hand tributary of the Anadyr River) in the north.

In this area flora-bearing layers were discovered for the first time by B. N. Eliseev. Along the Grebenka River, a right-hand tributary of the Anadyr River, he described conglomerate and sandy-shaly deposits with a flora of *Asplenium jonstrupii* Heer, *Cladophlebis jelisejevii* Krysht., *C. oerstedtii* (Heer) Sew., *Nilssonia serotina* Heer, *Pseudocycas hyperbora* Krysht., *Gingko laramiensis* Ward, *Araucarites anadyrensis* Krysht., *Populus minuta* Krysht., *Menispermites septentrionalis* Holl., *Platanus* cf. *coloradensis Knowlt., Celastrus* sp., *Ampelopsis* cf. *meltesima* Holl., *Viburnum anadyrensis* Krysht.

A. N. Kryshtofovich [8] determined the age of the fossil flora as Late Cretaceous, no younger than Early Senonian.

In 1958 G. P. Terekhova, on the left bank of the Anadyr River, in the Ubienka River basin, divided the Cretaceous deposits into two series — Gilyatskaya (continental) and Orochenskaya (marine). In the rocks of Gilyatskaya series she collected plant remains of *Onychiopsis* cf. *psilotoides* (S. et W.) Ward, *Cladophlebis jelisejevii* Krysht., *C.* cf. *septentrionalis* Holl., *M.* cf. *reniformis* Daws., *C.* cf. *arctica* (Heer) Krysht., *Asplenium dicksonianum* Heer, *Sphenopteris* sp., *Pseudocycas hyperborea* Krysht., *Ginkgo* ex gr. *adiantoides* (Ung.) Heer, *Cephalotaxopsis heterophylla* Holl., *C. intermedia* Holl., *Sequoia heterophylla* Velen., *S. ambigua* Heer, *Torreya gracillima* Holl., *Podozamites lanceolatus* (L. et H.) Braun, *Corylus* cf. *jelisejevii* Krysht., *Menispermites septentrionalis* Holl., *M.* cf. *reniformis* Daws., *Trochodendroides* cf. *arctica* (Heer) Berry, *T. richardsonii* (Heer) Krysht., *Rulac quercifolium* Holl., *Viburnum anadyrensis* Krysht., *Magnolia amplifolia* Heer, *Rhamnus* cf. *septentrionalis* Krysht., and others, as concluded by A. F. Efimova, corresponding to the Cenomanian-Turonian or Turonian.

In 1962, during preparation of a legend for the Anadyr series of sheets of the State Geological Map at 1:200,000, G. G. Kaigorodtsev discriminated continental formations in the Krivorechenskaya suite with a stratotype on the Krivaya River (a right tributary of the Ubienka River), whereas the upward-lying marine deposits were assigned to the Dugovskaya suite.

The geological structure of the right bank of the Anadyr River was studied by V. G. Gavrilov, I. P. Vasetskiy, V. F. Belyi, V. V. Zavrazhnov and E. B. Nevretdinov. According to data from these researchers, the Krivoreychenskaya suite with erosion and angular unconformity lies on Valanginian and Hauterivian deposits and is covered conformably by the Upper Cretaceous. On the basis of lithological criteria it is divided into two subsuites: lower conglomerate and upper sandstone-conglomerate.

The lower subsuite (thickness 600 m) is made up of conglomerates with different pebble size and with thin interlayers of sandstones of various grain size; the upper subsuite (thickness 800-1,000 m) is made up of coarse-grained sandstones, siltstones and tuffites of an intermediate composition with a subordinate quantity of conglomerates.

The age of the plant remains collected by geologists in deposits of the Krivorechenskaya suite was determined by A. F. Efimova as Cenomanian-Turonian. This conclusion was accepted at the First Magadan Conference on the Development of Stratigraphic Schemes for the Northeastern USSR in 1959.

In 1964 E. B. Nevretdinov described the section of the Krivorechenskaya suite on the Bystraya River (right bank of Anadyr River) and collected floral remains of *Equisetites* sp., *Cladophlebis* sp., *Asplenium diksonianum* Heer, *Nilssonia serotina* Heer, *N. alaskana* Holl., *Nilssonia* sp., *Ginkgo adiantoides* (Ung.) Heer, *Cephalotaxopsis intermedia* Holl, *C. heterophylla* Holl., *C. magnifolia* Font., *Cephalotaxopsis* sp., *Sequoia reichenbachii* (Gein.) Heer, *S. concinna* Heer., *Sequoia* sp., *Menispermites septentrionalis* Holl., *M. reniformis* Daw., *Viburnum anadyrensis* Krysht., *Platanus* sp., *Protophyllum* sp., *Trochodendroides* cf. *arctica* (Heer) Berry, *Cissites* sp., *Sassafras* sp., *Rulac* cf. *quercifolium* Holl., *Dryophyllum* sp., *Phyllites* sp., *Phyllites* sp. 1, which, so concluded A. F. Efimova, can be dated to the Turonian-Cenomanian. This flora was reexamined in 1965 by V. A. Samylina and its Turonian-Senonian age was indicated. V. A. Vakhrameev [2], in analyzing the Grebenka floral assemblage, considers it to be Late Cenomanian or Turonian. Later V. A. Samylina [12], on the basis of an analysis of floral remains obtained as a

