Geol. of Pac. Ocean, 1999, Vol. 14, pp. 977-990
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Printed in Singapore

Flora and Correlation of Layers with Dinosaur Fossil Remains in the Russian Far East

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(Received June 9, 1997)

Pollen assemblages from locations of dinosaur remains (Kundur, Blagoveshchensk, Beringovsky, Kakanaut and Sinegorsk) were studied, and earlier paleobotanical data were summarized. The composition of phytomacrofossils varies, which is seemingly connected with burial of coastal local vegetation groups, while pollen-floral composition reflects the unity and common features of Late Cretaceous East Asian flora. Good preservation and abundance of pollen morphs permitted correlation of bone-bearing layers of the Russian East and estimation of their age as Middle Maastrichtian. We sampled a nearly continuous section near the Kundur settlement for its whole length. Late Campanian forms are gradually replaced by Maastrichtian, and then, by Danian forms. A particularly distinct flora change is recognized in the Middle Maastrichtian rather than at the junction of the eras. All the above-mentioned fossil reptile occurrences are also Middle Maastrichtian. So far, we cannot support a hypothesis of an extraterrestrial cause for the impact produced on the Earth's biota at the boundary between the Cretaceous and Paleogene owing to the known smooth changes in floral composition conditioned by a biocoenosis crisis.

INTRODUCTION

The stratigraphy of continental deposits has always been a vexed question due to the fact that it does not fit into the general geochronological scale developed for the marine animals. As Academician V.V.Menner stated at one time, the most promising way of correlation of marine and non-marine units is palynological analysis [21]. Using this method, we tried to divide the Maastrichtian layers. The rocks of this stage were distinguished in the Russian Far East either non-divided or divided up to the lower and upper substages, while the latest subdivision of the Cretaceous is of particular interest. This is a time of the threshold of the global crisis, which broke out at the boundary between the Mesozoic and Cenozoic and left traces in many areas of the Earth. Some Maastrichtian deposits in the Russian Far East contain fossil reptile remains. Elucidation of their exact age, the specific features of habitat and changes in conditions of their life will throw light on the reasons for extinction of dinosaurs, which dominated the whole Mesozoic. The employment of the palynological method for solving the above problems showed its high resolution capacity when dividing stratigraphic units, as being no inferior to division by ammonites. Sometimes it gives more profound information on the change of vegetation, continental paleoecosystems and paleogeography. The evolutional changes in Maastrichtian pollen flora allow us to distinguish three stages in its development (in all likelihood, reflecting reconstructions in ecosystems), which are distinctly registered in the territory of the Far East. Fossil reptile-bearing layers in the Russian Far East are known in Priamurie, Koryak Upland and Sakhalin (Fig.).

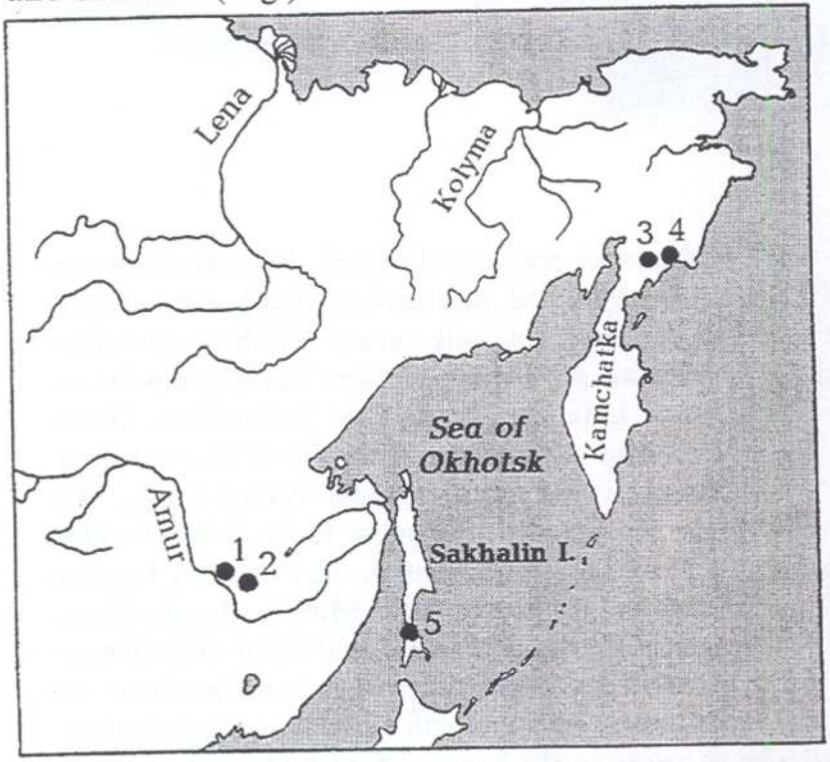

Figure General sketch-map of fossil reptile sites.

