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Changes of the terrestrial vegetation at the end of Late Cretaceous (Amur-Zeya Basin, Russian Far East)

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Abstract: According to the paleobotanical data, paleoenvironments, climate and evolution of vegetation in eastern Asia have been reconstructed for the Berriasian Maastrichtian stages. During the Cretaceous, two critical boundaries in the development of terrestrial flora: Albian-Cenomanian and Maastrichtian-Danian (Markevich, 1995) were marked out. The latter is devoted much attention as it was at the boundary between Mesozoic and Cenozoic eras. The first crisis has been thoroughly studied using the fossil insects. 4 stages in the crisis development: preparatory, paradoxical, dramatic and calming were established including additional symptoms of the ecological crisis. We attempted to define a reaction of vascular plants, as an indispensable components of biota, to the biocoenosic crisis. Sufficient and diverse palynological material enables us to trace dynamics of the fossil flora changes, while the fossil megaflora characterises the coastal vegetation. As established by the previous researches, development and relaxation of ecological crises in the past were quite long even on a geologic time scale. Our data suggest that the biocoenotic crisis began in the Campanian-Early Maastrichtian and ended in the Paleogene. Using the symptoms of ecological crises and paleobotanic data, it is possible to determine the above-mentioned stages of crisis evolution for the Cretaceous-Paleogene biocoenosic crisis in the Russian Far East.

INTRODUCTION

The Cretaceous and Tertiary continental sediments are widely distributed in the basin of the Amur and Zeya rivers (Fig. 1). The Lower Cretaceous is represented by volcanic and volcaniclastic deposits formed at the orogenic stage of the basin development. The platform stage started since the Cenomanian time. During the whole Late Cretaceous, clayey and sandy-pebbly sediments were accumulated in the conditions of extended planes with numerous lakes and rivers, that is indicated by predomination of fine, well sorted, and laterally stable sediments.

Study of the Upper Cretaceous sediments' stratigraphy started in the middle of the last century and has been greatly contributed by the following researchers: F.B. Shmidt, O. Heer, P.K. Yavorsky, A.I. Poyarkova, S.F. Malyavin, S.V. Konstantov, V.P. Rentharten, N.I. Chernyshov, S.V. Muzylev, A.N. Ryabinin, A.N. Kryshtofovich, T.N. Baykovskaya, E.D. Zaklinskaya, V.I. Fin'ko, A.P. Sorokin, G.M. Bratceva, P.I. Bityutskaya, I.B. Mamontova, V.A. Krassilov.

It is currently believed that the Tsagayan Formation of the Maastrichtian-Danian age overlays the Zavitinskaya or Kundur Formations of the Late Cretaceous age and under lays the Kivda Formation of the Tertiary age.

A.Ya. Gurov and Manakin, a coronal of the Tsar Army, first found some dinosaur's bones in the Upper Cretaceous deposits at the right (Chinese) bank of the Amur River, lower to the Bureya River mouth, in 1902. In 1915–1916, V.P. Rentharten and N.P. Stepanov had studied the bone-bearing section there. Later, A.N. Ryabinin (1930a; 1930b) analyzed the material obtained. Yu.L. Bolotsky has been systematically studying the deposits with the reptilian fossils since the beginning of the eighties (Bolotsky and Moiseenko, 1988; Bolotsky, 1990; Bolotsky and Kurzanov, 1991; Moiseenko, Sorokin and Bolotsky, 1997). It should be mentioned that fauna of conchostracans, bivalves, and gastropods has been found in deposits of the Kundur Formation. G.G. Martinsson identified this fauna as Barremian-Aptian. That older (than correct) dating was probably done because of a bad preservation of the shells.

Our first knowledge about the plant fossils was obtained by Heer (1878) who described the F.B. Smidt's collection picked up at the foot of the Belaya (Tsagayan) Mount, right bank of the Bureya River. The fossils were identified as Miocene in age. Later, Konstantov (1913, 1914), who collected more fossils from the same location, concluded the Eocene age of the flora. Since 1914, Kryshtofovich has been studying flora of the Tsagayan Formation from the Bureya River area. As the result of this study, the flora-bearing deposits were dated as the Late Cretaceous-Danian. A deep analysis of the Tsagayan flora was done by Krassilov (1976). More recently, Kamayeva (1990) studied stratigraphy and flora of the Tsagayan, Kivda and Raichikhinsk Formations.