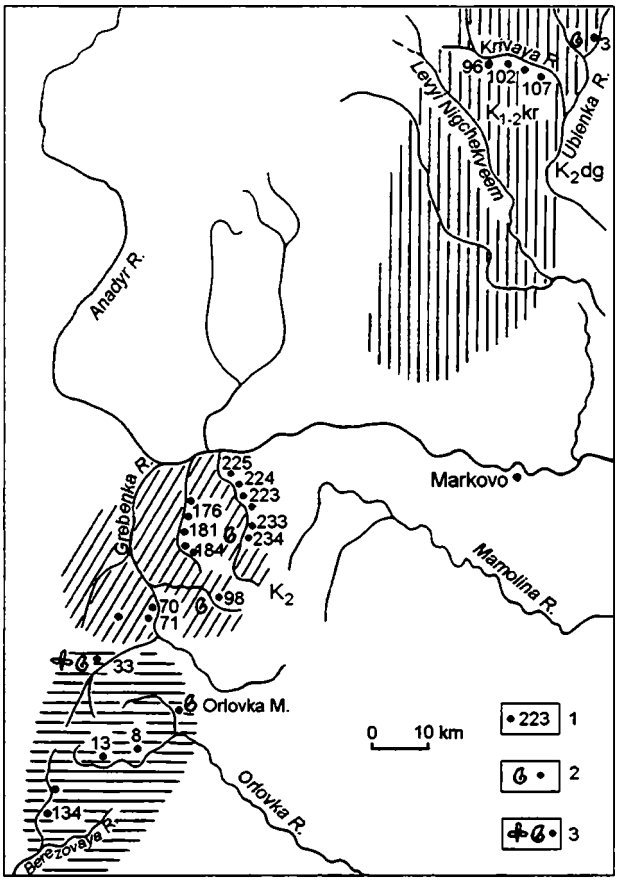


Fig. 1 Overview map of location of principal sections of Krivorechenskaya suite.

1 — with flora, 2 — with fauna, 3 — with flora and fauna. Exposures 8, 13 — Srednyaya Orlovka River; exposure 33 — Malaya Grebenka River; exposures 70, 71 — Grebenka River (Eliseevskoe exposure); exposure 234 — Bystraya River; exposure 98 — Gornaya River.

result of a preliminary determination of the collections and with allowance for the overlying layers with fauna, concluded that the Grebenka stratoflora has a Turonian age. At the Second Interdepartmental Stratigraphic Conference in Magadan these flora-bearing deposits were assigned to the Turonian, excluding the top [11].

In 1975 A.D.Devyatilova and G.G.Fillipova, in the course of stratigraphic research on the right bank of the Anadyr River, studied the Krivorechenskaya suite along the Grebenka, Chukotskaya and Bystraya Rivers and in the Srednyaya Orlovka region (see Fig. 1). A great assemblage of floral remains was collected in the deposits of the suite. Remnants of bivalves resembling *Inoceramus* ex gr. *nipponicus* (Nagao et Mat.) were found along the Malaya Grebenka River (exposure 33), together with plant imprints. Better-preserved fauna was found in the middle course of the Gornaya River (exposure 98) and at the headwaters of the Bystraya River (exposure 234), where marine layers cover deposits containing flora. In the presence of remnants of shells resembling *I. nipponicus*, the age of the Grebenka floral assemblage in its stratotypic region is determined as Cenomanian [6]. Later a high percentage of the taxons in the Grebenka assemblage was described in monograph [16].

With respect to lithology, the Krivorechenskaya suite on the right bank of the Anadyr River was divided by A. D. Devyatilova into three subsuites.

The Lower Krivorechenskaya subsuite, lying with an angular unconformity on the eroded surface of Upper Jurassic, Valanginian and Hauterivian deposits, is represented by conglomerates with lenses and strata having grains of different size, predominantly coarse-grained sandstones and rare interlayers of siltstones. The subsuite thickness is 500-600 m.

The Middle Krivorechenskaya subsuite is made up of conglomerates with small and large pebbles, sandstones and siltstones. The siltstones and sandstones contain numerous imprints of satisfactorily and well-preserved leaves; the subsuite thickness is 400-500 m.

The Upper Krivorechenskaya subsuite consists of sandstones and siltstones and has a three-layer structure.

Volcanomictic sandstones and siltstones, in which there are lenses and thin interlayers of small-pebble conglomerates and gravelites, predominate in the lower part with a thickness 100-110 m.

The middle part of the subsuite with a thickness 140-150 m is characterized by a flyschoid intercalation of sandstones and siltstones which contains conglomerate strata. Remains of coniferous and gingko species are encountered in siltstones.

The upper part with a thickness 130-150 m is represented by coarsely layered sandstones and gravelites with lenses and spherical segregations of

sandy-carbonate deposits. The thickness of the Upper Krivorechenskaya subsuite is 300-350 m. The thickness of the Krivorechenskaya suite is 1500 m E. B. Nevretdinov in 1974 and A. D. Devyatilova in 1976 studied the Krivorechenskaya suite on the left bank of the Anadyr River. In this region the suite is divided into the Lower and Upper Krivorechenskaya subsuites with a thickness 1600 m. The plant remains collected by them from the upper part of the suite supplemented the Grebenka floral assemblage [15].

In 1978 E. L. Lebedev, on the right bank of the Anadyr along the Grebenka and Bystraya, made a collection of fossil flora from the section of the Upper Krivorechenskaya subsuite. After analyzing the composition of the principal groups of plants of this collection, he concluded that there was a Late Cenomanian-Early Turonian age of the Grebenka assemblage [10].

In 1983, V. V. Lebedev, along the Malaya Grebenka River, in the lower part of the Upper Krivorechenskaya subsuite, additionally collected fauna (exposure 33) which, as concluded by G. P. Terekhova in [13], can be assigned to the top of the Albian-bottom of the Cenomanian (layers with *Neogastroplites* spp., *Marshallites columbianus*).

In 1988 S. V Shchepetov and A. B. German collected fauna and flora in deposits of the Krivorechenskaya suite along the Grebenka, Gornaya and Malaya Orlovka Rivers (at Orlovka). V. P. Pokhialainen concluded that the faunal remains from the section at Orlovka belong to the second half of the Cenomanian, possibly to some part of the Early Turonian (*Inoceramus nipponicus* zone). The plant remains from this section have been assigned by S. V. Shchepetov and A. B. German to the Grebenka floral assemblage [17].

G.P.Terekhova[13], in studying the principal faunal finds from both the upper part of the Krivorechenskaya suite and from the conformably overlying deposits of the Dugovskaya suite, concluded that the upper age limit of the Krivorechenskaya suite is a moving boundary. She feels that the upper age boundary and the Grebenka floral assemblage collected from it changes from the Late Albian on the right bank of the Anadyr River (Malaya Grebenka) to the Late Turonian on the left bank (Ubiyenka River basin).