1 – Blagoveshchensk; 2 – Kundur; 3 – Kakanaut; 4 – Beringovsky; 5 – Sinegorsk.

PRIAMURIE (BLAGOVESHCHENSK AND KUNDUR LOCALITIES)

Priamurie is a region with the richest history of study of fossil fauna and flora, whose classical occurrences have been examined by many distinguished scientists [5, 13, 15, 26, 27]. The first information on dinosaur finds in the region appeared in 1902 after A.Ye.Gurov had found bone fragments on the right bank of the Amur River in the Belye Kruchi locality. A.N.Ryabinin described the duck-billed dinosaur *Mandshurosaurus amurensis* from this exposure in his monograph [27]. Later, fossil vertebrates were studied by A.K.Rozhdestvensky [26], L.A.Nesov [22, 23], and Yu.L.Bolotsky [2, 3, 4, 20]. The richest collection belongs to Yu.L.Bolotsky; the specimens were sampled from the Blagoveshchensk and coeval Kundur localities in Priamurie. It is dominated by bones and teeth of the herbivorous hadrosaurs: Hadrosaurinae–*Mandshurosaurus* cf. *amurensis* Riab., Lambeosaurinae – *Amurosaurus riabinini* Bolotsky et Kursanov. Teeth of predaceous dinosaurs, crocodile and fossil turtle remains were also detected (Table 1). The most favorable for

Table 1 Fossil reptiles from the Maastrichtian in the Russian East (according to Bolotsky, 1990; Bolotsky & Moiseenko, 1988; Nesov & Golovnyova, 1990).

FOSSIL REPTILES	Priamurie		Magadan region		Sakhalin
	Blagoveshchensk	Kundur	Kakanaut R.	Beringovsky	Sinegorsk
superorder Crocodilia	▨	▨			
family Dermatemydidae					
Mongolemys cf.*planicostatus*	▨	▨			
family Trionychidae					
Trionyx sp.	▨	▨			
family Tyrannosauridae	▨	▨			
family Ornithomimidae	▨	▨			
family Dromaeosauridae	▨	▨			
family Troodontidae	▨	▨	▨		
family Titanosauridae	▨				
family Hadrosauridae					
subfamily Hadrosaurinae	▨	▨			
subfamily Lambeosaurinae	▨	▨	▨		▨
family Nodosauridae		▨			
family Elasmosauridae				▨	

paleontological examination is a section near the Kundur settlement. It is noted for great persistence and relative continuity. The abundance and perfect preservation of pollen forms permit us to get an idea about a successive development of floras, character of their change in the course of formation of the layers. Macrofloral finds, and also limnofaunal finds in the lower part of the section (conchostracs, ostracodes) add to the picture of the paleoenvironment of the sedimentation basin. Data on pollen characterizing a continuous succession in paleofloral change can be standard for not only Priamurie but also the whole Far East. The pollen assemblage from the lower part of the Kundur section is dominated by warm-loving subtropical species of Pteropsida, Gymnospermae (for the most part similar to Podocarpaceae, Araucariaceae, Ginkgoaceae, Cycadophyta), and also Angiospermae (Table 2). Among the latter there is a numerous group similar to Proteaceae, Santalaceae, Loranthaceae, Fagaceae, and plants with unspecified affinity producing pollen of "unica" and "oculata" type. In all likelihood, these were the forests growing in a warm (subtropical) humid climate in Late Campanian – Early Maastrichtian time [20]. The lower part of the section shows the fossil plants *Asplenium* sp., *Ginkgoites* sp., *Taxodium olrikii* (Heer), *Pityostrobus* sp., *Trochodendroides* ex gr. *arctica* (Heer), "*Platanus*" *raynoldsii* Newb. The pollen assemblage from the middle part of the section (which comprises bone-bearing beds) is characterized by an increased proportion of deciduous warm-temperate species close to Platanaceae, Ulmaceae, Betulaceae. Persistently plentiful are the species close to Taxodiaceae, Cycadophyta and Cyatheaceae. The onset of climatic worsening – slight cooling and drying, is indicated by appearance of Gnetaceae and Hirmeriellaceae, and also by a dramatic change in the species composition of Angiospermae with "unica" and "oculata" pollen. Many of them are absent there, such as the warm-loving Campanian species *Aquilapollenites striatus* Nort., *A. conatus* North., *A. amygdaloides* Sriv., *Parviprojectus dolium* Samoil., *Wodehouseia aspera* (Samoil.) Wiggins., *W.*

Table 2 Pollen of Angiospermae from Kundur site.