Palynoflora from the deposits of the Amur River Basin has been studied by Zaklinskaya (Fin'ko and Zaklinskaya, 1958), Bratceva (1965, 1969), Chlonova (1969) and Markevich (Markevich *et al.*, 1994; Markevich, 1995 and Markevich and Bugdaeva, 1997).

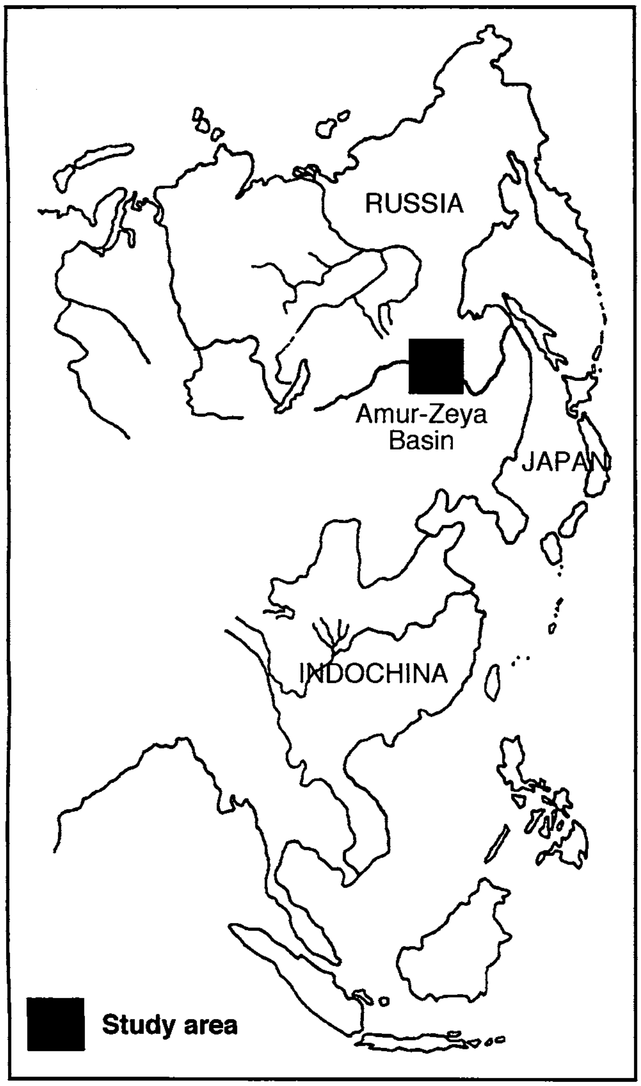

Figure 1. Location map of the study area.

In 1990, the Arkhara-Obluch'e road was built in the area, that allowed study of the previously closed sections of the Upper Cretaceous deposits. The earlier studies were mainly based on the drill cores, because the deposits being quite soft had been almost completely covered by soil. We obtained a possibility to study a long continued section of the deposits in the area between the Mutnaya and Udurchukan Rivers in 1997. Bolotsky (1990) discovered a location with numerous bones of dinosaurs, crocodiles and turtles there.

In 1993 and 1997, we together with the Chinese researchers (Chen Peiji, Li Wenben, Cao Zhengyao, and Cao Meizhen fron the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences; Lyu Zhaojun and Wang Symin from the Chanchung University) studied the section near the Kundur Village. In addition to the authors, the Russian team included A.P. Sorokin (Corresponding Member of the Russian Academy of Sciences, AmurKNII, Blagoveshchensk), G.L. Kirillova (Khabarovsk), and V.P. Nechaev (Vladivostok).