On the basis of lithological criteria L. A. Ankudinov [1] divided the Krivorechenskaya suite into four subsuites. The first and second subsuites correspond to the Lower and Middle Krivorechenskaya subsuites defined by A. D. Devyatilova (Fig. 2).

The third subsuite, with a thickness up to 350 m, is made up of sandstones of marine origin, siltstones, mudstones with rare interlayers of gravelstones and conglomerates. Individual outcrops of these rocks were encountered along the Malaya Grebenka and Gornaya Rivers.

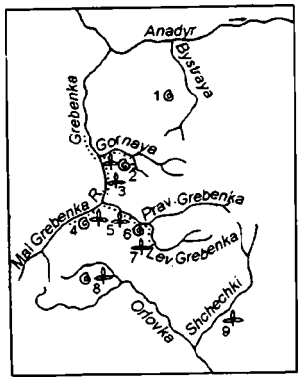
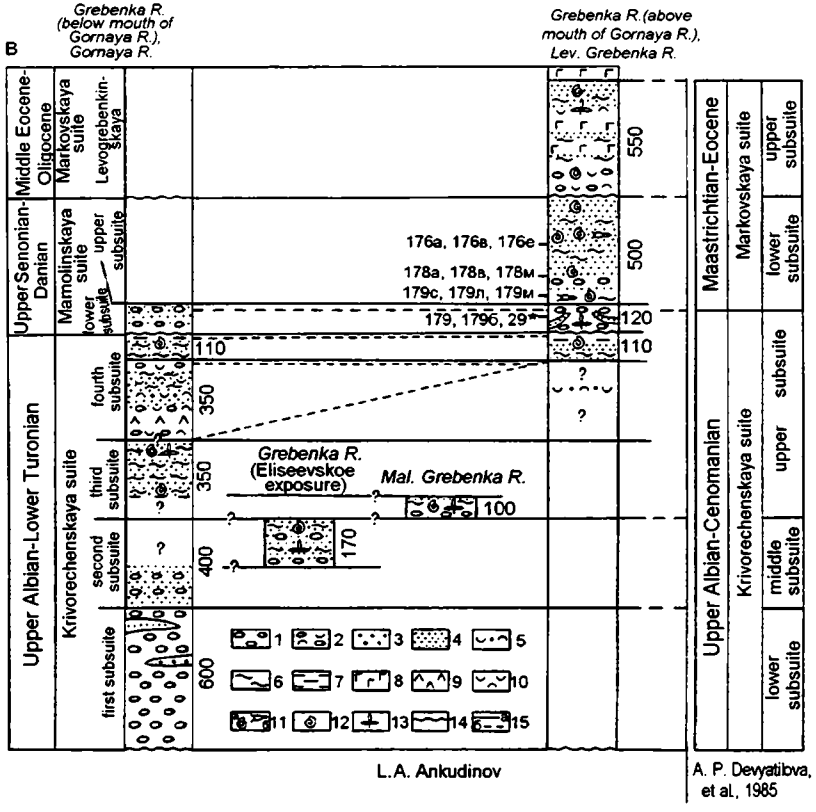


Fig. 2 Location of organic remains (A), sections and their correlations (B).

A. 1-9 (Figures — author and year of sampling): 1 — Devyatilova, 1975, Devyatilova, 1982, Shchepetov, 1988; 3 - Eliseev, 1933, and elsewhere; 4 — Lebedev, 1983; Shchepetov, 1990; 5, 6 — Ankudinov, 1984; 7 — Devyatilova, 1975; 8 — Devyatilova, 1982; 9 — Belyi, 1959 and elsewhere; dots — routes for construction of sections. B. 1 — conglomerates, 2 — tuff-conglomerates, 3 — gravelstones, 4 — sandstones, 5 — tephrogenic sandstones, 6 — siltstones, 7 — mudstones, 8 — basalts, 9 — andesibasalts, 10 — tuffs, 11 — mollusks (a), crustaceans (b), 12 — foraminifera, 13 — flora, 14 — unconformity, 15 — comparison of sections prepared by L. A. Ankudinov (a) and A. D. Devyatilova (b). The numbers of samples with pollen assemblages are marked by an asterisk.



On the Malaya Grebenka River L. A. Ankudinov assigns an isolated outcrop on the right bank (4 km from the mouth), made up of sandstones and siltstones with lenses and thin intercalations of conglomerates and gravelstones with a total thickness 100 m, in which V. V. Lebedev in 1983:(exposure 33) found faunal remains of Late Albian-Early Cenomanian age [13], to the bottom of the section of the third subsuite (according to A. D. Devyatilova, the lower part of the Upper Krivorechenskaya subsuite).

On the Gornaya River the third subsuite emerges 6 km from the mouth in the left slopes of the valley for a distance of 800 m (Fig. 2). Its rocks are represented by siltstones and mudstones, which are observed with considerable interruptions in small bedrock exposures and slides. Near the upper boundary of the subsuite A. D. Devyatilova and L. A. Ankudinov in 1982 found fauna assigned by G. P. Terekhova to the bottom of the Middle Cenomanian (layers with *Turrilites costatus).*

The fourth subsuite, according to data published by L. A. Ankudinov, is characterized by lithologically well-expressed two-layer structure. Predominantly continental rocks — tuff-conglomerates, tuffs, tuffites, tephrogenic sandstones and siltstones, basalts and andesibasalts developed in the lower part, whereas predominantly marine sedimentary rocks developed in the lower part (110 m): siltstones, mudstones, sandstones, rarely tephroid sandstones. Almost the entire section is traced on the left side of the Gornaya River (7 km from its mouth).

On the basis of paleontological finds in the section of the fourth subsuite its age, according to Ankudinov, can be dated as the Late Albian-Early Turonian.

A. D. Devyatilova assigns the volcanogenic-sedimentary and marine deposits of the fourth subsuite to the upper subsuite of the Krivorechenskaya suite and this is dated to the Late Albian-Cenomanian.

As indicated by an analysis of research carried out in the considered territory during different years, the Krivorechenskaya suite is made up of terrigenous continental and coastal-marine sedimentary deposits and can be divided into two subsuites on the left bank and into three or four subsuites on the right bank of the Anadyr River. It has been established that the composition of fossil plants in the section of the flora-bearing horizon and along its strike from southwest to northeast experiences no substantial changes and these plants have been regarded as a unified floral assemblage, called the Grebenka assemblage [14].