System	Cretaceous		
	Upper Cretaceous		
	Maastrichtian		
Taxons / Stage	Lower	Middle	Upper
Aquilapollenites subtilis	▨	■	▨
Kuprianipollis elegans	▨	▨	▨
K. santaloides	■	■	▨
Fothergilla gracilis	▨	▨	▨
Hamameliidaceae	▨	▨	■
Fagaceae	▨	▨	■
Yuglanspollenites	▨	▨	■
Cranwellia striata	■	▨	
C. aspera	■	▨	
C.sp.	■	▨	
Aquilapollenites conatus	■	■	
Orbiculapollis globosus	■	■	
O. lucidus	▨	▨	■
Proteacidites bellus	■	▨	
P. thalmanii	■	■	
Wodehouseia aspera	■	▨	
Aquilapollenites insignis	■	▨	
A. trialatus	■	▨	
A.striatus	■		
A. amygdaloides	■		
Parviprojectus dolium	■		
Mancicorpus anchoriforme	■		
Wodehouseia gracile	■		
Liliacidites variegatus		■	
Fibulapollis mirificus		■	
Aquilapollenites asper		■	
A. quadrilobus		■	
A. cruciformis		■	
A. amurensis		■	
Mancicorpus tenue		▨	
Wodehouseia spinata		■	
Triatriopollenites radiatostriatus		■	
Tricolpites gracilis		▨	
Erdmanipollenites albertensis		▨	
Ulmipollenites krempii	▨	■	■
U. tricostatus	▨	■	■
U. planaeriformis		■	■
Triatriopollenites aroboratus		▨	■
Triporopollenites plectosus		▨	■
Quercites sparsus	▨	▨	▨
Myricapollenites imperfectus			■
Comptonia sibirica			■
Tricolpites aff.variegatus			■
T. discus			■
T. coryloides			■

Conventional signs to Table 2

▨ rare fossil pollen ■ abundant fossil pollen *gracile* (Samoil.) Pokr., *Mancicorpus solidum* N. Mtch. The dominating species are *Aquilapollenites subtilis* N. Mtch., *A. insignis* N. Mtch., *A. cruciformis* N. Mtch., *A. quadrilobus* M. Mtch., *A. amurensis Bratz.*, *Wodehouseia spinata* Stanl., i.e., taxons typical of Maastrichtian pollen forms (Table 2). The diversity of those allied to Proteaceae, Santalaceae is reduced; and likewise of Gymnospermae, warm-loving, allied to Araucariaceae, Podocarpaceae, Cycadophyta [20]. The age of the pollen assemblage from the fossil dinosaur-bearing layers is Middle Maastrichtian. The pollen assemblage from the upper part of the section displays a distinct reduction in the amount of "unica" pollen (only two species and rare specimens) and other species of Angiospermae characteristic of the Early and Middle Maastrichtian pollen floras. The dominant species become those related to the modern communities: Ophioglossacea, Taxodiaceae, Myricaceae, Ulmaceae, Platanceae, Betulaceae, Tuglandaceae, Fagaceae, and also plants with the pollen *Orbiculapollis* (*O. globosus* (Chlon.) Chlon., *A. lucidus* (Chlon.) Chlon.), etc. Trisulcatus and Trisulcatus porosus type pollen (*Triatriopollenites plicoides* Zakl., *T. confusus* Zakl., *Triporopollenites plectosus* Zakl., *Tricolpites* aff. *variexinus*, *T. vulgaris.*, etc.) is abundant and diverse. All this is evidence that the climate tends abruptly towards cooling and drying. Such a dramatic change in pollen-floral taxonomic composition is typical of the end of the Maastrichtian – beginning of the Danian in different regions of East Asia [5, 17, 32, 33]. Thus, a consistency is traced in the change of Priamurie pollen-floral diversity through the Maastrichtian. In the upper part of the section were detected macroremains of the plants *Equisetum* cf. *arcticum* Heer, *Taxodium* sp., "*Cephalotaxopsis*" sp., *Czekanowskia* (?) sp. nov., *Nyssa* cf. *bureica* Krassil., *Diplophyllum amurense* Krassil., microphyllous *Trochodendroides* ex gr. *arctica* (Heer), "*Platanus*" *raynoldsii* Newb. The phytofossil burial site is replete, chaotic, and shows no orientation. Coniferae predominate: "*Cephalotaxopsis*" and *Taxodium*. The presence of *Trochodendroides* ex gr. *arctica*, "*Platanus*" *raynoldsii*, *Nyssa* cf. *bureica*, *Diplophyllum amurense* and *Taxodium* is suggestive of similarities to Tsagayanian flora, described by A.N.Krishtofovich and T.N.Baikovskaya [15], and by V.A.Krasilov [13]. But distinctions are also apparent. In the classical Tsagayanian sites, leaf roofs are observed formed of Angiospermae leaves (in the Middle Tsagayan subsuite, *Diplophyllum amurense*, *Trochodendroides arctica*, *Viburniphyllum finale*; in the Upper Tsagayan subsuite, *Tiliaephyllum tsagajanicum*, *Trochodendroides arctica* and '*Platanus' raynoldsii*), and in Priamurie the conifers "*Cephaloptaxopsis*" and *Taxodium* are the dominant species devoid of leaf roofs. Microphyllous *Trochodendroides* and '*Platanus*" are noticeable. L.B.Golovnyova [23] indicated pervasive *Cephalotaxopsis*, *Sequoia* and microphyllous Platanaceae and *Trochodendroides* in the Early Gornorechenskian flora of the Koryak Upland. The Late Gornorechenskian flora is dominated by *Glyptostrobus*, *Celastrus*, *Macrovenulus* and megaphyllous Platanaceae. These two floras give Middle Maastrichtian age. L.B.Golovnyova draws a parallel between the Gornorechensk assemblage and the Kakanaut, which is distinguished by prevalence of "*Cephalotaxopsis*", *Myrica*, *Celastrus*, microphyllous Platanaceae and *Trochodendroides*, sometimes *Encephalartopsis*. One can speculate that the floral assemblage from the upper part of the section near the Kundur settlement, so distinctly different from typical Tsagayanian flora, is comparable with the Lower Gornorechensk and Kakanaut assemblages from the Koryak Upland. The age of Tsagayanian flora was estimated as Danian; and Gornorechenskian and Kakanautian, as Middle Maastrichtian. Making allowance for the undoubted inheritance between Tsagayanian flora and the described assemblage, the age of the latter can be inferred as Late Maastrichtian. Qualifying a microphyllous feature of Platanaceae and *Trochodendroides* as their reaction to cooling, it is reasonable to assume that cooling in low latitudes set in later than on the Koryak Upland, and similar environments in the Amur basin developed in the Late rather than in the Middle Maastrichtian.