STRATIGRAPHY

The section starts 900 m from the bridge across the Udurchukan River (Figs. 2–3). The following deposits are there (upward description after G.L. Kirillova):

Section 15:

1. Sandstone gray, bedding, bearing a plant detritus along the bed boundaries — 1.8 m;
2. Very solid, gray, calcareous sandstone bearing a rare plant debris in the upper part — 0.5 m;
3. Thin interbedding of solid, gray and light-gray sandstones and calcareous siltstones — 0.5 m;
4. Gray, not so solid, bedding, fine sandstones interbedding with dark-gray siltstones (interlayers of 1–10 mm in thickness) — 1.3 m;
5. Brownish-gray, bedding, not so solid sandstone with abundant plant debris — 1.5 m;
6. Dark-gray siltstone — 1.5 m;
7. Yellowish-greenish-brown, fine, laminating sandstone — 3 m;
8. Fine-grained clastic deposits, dark siltstones and sandstones — 6 m;
9. Very solid, calcareous sandstone with numerous water-current imprints at the bed boundaries — 1 m;
10. Gray and yellow-gray, bedding sandstones with a plant debris. G.L. Kirillova identified these deposits as shallow-lake turbidites — 8 m.

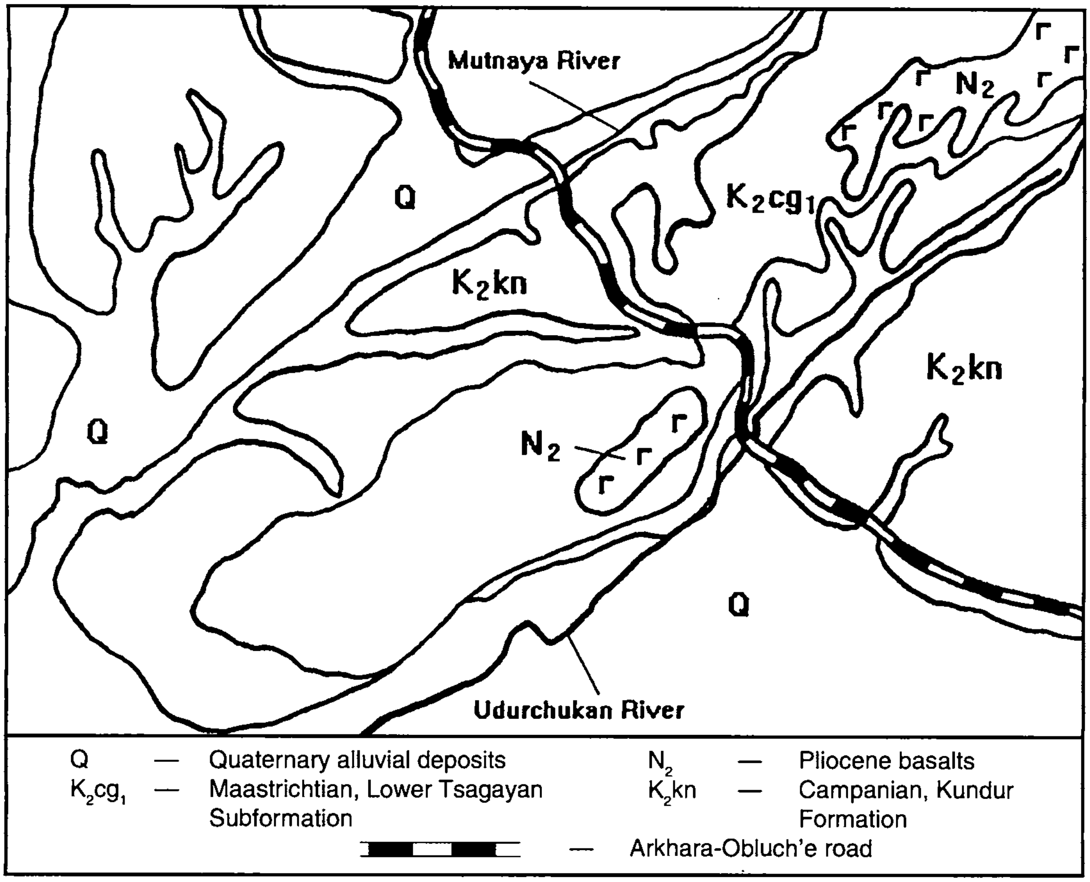

Figure 2. Geological map of south-east part of Amur-Zeya basin (created by A.P. Sorokin, scale 1 cm : 2 km)