In 1995 the author reexamined collections of the Grebenka assemblage which are stored at the Sevvostokgeolkom. A repeated study of the fossil

plants from the sections of the flora-bearing horizon of the Krivorechenskaya suite on the right and left banks of the Anadyr River gives evidence that the floral remains collected in the southwestern sector of the suite in the deposits along the Berezovaya, Srednyaya Orlovka and Malaya Grebenka Rivers differ somewhat from those collected in the sections of the Grebenka, Chukotskaya, Bystraya and Ubienka Rivers (Table 1). The difference is in the composition of the ferns, holosperms and angiosperms.

In the Srednyaya Orlovka River basin A. D. Devyatilova in 1967 found *Equisetites* sp., *Asplenium dicksonianum* Heer, *Cladophlebis* aff. *williamsonii* (Brongn.) Brongn, *Desmiophyllum magnum* (Samyl.) Samyl., *Podozamites eichwaldii* Schimp., *P. lanceolatus* (L. et H.) Braun, *Cephalotaxopsis* cf. *intermedia* Holl., *Araucarites* sp., *Sequoia* sp., *Athrotaxopsis grandis* Font., which, as concluded by A. F. Efimova, can be dated as Aptian-Albian. In the construction of partial sections in this sector A. D. Devyatilova assigned the bottom of the suite with the enumerated taphoflora to the Upper Albian. Subsequent collections of plant remains from these deposits, as well as from the rocks along the Berezovaya and Malaya Grebenka Rivers considerably supplemented the plant listing (see Table 1). The most widely occurring groups of plants were ferns and conifers; cycadophytes and ginkgoes are less frequently

Table 1 Distribution of fossil plants of Grebenka assemblage on right and left banks of Anadyr river (Krivorechenskaya suite).

Fossil plants	Lower subassemblage			Upper subassemblage				
	Berezovaya R.	Srednyaya R. Orlovka R.	Malaya Grebenka R.	Grebenka R	Chukotskaya R.	Bystraya R.	Krivaya R.	Vetvistaya R.
1	2	3	4	5	6	7	8	9
Thallites sp.	-	+	-	+	-	-	-	-
Equisetites sp.	-	+	+	+	+	+	+	-
Gleichenites zippei (Corda) Sew.	+	+	+	+	+	+	+	+
Coniopteris grebencaensis Philipp.	-	+	+	+	+	+	+	-
C. anadyrensis Philipp.	-	-	+?	+	+	-	-	-
Coniopteris sp.	+	+	-	+	-	-	-	-
Asplenium dicksonianum Heer	+	+	+	+	+	+	+	+
A. rigidum Vassilevsk.	+	-	-	+	-	-	-	-
Hausmannia sp.	-	+	+	-	-	-	-	-

Table 1 (continued).

1	2	3	4	5	6	7	8	9
Birisia jelisejevii (Krysht.) Philipp.	+	+	+	+	+	-	+	+
Cladophlebis aff. *frigida* (Heer) Sew.	-	+	+	+	-	+	+	-
Cladophlebis sp.	-	+	-	+	-	-	+	-
Sphenopteris sp.	-	+	+	-	-	+	+	-
Arctopteris sp.	-	+	-	-	-	-	-	-
Sagenopteris variabilis (Velen.) Velen.	+	+	+	+	-	-	-	-
Pseudocycas (Cycas) hyperborea Krysht.	+	-	-	+	-	+	-	-
Nilssonia serotina Heer	+	+	+	+	+	-	+	+
N. yukonensis Holl.	+	+	-	+	-	+	-	-
N. alaskana Holl.	-	+	+	+	+	+	-	-
Taeniopteris sp.	+	+	+	-	+	-	-	-
Ginkgo ex gr. *adiantoides* (Ung.) Heer	+	+	+	+	+	+	+	+
G. ex gr. lepida Heer	+	-	+	+	-	-	+	-
G. ex gr. *huttonii* (Sternb.) Heer	+	+	+	+	+	+	-	-
Desmiophyllum sp.	-	+	+	-	-	+	-	-
Dammarites emarginatus Lesq.	-	+	-	+	+	-	-	-
Cephalotaxopsis (Taxites) intermedia Holl.	+	+	+	+	+	+	+	+
C. (Taxites) heterophylla Holl.	+	-	-	+	+	+	+	+
Elatocladus gracillimus (Heer) Sveshn.	-	+	+	-	-	-	-	-
Araucarites sp.	-	+	+	-	-	-	-	-
Sequoia fastigiata (Sternb.) Heer	-	+	-	+	+	+	-	-
Sequoia sp.	+	+	-	+	-	-	-	+
Pagiophyllum triangulare Pryn.	-	+	-	+	-	-	-	+
Florinia borealis Sveshn. et Budants.	-	+	+	+	-	-	-	+
Pityocladus sp.	+	+	-	+	+	-	+	-
Athrotaxopsis grandis Font.	-	+	-	+	-	-	-	-
Pityophyllum nordenskioldii (Heer) Nath.	+	+	+	+	+	+	+	-
Podozamites lanceolatus (L. et H.) F. Braun	-	+	-	-	+	+	+	+
Cedrus sp. - scale	+	+	+	+	+	+	+	-
Menispermites aff. *septentrionalis* Holl.	+	+	+	+	+	+	+	+
Grebenkia kryshtofovichii E. Lebed.	+	-	+	+	+	+	+	+

Table 1 (continued).