MAGADAN AREA (BERINGOVSKY AND KAKANAUT LOCATIONS)

Two locations of fossil reptile remains are known in the Magadan area [23]. The first is the Beringovsky settlement (Ugolnaya Bay, upper part of the Koryak suite). Crustacean tracks, teeth and bones of different fishes, teeth and vertebrae of the long-necked plesiosaurs Elasmosauridae [24], and also plentiful plant remains have been found there. The Koryakian floral assemblage is similar to the Early Rarytkinian assemblage from the middle subsuite, Rarytkin suite, only differing in several species [7-9]. The latter assemblage is characterized by *Nyssa tschukotica* sp. nov., *Celastrus septentrionalis* (Krysht.) Golovn., *Talowia lanceolata* sp. nov., *Arthollia rarytkensis* Golovn., *Haemanthophyllum cordatum* Golovn., *Vitis rarytkensis* Krysht., *Quereuxia angulata* (Lesq.) Krysht. Both in the Early Rarytkian and Late Rarytkian sub-assemblages the following species are dominant: *Corylus anadyrensis* Budants., *Trochodendroides arctica* (Heer) Berry, *Metasequoia districha* (Heer) Miki, *Glyptostrobus nordenskioldii* (Heer) R.W.Brown, *Microconium beringianum* Golovn. [23]. The taxonomic composition of the pollen assemblage from these layers is very poor but the preservation of the pollen forms is good. Spores are represented by Cyatheaceae- and Gleicheniaceae-allied, trilete flat from the Leiotriletes group. Among Gymnospermae prevail Pinaceae, Ginkgoaceae and cycadophytes with minor Gnetaceae-related species. Angiospermae are more diverse (Table 3). They are mostly Platanaceae-, Fagaceae- and Ericaceae-allied, and also species whose relation to the modern communities is not defined: *Aquillapollenites trialatus* Rouse, *A. cruciformis* N. Mitch., *A.* sp., *Parviprojectus dolium* Samoil., *Fibulapollis mirificus* Chlon., etc. The taxonomic composition of the pollen assemblage is similar to the assemblage from the middle subsuite, Tsagayan suite of the Kundur fossil dinosaur location of Middle Maastrichtian age. The resemblance is set by species of the genera *Aquilapollenites*, geographically widespread and age-constrained. The second fossil reptile site is located on the Koryak Upland in the Pekulneiskoye Lake basin, on the left bank of the Kakanaut River (upper part of the Kakanaut suite). Remains of predaceous and herbivorous dinosaurs, and also thin hollow bones, which might belong to birds, were also detected there. Oryctocoenosis resulted from burial by a mud-flow or "quick ground", composed of a mixture of volcanic ash and water [23]. The Kakanautian floral assemblage shows similarities to that from the Gornorechensk area: both display general dominant species and relatively small leaves. Coniferae are represented by abundant "*Cephalotaxopsis*", and among the angiosperms rule *Myrica heterophylla* sp. nov., microphyllous *Trochodendroides*, *Celastrus* sp. and *Platanus* (2-3 species).

Table 3 Pollen of Angiospermae from Beringovsky and Kakanaut sites.