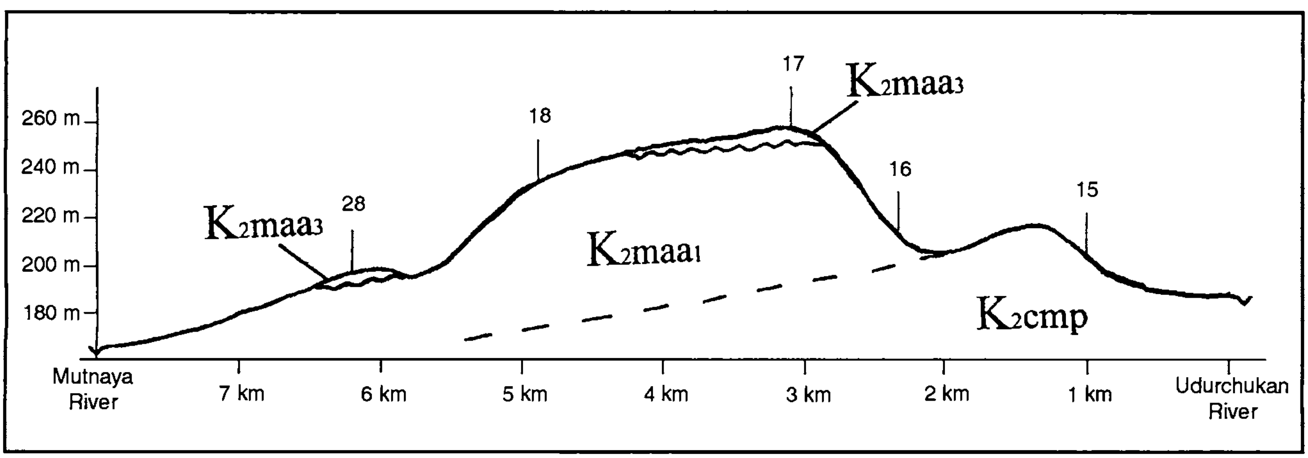

Figure 3. Section of the Campanian-Maastrichtian deposits (Priamurye).

Section 16

2.2 km off the Udurchukan River Bridge. There are yellow-gray poorly sorted sand overlain by gray clay (0.3–0.5 m in thickness), and, then, yellow sand with coal interbeds (0.3 m).

Section 17 — Upward description:

1. Pebble with a sandy matrix, yellowish-gray, polymictic — 15 m.
2. Yellowish-gray, poorly sorted sand with some well rounded polymictic pebble and gravel. The coarse material traces a cross and lens-form bedding like that in the sections of Sites 28 and 29. The deposits near the upper, uneven boundary of the bad are rusty, containing abundant iron hydroxides. Thickness is 0.8–1 m.
3. Mixtite, that is claystone with abundant (10–30%) gravel and, less commonly, pebble. The coarse-grained material is polymictic in composition, containing clasts of gray quartz (90%), metamorphic rocks and felsic volcanics. The claystone is dark-gray, greenish or brownish in some spots, massive, quite homogenous that distinctly differs it from claystone of Section 28. There is no plant debris. Pebble is concentrated in the lower part (1 m) of the layer, where some dinosaur bones have been found out. There is a thin weathering crust, bearing a tiny (1–2 cm) interlayer of iron hydroxides. This mixtite layer is traced by many small outcrops till Section 18. Its thickness is varying from 5 to 6 m.
4. Pebble resembling that described in paragraph 1 of this section and paragraphs 4 and 8 of Section 28. Thickness is about 10 m.
5. Yellowish-gray, poorly sorted, cross-bedding sand with some polymictic pebble and gravel — 0.5 m.
6. Greenish-gray, rusty in many spots, sandy claystone with some gravel in the upper part. Throughout the layer, massive and quite soft claystone of light-greenish-gray color contains numerous rounded masses of a darker and more solid claystone. Thickness of the layer is 1 m.
7. Yellowish-gray, coarse, clayey and pebbly sand — 0.5 m.