1	2	3	4	5	6	7	8	9
Sorbites sp. - Small leaves	-	+	+	-	-	-	-	-
Leguminosites sp. - Small leaves	-	+	+	-	+	+	-	+
Lindera (?) media Philipp.	-	+	+	+	+	+	-	-
Celastrophyllum latifolium Font.	+	+	+	-	+	+	+	-
Thallites arctica Philipp.				+	-	+	-	-
Osmunda sp.				+	+	-	+	-
Gleichenites asiatica Philipp.				-	+	+	-	-
G. microphylla Philipp.				-	-	-	+	-
Sphenopteris sp.1				-	-	-	+	-
Hausmannia bipartita Samyl. et Shczep.				+	+	-	-	-
Birisia (?) oerstedtii (Heer) E.Lebed.				+	-	-	+	-
Cladophlebis vakrija Philipp.				+	+	-	+	-
Cl. ubiencaensis Philipp.				+	-	-	+	-
Cladophlebis sp.1				+	+	-	+	-
Arctopteris penzhinensis E. Lebed.				+	-	-	+	-
Nilssoniocladus sp.				+	-	-	-	-
Sphenobaiera vera Samyl. et Shczep.				+	+	-	+	+
Sphenobaiera aff. *flabellata* Vassilevsk.				-	+	-	+	-
Phoenicopsis ex gr. *angustifolia* Heer				+	-	-	-	-
Elatocladus smittiana (Heer) Sew.				+	+	+	+	+
Elatocladus sp.				-	+	-	-	-
Araucarites anadyrensis Krysht.				+	+	+	+	+
Sequoia reichenbachii (Gein.) Heer				+	+	+	+	-
S. obovata Knowlt.				+	+	+	+	+
Sequoia sp.1 - small seed cone				-	-	-	+	-
Thuja cretacea (Heer) Newb.				+	-	-	-	-
Cryptomeria aff. *subulata* Sveshn. et Budants.				+	-	-	-	+
Pityostrobus sp.				+	-	-	+	-
Magnoliaephyllum alternans (Heer) Sew.				+	+	-	+	+
Menispermites marcovoensis Philipp.				+	+	-	+	+
M. vasetskii Philipp.				+	+	+	-	-

Table 1 (continued).

1	2	3	4	5	6	7	8	9
Platanus louravetlanica Herman et Shczep.				+	-	-	+	-
P. embicola Vachr.				-	+	-	+	+
Credneria aff. *inordinata* Holl.				+	+	-	+	-
Protophyllum aff. *sternbergi* Lesq.				-	+	-	+	-
Paleonuphar terechovae (Philipp.) Philipp.				+	+	-	-	-
Sorbites asiatica Philipp.				+	+	-	+	+
Schefflerae phyllum venustum (Philipp.) Philipp.				-	+	+	+	-
Dalbergites sp.				+	+	-	-	-
Dalembia pergamentii Herman et E. Lebed.				+	+	+	+	-
Dalembia vachrameevii E.Lebed. et Herman				+	-	-	-	-
Grebenkia acuminata Philipp.				+	-	-	-	-
Cissites orbiculatus Philipp.				+	+	-	-	-
Araliaephyllum arenaria (Philipp.) Philipp.				+	+	+	-	-
A. devjatilovae Philipp.				-	+	-	-	+
A. (?) dentatum Philipp.				+	-	-	-	-
Leguminosites acuminata Philipp.				+	+	+	-	+
Zizyphums sp.				-	-	+	-	-
Sapindopsis sp.				-	-	+	-	-
Dicotylophyllum lanceolatum Philipp.				+	-	-	-	-
Dicotylophyllum sp.1				+	-	-	+	-
Dicotylophyllum sp.2				+	-	-	+	-

Note Research materials of A.D.Devyatilova and G.G.Filippova, 1975; A.D.Devyatilova, 1982; V. V. Lebedev, 1982-83; A. S. Bochkareva, 1984 (right bank of Anadyr River); E. B. Nevretdinova, 1974; A. D. Devyatilova, 1976 (left bank of Anadyr River).

encountered. Angiosperms are rarely encountered in this sector and are characterized by small-leaved forms.

Gleichenites zippei (Corda) Sew., *Asplenium dicksonianum* Heer, *Birisia jelisejevii* (Krysht.) Philipp.are frequently encountered among the ferns, less common are the leaves of *Asplenium rigidum* Vassilevsk., *Hausmannia* sp. and *Cladophlebis* sp. *Sagenopteris variabilis* (Velen.) Velen. is present among the kaitonians. The cycadophytes include *Pseudocyca* (Cicas) *hyperborea* Krysht. and there are three species of *Nilssonia*, genus *Taeniopteris*. There are three

species of ginkgoes: *Ginkgo ex gr. adiantoides* (Ung.) Heer, *G.* ex. gr. *huttonii* (Sternb.) Heer, *G.* ex gr. *lepida* Heer. Remains of the composite genus *Desmiophyllum* are numerous along the Srednyaya Orlovka River.

Among the conifers discovered along the Berezovaya, Srednyaya Orlovka and Malaya Grebenka Rivers the most widely occurring are *Cephalotaxopsis (Taxites) intermedia* Holl., *Sequoia fastigiata* (Sternb.) Heer, *Pagiophyllum triangulare* Pryn., *Florina borealis* Sveshn. et Budants; *Elatocladus gracillimus* (Holl.) Sveshn. is encountered less frequently. The remains of *Pagiophyllum triangulare* Pryn., numerous in the section along the Srednyaya Orlovka River, in combination with the leaves of *Desmiophyllum,* constitute the main background of the fossil flora.

Angiosperms in the basins of the Srednyaya Orlovka and Malaya Grebenka Rivers are encountered extremely rarely and are characterized by small leaves.

The enumerated fossil plants from the basins of the Berezovaya, Srednyaya Orlovka and Malaya Grebenka Rivers belong to the lower subassemblage of the Grebenka floral assemblage, the age of which is determined from the relationship with the marine fauna of the Late Albian-onset of the Early Cenomanian. At the same time, an exposure (exposure 33) along the Malaya Grebenka River containing Late Albian-Early Cenomanian bivalve mollusks is located 4 km to the southwest of the principal section (Grebenka River, Eliseevskoe exposure) and on the basis of lithology it can be assigned to both the lower and upper layers of the flora-bearing horizon.

With respect to the composition of angiosperms (5 species), it most likely is related to the lower layers (base of the horizon). Then an increase in the diversity of flowering plants (26 species) in the higher layers of the principal section, above which lie marine sediments with Late Cenomanian fauna, becomes evident.