System	Cretaceous		
	Upper Cretaceous		
Taxons / Stage	Maastrichtian		
	Lower	Middle	Upper
Aquilapollenites subtilis		■	■
Kuprianipollis elegans	■	■	▨
K. santaloides	■	■	▨
Fothergilla gracilis			
Hamameliidaceae		■	■
Fagaceae	■	■	■
Yuglanspollenites	▨	■	■
Cranwellia striata	■	■	▨
C. aspera	▨	■	
C.sp.	▨	■	
Aquilapollenites conatus	■		
Orbiculapollis globosus	■	■	■
O. lucidus	■	■	■
Proteacidites bellus	■		
P. thalmanii	▨	■	
Wodehouseia aspera	▨	■	▨
Aquilapollenites insignis	■	■	
A. trialatus	■	■	
A.striatus	■		
A. amygdaloides	■		
Parviprojectus dolium	■	■	▨
Mancicorpus anchoriforme		▨	■
Wodehouseia gracile			
Liliacidites variegatus	▨	▨	■
Fibulapollis mirificus		■	
Aquilapollenites asper	▨	■	
A. quadrilobus	▨	■	
A. cruciformis	▨	■	
A. amurensis			
Mancicorpus tenue		■	
Wodehouseia spinata	■		
Triatriopollenites radiatostriatus			▨
Tricolpites gracilis	▨	▨	▨
Erdmanipollenites albertensis			
Ulmipollenites krempii	■	■	▨
U. tricostatus	■	■	▨
U. planaeriformis	▨	■	■
Triatriopollenites aroboratus	▨	▨	■
Triporopollenites plectosus		▨	■
Quercites sparsus	▨	▨	■
Myricapollenites imperfectus	▨	▨	■
Comptonia sibirica		▨	■
Tricolpites aff.variegatus			■
T. discus			■
T. coryloides		■	■

Conventional signs are same as in Table 2.

The cycadophyte *Encephalartopsis vassilevskajae* forms monodominant "leaf roofs" [14]. The conifers *Araucarites, Metasequoia, Glyptostrobus* are rare, and the angiosperms *Corylus anadyrensis* Budants. and microphyllous Betulaceae are limited. Finds of *Pterospermites, Liriophyllum, Cissites, Tiliaephyllum* of the water plant *Quereuxia angulata* (Lesq.) Krysht. are few. In this assemblage, as compared to the Gornorechensk one, *Ginkgo* and *Nilssonia* are recognized in greater amounts [9]. The pollen assemblage from the bone-bearing layers of the Kakanaut location shows abundant species allied to Cyatheaceae, Ophioglossaceae, Pinaceae and Podocarpaceae, Ginkgoaceae and Cycadophyta, and also to Taxodiaceae. Angiosperms are largely represented by "unica" type pollen, characteristic of Middle Maastrichtian pollen forms, and also Platanaceae-, Fagaceae-, Loranthaceae- and Santalaceae-allied. Cysts of dinoflagellates, acritarchs and chitin scraps are plentiful. In its taxonomic composition, the pollen assemblage is close to the assemblage from epy fossil dinosaur-bearing layers in Ugolnaya Bay and in Priamurie. In our opinion, it is reasonable to compare taxonomic composition of assemblages from the bone-bearing beds with those from continental deposits of the lower and middle subsuites of the Rarytkin suite holding bountiful vegetation remains (samples of L.B.Golovnyova). The pollen assemblage from the lower part of the section of the Rarytkin suite (at the boundary with the Gornorechensk suite) is characterized by substantial diversity and dominance of Angiospermae, primarily representatives with "unica" pollen. They are accompanied by warm-loving species allied to Santalaceae, Loranthaceae, Buxaceae, Plaranaceae, and also to warm-temperate Ulmaceae. Gymnospermae are distinguished by Pinaceae and Taxodiaceae. Pteropsida are scarce. In taxonomic composition this assemblage is allied to the pollen assemblages from the Campanian – Lower Maastrichtian deposits of East Asia [18-20, 32, 33], and in all likelihood, its age is Early Maastrichtian. So far, no transitional assemblage is known between the Barykov (Santonian – Early Campanian) and Gornorechensk (Middle Maastrichtian) floral stages [7, 23]. Thus, palynological data make it possible to fill the Late Campanian – Early Maastrichtian gap. The floral assemblage from the upper part of the lower subsuite, Rarytkin suite, corresponds to the Gornorechensk stage of the Anadyr-Koryak subregion [7, 8]. It is distinguished by a dominance of angiosperms (the genera *Peculnea, Trochodendroides, Celastrinites, Renea, Dyrana, Platanus, Viburnum, Quereuxia, Palaeotrapa, Corylus*). Coniferae are few, and are represented by *Sequoia minuta, Cryptomerites, Taxites,* with the accompanying younger *Metasequoia* and *Glyptostrobus*. *Ginkgo* and *Nilssonia* are rather illustrative which could form monodonimant communities. The ferns are exemplified by solitary *Osmunda* [8]. The floral assemblage is dated as Middle Maastrichtian. The pollen assemblage from the lower part of the middle subsuite, Rarytkin suite, is dominated by Angiospermae. They are widely illustrated by "unica" and "oculata" pollen: *Aquilapollenites, A. reductus, A. amygdaloides, A. insignis, A. cruciformis*, which are accompanied by various species allied to Santalaceae and Loranthaceae, and also Buxaceae, Menispermaceae, Ericaceae, Platanaceae and Fagaceae. Pteropsida show copious representatives allied to Cyatheaceae, Dixodiaceae, Schizaeaceae, Ophioglossaceae, etc. The pollen assemblage is dated as Middle Maastrichtian by likeness in taxonomic composition to coeval assemblages from the Russian East. Rarytkian flora holds abundant Coniferae and Angiospermae. *Corylus* and some species of *Trochodendroides, Metasequoia, Glyptostrobus* and *Microconium* are widespread. *Taxodium* sp., *Platanus raynoldsii* Newb., *Quercus groenlandica* Heer, *Arthollia* sp., *Rarytkinia* sp., *Celastrinites* sp., *Nyssa* sp., *Platimelis* dp., *Viburnum* sp., *Vitis* sp., *Quereuxia* sp., *Haemanthophyllum* sp. are characteristic. Remains of *Ginkgo* sp. are rare, and cycadophytes are absent. The ferns are represented by *Onoclea* sp. and *Coniopteris* sp. [8]. The pollen assemblage from the upper part of the Rarytkin suite shows a distinct change in taxonomic composition. Angiospermae and Pteropsida become more copious and diverse. Essentially dominant are flat monolete spores of species allied to Ophioglossaceae, and also *Leiotriletes* spp. Gymnospermae are distinguished by abundant pollen of species allied to the modern families: Betulaceae, Tuglandaceae, Fagaceae, Ericaceae. The diversity and amount of "unica" and "oculata" pollen is reduced sharply. The taxonomic composition of the assemblage reflects a stage in Cretaceous pollen flora transitional from the Late Maastrichtian to the Early Danian in the Russian East.