Section 18

This section is named as the Kundur Locality of dinosaur, crocodile, and turtle bones. It consists of mixtite similar to that described above (Layer 3, Site 17). Thickness is not less than 3 m; overlaying and underlaying deposits being covered by soil.

Section 28

Quarry for the road construction material, upward description:

1. Brownish-grey claystone with poorly-preserved plant remains — about 1 m.
2. Pebble with gray, in some spots rusty, sandy matrix — 1 m.
3. Yellowish-gray and gray, poorly sorted sand with fine, polymictic pebble in the upper, lower and other parts. There is a lens-form crossbedding indicating a water current from 350°. Thickness of the layer is 0.8–1 m.
4. Lens of chocolate-brown claystone with numerous plant detritus — up to 0.8 m in thickness.
5. Gray, rusty-gray in some spots pebble with sandy matrix. Separate lenses reaching 20–30 m in thickness are distinguished by deposits with different pebble-sand ratio: either pebble with more abundant sandy matrix (up to sand with some pebble) or coarse pebble with insignificant matrix. Thickness of the layer is 4–5 m.
6. Lens of gray, crossbedding sand with some fine pebble and gravel. Thickness is up to 0.7 m.
7. Chocolate-brown, brownish-gray and sandy in the middle part claystone with numerous plant debris and horizontal bedding throughout the layer. Thickness of the layer is up to 1.2 m.
8. Yellowish-gray, poorly sorted sand with fine pebble and gravel of polymictic composition. There are lenses of fine pebble and claystone in the upper part (30 cm) of the layer which total thickness is up to 1.5 m.
9. Pebble like that in layer 5. Thickness is about 4.5 m.

CAMPANIAN FLORA

The palynological assemblage has been studied from sandstone of Section 15 (samples 1 and 2). It is characterized by a significant role of pteridophytes (Fig. 4). Among them, the most abundant are those close to Cyatheaceae and Dicksoniaceae, as well as Polypodiaceae. Among gymnosperms, there is a lot of Ginkgocycadophytus, as well as various bisaccate pollen close to Pinaceae and Podocarpaceae. The Araucariaceae are also numerous. Pollen close to that of Taxodiaceae reaches 15%. There are some Gnetales. Pollen of angiosperms is diverse and reaches more than 30%. It is predominated by Tricolpites, Tricolpopollenites that probably belongs to Platanaceae and Fagaceae. In addition, we have found pollen of the plants related to the modern ones: Betulaceae (Alnuspollenites sp.), Juglandaceae (Juglanspollenites sp.), Santalaceae [Kuprianopollis elegans (Zakl.), K. santaloides (Zakl.) Kom.], Loranthaceae [Cranwellia striata (Coup.) Sriv.], Proteaceae (Proteacidites thalmanii Anders., P.bellus Samoil.), Ericaceaea. The "unica"-type pollen is the most diverse. It was produced by plants which relation to the modern families is still under discussion. These are Aquilapollenites cruciformis N. Mtch., A. reductus Nort., A. subtilis N. Mtch., A. cateniceticulatus Sriv., A. insignis N. Mtch., A. amygdaloides Sriv., A. conatus Nort., A. sp.; Parviproectus amurensis Bratz., P. dolium Samoil.; Mancicorpus tenue N. Mtch., M. anchoriforme N. Mtch., M. solidum N. Mtch.; Duplosporis borealis Chlon. The Oculata-type pollen is represented by Wodehouseia aspera (Samoil.) Wigg., W. spinata Stanl., W. gracilis (Samoil.), as well as Orbiculapollis lucidus (Chlon.) Chlon., O. globosus (Chlon.) Chlon.

The following plant fossils have been collected from these beds: Asplenium sp., Ginkoites sp., Taxodium olrikii (Heer), Pityostrobus sp., Trochodendroides ex gr. arctica (Heer), "Platanus" raynoldsii Newb.