Almost all the considered taxons of the lower subassemblage, other than *Taeniopteris* sp., *Hausmannia* sp., *Arctopteris* sp. and *Araucarites* sp., which with better preservation may prove to be independent species, are present in the stratotypic region of occurrence of the upper subassemblage of the Grebenka floral assemblage along the Grebenka, Chukotskaya and Bystraya Rivers. In this sector the listed composition of the fossil flora is more diverse in comparison with the composition from the lower-lying layers. Appearing among the ferns are *Gleichenites asiatica* Philipp, *Arctopteris penchinensis* E. Lebed., *Hausmannia bipartita* Samyl. et Shczep. Among the bennettites V. A. Samylina detected *Nilssoniocladus* sp., and among the ginkgoes — *Sphenobaiera vera* Samyl. et Shczep.

Present here are *Sphenobaiera* aff. *flabellata* Vassilevsk and *Phoenicopsis* ex gr. *angustifolia* Heer. *Thuja cretacea* (Heer) Newb., *Elatocladus smittiana* (Heer) Sew., *Elatocladus* sp., *Cryptomeria* aff. *subulata* (Heer) Sew. appear among the conifers.

There is an increase in the diversity of species among the angiosperms: *Magnoliaephyllum alternans* (Heer) Sew., *Menispermites marcovoensis* Philipp., *Platanus louravetlanica* Herman et Shczep., *Dalembia vachrameevii* E. Lebed, et Herman, *Sorbites asiatica* Philipp. Numerous imprints of *S. asiatica* have been found along the Chukotskaya River and are associated with the top of the flora-bearing horizon. Remains of *Cissites orbiculatus* Philipp., *Paleonuphar terechovae* (Philipp.) Philipp. and many other flowering plants are found in a lesser quantity. An increase in the diversity of angiosperms was caused by a change in environmental conditions, as is indicated by the presence upward in the section of marine sediments containing Middle and Late Cenomanian fauna. It must be noted that along the Gornaya River, where the remains of Middle Cenomanian fauna (*Turrilites costatus*) have been found, and along other watercourses of the right bank of the Anadyr River, including the Bystraya River (*Inoceramus* aff. *nipponicus*), the composite section of the Krivorechenskaya suite was constructed using data for scattered small exposures, the space between which is covered by a mantle of Quaternary deposits. The thickness of particular sections was computed by means of graphs. Due to the separation of exposures over the entire area of the right bank of the Anadyr, here it is impossible to preclude tectonic dislocations. Their presence is confirmed by studies made by A.I. Dvoryankin, et al. [5] on the left bank of the Anadyr River, in the Chineiveem River basin. Prior to this research it had been assumed that the northwestern margin of the Penzhina downwarp, adjacent to the Okhotsk-Chukotka volcanogenic belt (OChVB), represents a monocline dipping gently to the southeast with a continuous buildup of the section of the Upper Cretaceous deposits toward the center of this downwarp.

In the mapping of a sector on the right bank of the Chineiveem River A. I. Dvoryankin and his coauthors established that this monocline in actuality is a series of tectonic blocks of northeasterly orientation. It was found that the field of rocks, discriminated earlier in the Krivorechenskaya suite, also forms a tectonic block with a width of about 4 km, bounded by a fault of arcuate configuration. A Chineiveem floral assemblage, considerably different from the Grebenka floral complex with respect to the composition of conifers and angiosperms, was discovered in the deposits of this block. E. L. Lebedev dates Chineiveem paleoflora as Senonian.

The tectonic block of psephytic tuffogenic-terrigenous rocks with a Chineiveem floral assemblage is in contact on the southeast with a stratum which earlier had been assigned to the Dugovskaya suite of the Late Turonian. As a result, a more ancient Cenomanian age of the flora-bearing stratum has been recognized and it is considered an analogue of the Krivorechenskaya suite.

Earlier researchers (G. P. Terekhova, L. A. Ankudinov, A. D. Devyatilova, and others) felt that the Turonian Dugovskaya suite, dated on the basis of fauna, is replaced upward in the section in the considered sector, without indications of an unconformity, by a stratum in which Chineiveem Senonian flora has been discovered. Thus, a system of tectonic plates, tilted in the same direction in which locally more recent deposits underlie more ancient deposits, stands out in place of a monocline limb.

On the right bank of the Anadyr River, as in the Chineiveem River basin, the rocks of the Krivorechenskaya suite probably consist of blocks ("slices") of a northeasterly direction. A bedrock outcrop (exposure 33) along the Malaya Grebenka River with fauna of the Late Albian-beginning of the Early Cenomanian and flora of the lower subassemblage of the Grebenka floral assemblage may in fact be an uplifted tectonic block.

In the neighborhood of Ugolnaya Bay the paleoflora from the lower half of the Nizhneginterovskaya subsuite is of the same age as the lower subassemblage. At the base of the subsuite G. P. Terekhova [7] collected remains of the plants *Hausmannia* ex gr. *biloba* Pryn., *Hausmannia* sp., *Cladophlebis* aff. *williamsonii* (Brogn.) Brogn., *Sagenopteris* sp., *Nilssonia* sp., *Neozamites* sp., *Dicotylophyllum* sp., which, in the opinion of A. F. Efimova, date to the end of the Early Cretaceous. In the overlying sandstones and carbonaceous siltstones of the "striated" band of the Nizhnegipterovskaya subsuite, jointly with *Turrilites costatus* and inocerams, the presence of the following was noted: *Baiera* cf. *gracilis* (Bean.) Bunb., *Hedera* cf. *curva* Holl., *Sassaphras polevoii* (Krysht.) Jarm. (?), *Dalbergites elegans* Efimova, *Dicotylophyllum* sp. and a great many broken-off fragments of undetermined ferns and dicotyledons. Almost all the species were described by A. F. Efimova.

A. B. German [3], in reexamining flora collections from the Nizhneginterovskaya subsuite, broadened the list of the Ginterovian assemblage. Some species of ferns, cycadophytes, conifers and angiosperms found in this assemblage are present in the lower subassemblage of the Grebenka floral assemblage.