SOUTH SAKHALIN

On South Sakhalin, in the vicinity of Sinegorsk, an incomplete skeleton was discovered of the duck-billed "thick-sculled" dinosaur *Nipponosaurus sachalinensis* Nagao [35] in shallow-water marine deposits of the Ryugaze Group. Modern data refer this find to Members IV-V of the lower subsuite, Krasnoyarka suite [23]. The pollen assemblage has been studied from a unit coeval with the bone-bearing layers of the Kawakami quarry of the former Mitsubishi mine company. The pollen assemblage from the lower part of the lower subsuite, Krasnoyarka suite (members I-II) holding a diverse and copious fauna of ammonites, inocerams, pelecypods, gastropods and echinoids has been examined in the basin of the Naiba - exposure 0111/60, and Krasnoyarka - exposure 66, 67, [1, 6, 10, 11, 18, 19, 25]. It shows a dominance of spores of Pteropsida, chiefly Ophioglossaceae, accompanied by species allied to Schizaeaceae and Gleicheniaceae. Among Gymnospermae, Pinaceae-allied are abundant. The diversity and amount of Angiospermae are great. "Unica" and "oculata" pollen predominates, primarily at the expense of typical representatives of Late Campanian and Early Maastrichtian pollen floras: *Aquilapollenites striatus*, Nort., *A. reductus* Nort., *A. amygdaloides* Sriv., *A. insignis* N. Mtch., *Wodehouseria aspera* (Samoil.) *Wiggins, W. spinata* Stanl., etc. Also common is pollen close to the modern families: Ulmaceae, Tuglandaceae, Fagaceae, Buxaceae, Proteaceae, Mantalaceae, Loranthaceae. The pollen assemblage is dated as Late Campanian – Early Maastrichtian. Another pollen assemblage characterizes deposits of the Krasnoyarka suite (Krasnoyarka R. basin, exposure 62, member IV, exposure 59, member V) bearing diverse fauna of inocerams, ammonites, and brachiopods. Its Pteropsida hold abundant flat trilete spores *Leiotriletes* spp., (up to 16%); and Gymnospermae are represented by *Pinaceae*. The taxonomic composition of Angiospermae, accounting for ~25-30% on the average, yields a reduced proportion of typical Maastrichtian taxons with "unica" and "oculata" pollen (Table 4). We feel that this assemblage corresponds to the Middle Maastrichtian pollen assemblages from the Asian East, but in all likelihood, some distinctions reflect a paleoenvironment – influence of a sea. The pollen assemblage from the upper part of the lower subsuite,

Table 4 Pollen of Angiospermae from layers bearing fossil dinosaur remains, Sakhalin Island.