Taxonomic composition of the spores and pollen predominated by heat-loving forms (Cyatheaceae, Dicksoniaceae, Ginkgocycadophytus, Podocarpaceae, Araucariaceae and probably some coniferous) indicate subtropical climate. The angiopserms are chiefly represented by Loranthaceae, Santalaceae, Proteaceae. Among representatives of genus Aquilapollenites, the most common are also the heat-loving species, many of which are typical for the Campanian palynofloras, while the Maastrichtian ones are absent or represented by single examples.

EARLY MAASTRICHTIAN FLORA

The bone-bearing beds are hosted by the Lower Maastrichtian deposits: the lower part of the Section 17 with rare fragments of bones and Section 18 — the Kundur Locality — containing remains of crocodiles, turtles (Mongolemys cf. planicostatus, Trionyx sp.) and some dinosaurs of the families Tyrannosauridae, Ornithomimidae, Dromaesauridae, Troodontidae, Titanosauridae, Hadrosauridae, Nodosauridae (Yu.L. Bolotsky's identification). The deposits of Section 16 and the lower part of Section 28 are similar to them in age.

Palynological assemblage from the deposits of Section 16 and the lower part of Section 28 is still predominated by spores close to Cyatheaceae and Dicksoniaceae, as well as Polypodiaceae (Figs. 5–7). Among gymnosperms, Taxodiaceae are predominating and associated with Ginkgocycadophytus. A role of plants with bisaccate pollen close to Pinaceae is unsignificant. A characteristic feature of the palynoflora is an increased content and taxonomic diversity of angiosperms. Among Aquilapollenites, the typically Campanian heat-loving species had gone.

The palynological assemblage from the bone-bearing beds (samples 1, 2a, 4a from the lower part of section 17; samples 1 and 3 from section 18) is