In the Eastern Chukotka sector of the OChVB the paleoflora collected by V. P. Arkaviy in 1975 in the rocks of the Nyrvakinotskaya stratum on the

northern shores of Krest Bay is close in age to the lower subassemblage of the Grebenka floral assemblage.

The Nyrvakinotskaya stratum lies with an angular unconformity on Lower Cretaceous terrigenous-sedimentary deposits and conformably or with insignificant erosion is covered by the Amgenskaya stratum.

The stratum is made up of andesites, predominantly hornblendes, tuffs of andesites, as well as tuff sandstones, tuff siltstones and tuff conglomerates. Thickness up to 1,000 m.

The tuff aleuroltes contain plant remains of *Asplenium dicksonianum* Heer, *Cladophlebis* sp., *Tchukotopteris* sp., *Taeniopteris rhitidorachis* Krysht., *Phoenicopsis angustifolia* Heer, *Desmiophyllum* sp., *Sequoia fastigiata* (Sternb.) Heer, *Parataxodium* sp., *Cephalotaxopsis hetrophylla* Holl., *Torreya gracillima* Holl., *Araucarites* aff. *anadyrensis* Krysht., *Podozamites graminens* Heer, *P. eichwaldii* Schimp. (determinations by author).

The Barandzhinian plant assemblage, collected by E. L. Lebedev [9] in the coal-bearing deposits of the Barandzhinian stratum along the Barandzha and Shirokaya Rivers and the stream Ugolnyi (Tas-Burgagylkan interfluve) is situated in the Okhotsk sector of the OChVB (Northern Priokhotye) at the same stratigraphic level with the lower subassemblage of the Grebenka floral assemblage.

About 70 species of ancient plants (the list has not been published) was collected in the flora-bearing layers of the Barandzhinian stratum. In the makeup of this unusual assemblage there is a predominance of the conifers *Cephalotaxopsis intermedia* Holl., *Podozamites* sp., *Nageiopsis* sp., *Pagiophyllum triangulare* Pryn., *Elatocladus smittiana* (Heer) Sew. and various kinds of cycadophytes. Angiosperms are rare. E. L. Lebedev dates the Barandzhinian plant assemblage as Late Albian.

S. V. Pekanov and I. F. Semyshev, specialists of the Khasynsk State Mining-Geological Enterprise "Kompleks," in 1966 repeated collections of Barandzhinskaya flora in the Shirokaya River basin. In that flora the author found 34 species of Cretaceous plants. With respect to the composition of cycadophytes, conifers and angiosperms, the Barandzhinskiy plant assemblage is more ancient than the Armanian assemblage from the Arman River basin (Northern Priokhotye). It corresponds, most likely, to the lower subassemblage of the Grebenka flora assemblage.

The upper subassemblage of the Grebenka floral assemblage with respect to the systematic makeup of the principal groups of plants (ferns, gymno- and angiosperms) has a great similarity to the Armanian, determined in a section of the suite of the same name on the Arman River. Among the ferns

in both assemblages the most important are the genera *Asplenium, Birisia* and *Cladophlebis*. A great similarity is observed in the species composition of *Gleichenites*. *Sagenopteris variabilis* is characteristic for them. Among the cycadophytes *Nilssonia* and *Taeniopteris* are common. In the upper subassemblage of the Grebenka assemblage ginkgos are represented by three species, and in the Armanian subassemblage — by two. The remains of the relict genus *Czekanowskia*, known in Armanian flora, has not been found in the upper Grebenka subassemblage. Among the angiosperms leaves of the Platanoceae type are common, as well as *Dalembia, Celastrophyllum, Menispermites, Dalbergites, Araliaephyllum, Trochodendroides* and other dicotyledons.

The greatest similarity of the Upper Grebenka subassemblage and Armanian assemblage is manifested in the composition of the conifers. Noteworthy among them are *Cephalotaxopsis (Taxites), Pagiophyllum* and *Sequoia*. *Podozamites* imprints are frequently encountered in the Armanskaya suite (three-four species), individual leaves of *P. lanceolatus* (L. et H.) Braun have been found in the upper subassemblage of the Grebenka assemblages. *Thuja cretacea* (Heer) Newb. has been discovered in only one layer along the Grebenka River and the morphologically close genus *Libocedrus* has been established in several buried sites in the Armanskaya suite.

Thus, in addition to the similarity of the systematic composition of the upper subassemblage of the Grebenka assemblage and Armanskaya paleoflora there is some difference probably associated with plant habitation conditions in different landscape zones. The Grebenka assemblage developed on the open seaside plain, whereas the Armanian "burials" reflect the vegetation of intermontane depressions. *Libocedrus arctica* Sveshn. et Budants, and *Sequoia minuta* Sveshn., characteristic for the higher stratigraphic levels of the Upper Cretaceous of the Siberian-Canadian paleoflora region, appear in the makeup of the coniferous Armanian assemblage. In the makeup of the angiosperms there is a predominance of leaves with a serrated edge *Zizyphus, Araliaephyllum, Dalembia*, and others, giving evidence of a colder climate in the Armanian in comparison with the climate of the Late Grebenka period. In the northern latitudes during the Middle Cretaceous the cooling maximum, according to recent data [4], falls in the Turonian. Accordingly, in the monographic description of all the plant groups of the Armanian assemblage from the stratotypic section on the Arman River (the author studied only the angiosperms [16]), its age may be somewhat younger than the upper subassemblage of the Grebenka floral assemblage.

A description of *Paleonuphar terechovae* (Philipp.) Philipp. from the upper subassemblage of the Grebenka floral assemblage is given.