System	Cretaceous		
	Upper Cretaceous		
Stage	Maastrichtian		
Taxons	Lower	Middle	Upper
Aquilapollenites subtilis	▒	■	
Kuprianipollis elegans	■	■	
K. santaloides	■	▒	▒
Fothergilla gracilis		■	
Hamameliidaceae	▒	■	■
Fagaceae	▒	■	■
Yuglanspollenites	▒	■	■
Cranwellia striata	■	■	
C. aspera	■	■	
C.sp.	■	▒	▒
Aquilapollenites conatus			
Orbiculapollis globosus	▒	■	
O. lucidus	■	■	■
Proteacidites bellus	■	▒	▒
P. thalmanii	▒	▒	▒
Wodehouseia aspera	■	■	
Aquilapollenites insignis	■	▒	
A. trialatus			
A.striatus	■		
A. amygdaloides	■		
Parviprojectus dolium		■	
Mancicorpus anchoriforme		■	
Wodehouseia gracile		■	
Liliacidites variegatus		■	■
Fibulapollis mirificus		■	
Aquilapollenites asper		■	
A. quadrilobus		■	
A. cruciformis		■	
A. amurensis			
Mancicorpus tenue		■	
Wodehouseia spinata	▒	■	
Triatriopollenites radiatostriatus			
Tricolpites gracilis		■	
Erdmanipollenites albertensis			
Ulmipollenites krempii	■	■	■
U. tricostatus	■	■	■
U. planaeriformis	■	■	■
Triatriopollenites aroboratus		■	■
Triporopollenites plectosus			■
Quercites sparsus	▒	▒	
Myricapollenites imperfectus			■
Comptonia sibirica			■
Tricolpites aff.variegatus			▒
T. discus			▒
T. coryloides			▒

Conventional signs are same as in Table 2.

Krasnoyarka suite, holds a reduced number of Schizaeaceae- and Gleicheniaceae-allied spores. The diversity of Angiospermae pollen increases for the most part at the expense of plants whose relationship with the modern families has not been specified, but their taxonomic composition altered distinctly. The number of species typical of the Campanian-Lower Maastrichtian is reduced. Common are *Aquilapollenites aspera* N. Mitch., *A. subtilis* N. Mitch., *A. conatus* Nort., *A. quadrilobus* Rouse, *A. cruciferus* N. Mitch. Pollen of Angiospermae, allied to the modern representatives, becomes more diverse, especially among Proteaceae, Loranthaceae, Betulaceae, etc. The pollen assemblage from siltstones of the upper part of the upper subsuite, Krasnoyarka suite, has been studied in exposure 58, Razvedochny Spring, Krasnoyarka R. It is dominated by Angiospermae with porate type pollen, species allied to Betulaceae, Ulmaceae, Tuglandaceae, Ericaceae, i.e. platyphyllous warm-temperate species of families close to the modern ones. Plant species which produced ""unica" and "oculata" pollen typical of the Early-Middle Maastrichtian become restricted. They are represented by *Orbiculapollis lucidius* (Chlon.) Chlon., *O. globosus* (Chlon.) Chlon., *Aquilapollenites aspera* N. Mitch., *Pentapollenites normales* Takah., *Mancicorpus tenue* N. Mitch., *Wodehouseia aspera* (Samoil.) *Wiggins, W. spinata* Stanl. *Triatriopollenites aroboratus* Pfl., *T. plicoides* Zakl., T. sp., *T. confusus* Zakl., *Anacolosidites insignis* Samoil., which are typical of the Late Maastrichtian – Early Danian, exhibit great diversity. We infer a Middle Maastrichtian age for the unit where a dinosaur skeleton has been discovered, though there are different points of view concerning this issue. Basing on investigations of T.Matsumoto, M.Matsukawa and I.Obata [34] place the bone-bearing layers at the Late Santonian – Early Campanian. As a proof they give the position of a *Nipponosaurus*-bearing horizon, lying 1500 m below the basal Paleogene beds, and state that it is subjacent with respect to the *Inoceramus orientalis*-bearing zone (today it is assigned into the genus *Pennatoceramus*). To add, member IV is distinguished by the rena *Inoceramus shikotanensis*, developed in the Kurils and Japan, the rena *I. kusiroensis* in member V known on the Koryak Upland, in the Kurils and Japan apart from Sakhalin. These index species define the age of the rena as Maastrichtian. The ammonite *Pachydiscus subcompressus* is ubiquitous in members IV and V. *Gaudriceras hamanakense*, recognized in the Maastrichtian in Japan and Sakhalin, is common in this zone. Apart from the above-mentioned inoceram and ammonite remains, quantities of remains of other bivalve molluscs and foraminifers were detected in members IV-V. These members are also distinguished by zones with *Neilo cuneistriata*, *Pleurogrammotodon splendens* and *Haplostiche naibica*, *Spiroplectammina grzybowskii*, being Maastrichtian index species.[11, 10, 25].