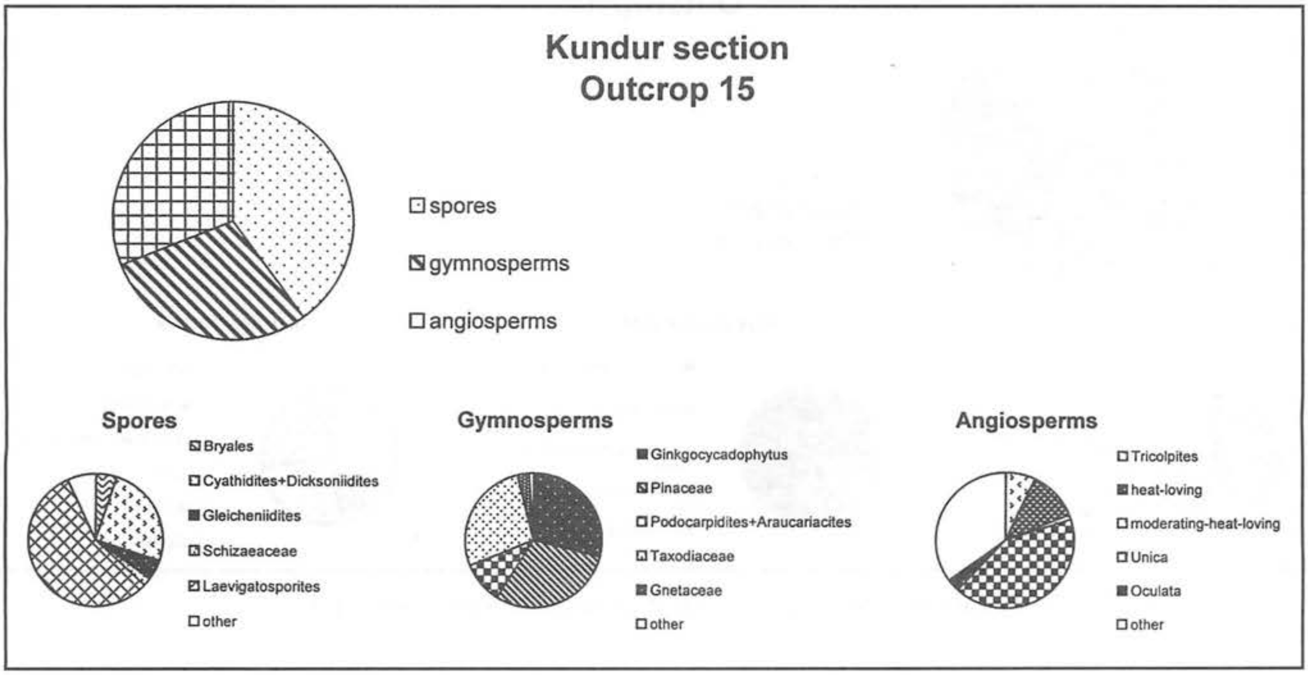

Figure 4. Palynological assemblage, Kundur section, outcrop 15.

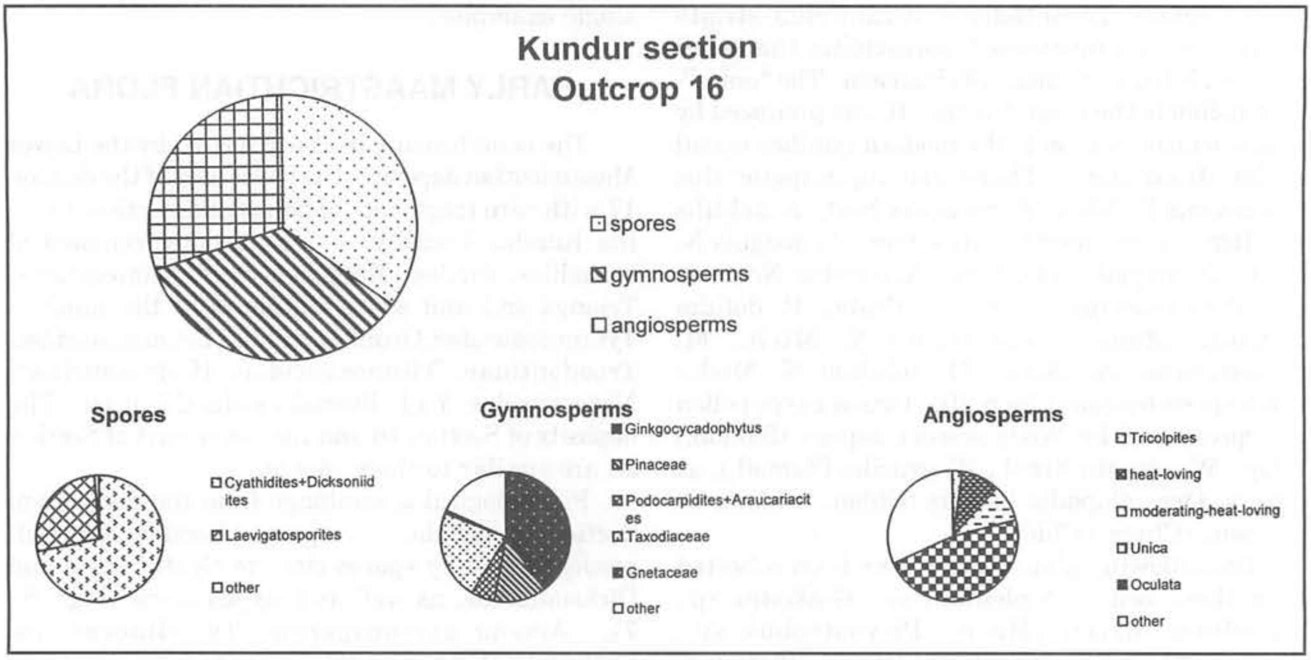

Figure 5. Palynological assemblage, Kundur section, outcrop 16.