Family Nymphaeaceae
Genus *Paleonuphar* Hollick, 1930
***Paleonuphar terechovae* (Philipp.) Philipp.**
Plate 2, Figures 1-4

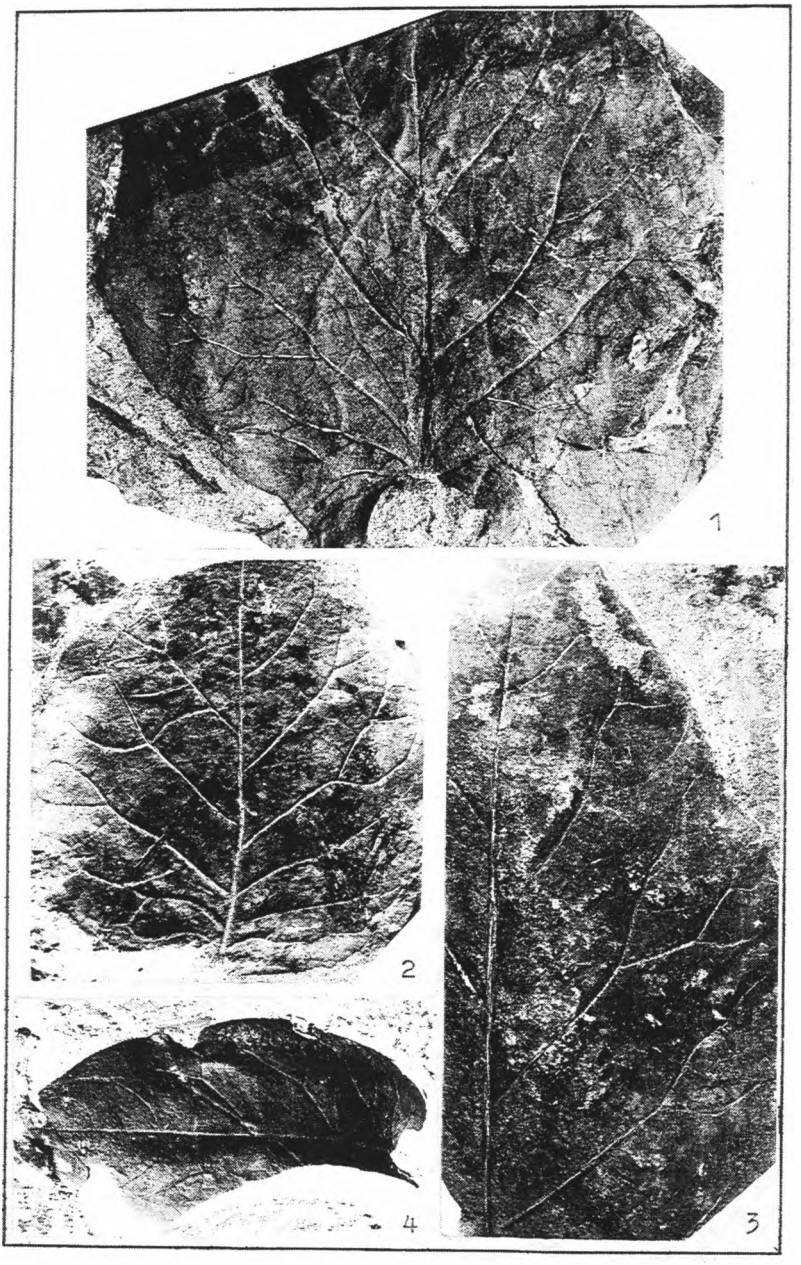
Protophyllum terechovae - Filippova, 1993, p. 137, Table 37, Figures 1, 2; Table 40, Fig. 1.

Description. Leaves are simple, stemlike, of different size (5-13 cm in length, 2-6 cm in width), egg-shaped or wide-egg shaped, have a somewhat sharpened, less commonly a very sharp tip, and a nodular or slightly emarginate base. The leaf base lobes sometimes are close together. The edge of the leaf plate is intact. The ribbing is pinnate or brachydodromic. The central rib at the base is massive; closer to the leaf tip the leaf thins out. The secondary ribs (7-9 pairs) are alternate or convergent in pairs, arcuate or bent in shape, and depart from the central rib at an angle 50-60°, forking out up to three times. A number of loops of irregular configuration form at the leaf edge. The length of the secondary ribs increases from the basal to the fourth pair, but upward begins to decrease. The basal ribs are short and depart from the middle rib above the place of attachment of the stem or directly from it, branch out in a forklike manner, and join one another and branchings of the secondary ribs. Below the basal ribs there are one or two pairs of thin infrabasal ribs oriented to the side and downwards into the lobes (projections) of the nodular leaf base. The tertiary ribbing is irregularly reticulate (the ribs are joined to one another and to the secondary veins, forming a grid whose angles vary). Short, thin intermediate ribs are traced irregularly between the secondary ribs.

Comparison. The Grebenka species with respect to morphological indicators (nodular base, intact edge, loop-shaped ribbing) has some similarity to *Paleonuphar inopina* Holl. ([19], p. 75, Plate 40, Fig. 5) from the Upper Cretaceous deposits of the Yukon River basin in Alaska, from which it differs with respect to the nature of the tip, somewhat different configuration of the leaves, branching off of the secondary ribs from the central rib and their number. In the Yukon species the leaf tip is slightly emarginate. The secondary ribs (12 pairs) depart from the central rib almost at a right angle and there are no intermediate ribs.

Paleonuphar terechovae has some similarity to *P. nordenskioldii* (Heer) Bell ([18], p. 36, Plate 18, Figures 2, 4) from the Upper Cretaceous of the Dunvegan formation in Western Canada. A similarity of these species is observed with respect to the size of the leaves, configuration of the base and forked branching of the secondary venules. The difference is in the higher-order

Plate



Figures 1-4. *Paleonuphar terechovae* (Philipp.) Philipp.

1 — almost complete leaf, Grebenka River, sampled by A. D Devyatilóva and G. G. Filippova, 1975, exposure 70; 2 — almost complete leaf, ChukotskayaRiver, sampled by same persons, exposure 173; 3 — lateral part of large leaf, Grebenka River, sampled by same persons, 1975, exposure 71; 4 — leaf, Grebenka River, sampled by I. P. Basetskiy, 1958, exposure 903.

ribbing. In the Canadian species the tertiary ribbing is ladderlike (the small ribs are almost perpendicular to the secondary veins) and the fourth-order venules form a more or less square network, whereas in the Anadyr species the higher-order ribbing is irregularly reticulate

The considered species has a still greater difference from other representatives of Nymphaeceae.

O c c u r r e n c e . Krivorechenskaya suite, Late Albian-Cenomanian, Grebenka and Chukotskaya Rivers, upper subassemblage of Grebenka floral assemblage.

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