CONCLUSIONS

When correlating taxonomic compositions of pollen assemblages from the dinosaur fossil remains-bearing Maastrichtian deposits of Priamurie, Koryak Upland and South Sakahlin, strong similarities are ascertained, and there are reasons to regard them as coeval (Tables 2, 3, 4). Thus, the age of the lower part of the Kundur section, upper part of the Koryak, lower part of the Rarytkin, and lower part of the Krasnoyarka suites is estimated as Early Maastrichtian. The pollen assemblages from the above units include over 50% common taxons. A comparison of taxonomic composition of pollen assemblages from the middle part of the Kundur section (reptile fossil remains-bearing layers) with assemblages from the upper part of the Kakanaut (dinosaur, bird and macroflora burial sites), lower part of the middle subsuite of the Rarytkin, upper part of the lower subsuite of the Krasnoyarka (the discovered skeleton of Lambeosaurinae) suites permit us to infer their Middle Maastrichtian age. Similarities in taxonomic composition also indicate strong similarities between the pollen assemblages of the upper part of the Kundur section, upper part of the Rarytkin suite and upper subsuite of the Krasnoyarka suite. The age of the pollen assemblages is determined as Late Maastrichtian – Early Danian. It is surprising that all the known fossil dinosaur locations in the Russian East are of Maastrichtian, to be more precise, Middle Maastrichtian age, despite their different facial confinement: the Priamurie taphocoenoses formed in a vast river valley environment as a result of burial by mud-flows from the ancient pra-Khingan; Kakanaut taphocoenoses, in a valley amidst volcanoes smothered by quick ground, while the South Sakhalin Lambeosaurinae is buried on a sea shoal near the coast. Marine deposits of the Koryak suite also hold teeth and vertebrae of the long-necked plesiosaurs Elasmosauridae [23]. L.A.Nesov presumed intrazonation of hadrosaurs [23], and M.Matsukawa and I.Obata [34] indicated distribution of this group of animals over the Asian continent in different-genesis formations (lacustrine, fluvial, eolian, and marine), but despite such adaptation to different-temperature conditions and environments, beginning in the Late Maastrichtian dinosaurs are absent in the oryctocoenoses of the Far East. V.A.Krasilov suggested confinement of dinosaurs to the non-forest biotopes and their extinction due to ecosystem reorganizations episodes [12, 30], as the top links of the succession. According to our data, vast savanna-like landscapes with oasis vegetation spread along rivers and lakes in Middle Maastrichtian time. Dinosaur biomass, as estimated by P.Beland and D.A.Russel [29], who worked at Canadian hypoautochthonous burial sites, made up 2 tons per hectare. To provide such quantities of the herbivorous reptile with forage required a rather lush and copious vegetation, probably, well renewed. An increasing afforestration of biotopes registered from the Late Maastrichtian, according to our data, could apparently lead to dinosaur extinction, since new vegetation could not ensure existence of the population of such huge animals. The conclusion we draw from the study of fossil flora conflicts with the popular hypothesis of Alvarez & Alvarez [28] and their followers of a sudden dinosaur extinction after the fall of an asteroid. Regretfully, no work has been conducted at the site of the above-described sections aimed at revealing an iridium anomaly, but we feel that a thorough tracking of changes in phytooryctocoenoses along the section together with sedimentological and paleogeographical data, permits reconstruction of paleoenvironments and conclusions on the causes of dinosaur extinction. Incidentally, the turtle *Trionyx* tracks have been recognized in the Priamurie taphocoenoses (Table 1). This same genus still exists in North America, Asia and Africa [16]. This reptile skipped over the Cretaceous-Paleogene boundary, probably, because it was not intimately linked to terrestrial biotopes and ecosystems. One can presume that for this reason too, have survived crocodiles till modern times, also having been dwelt in the Priamurie valleys. Land dinosaurs, as closely connected with terrestrial vegetation, became extinct due to reorganization of continental ecosystems. It should be reminded that though hadrosaurs dwelt in water [36], they fed on springs, cones and leaves of conifers growing on the bank of the water body [31].

Acknowledgments. The authors express appreciation to Yu.L.Bolotsky for his data on fossil reptiles of the Amur region and for fruitful discussion of stratigraphy of the Upper Cretaceous units of the region, taphonomy and biology of dinosaurs; to T.Kezina for assistance in field work and paleobotanical material on the Amur sections; to L.A.Nesov and L.B.Golovnyova for pollen samples from the Koryak dinosaur burial sites and discussion of results. Our thanks also go to V.G.Moiseenko, Academician of the Russian Academy of Sciences, Director of the Amur Multidisciplinary Scientific-Research Institute, Far East Branch, Russian Academy of Sciences, for assistance in arrangement of field work. The authors are also grateful to Professor V.A.Krassilov for counseling and consulting.

The research was supported by the grant on biodiversity from the International Science Foundation of George Soros.

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Translated by T.N.Denisko