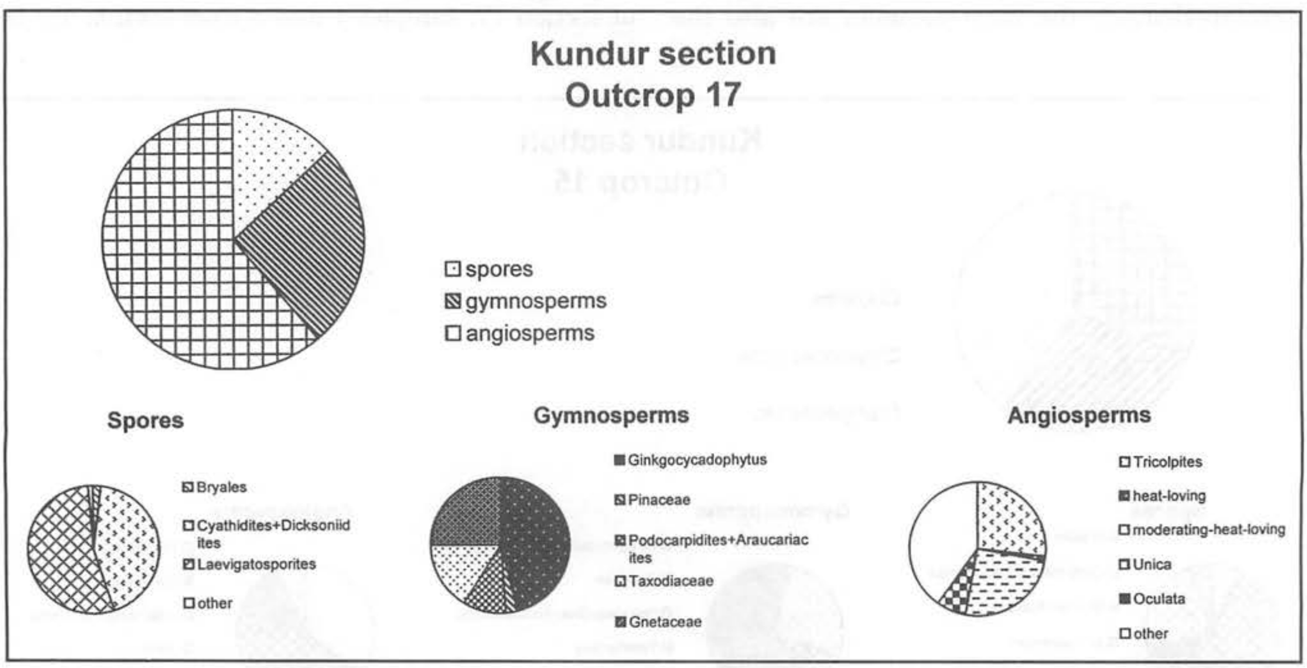

Figure 6. Palynological assemblage, Kundur section, outcrop 17.

characterized by an significantly decreased content and taxonomic diversity of the Pteridophyta spores. Among gymnosperms, pollen of Ginkgocycadophytus, as well as Taxodiaceae is abundant. Gnetaceae are also well represented (6 species, up to 17%). The species close to Pinaceae and Podocarpaceae (10 species) represent an insignificant part of the assemblage (up to 15% totally). Among angiosperms, which commonly predominate, the pollen probably belonging to Fagaceae and Platanaceae is numerous — Tricolpites spp., T. reticulatus Coup., Troporopollenites sp., T. plectosus Anders., Tricolpoporopollenites sp., T.radiatostriatus (N. Mtch.) Bratz. Triatriopollenites aroboratus Pfl., T. confusus Zakl. predominating in the Upper Maastrichtian is appearing. In the palynoflora, diversity of the pollen close to Ulmaceae, Lileaceae, Betulaceae, Juglandaceae, Nyssaceae, Myricaceae, Santalaceae, Proteacaeae and others is increasing. A role of the "unica"-type pollen is low. It is represented by Aquilapollenites cruciformis N. Mtch., A. quadrilobus Rouse, A. catenireticulatus Sriv., A. amygdaloides Sriv., Pentapollenites normales Takah., Fibulapollis mirificus Chlon., F. hamulatus Takah. The palynological assemblage chiefly inherits the characteristics of the Campanian one. It still contains numerous heat-loving ferns, although their diversity is significantly lower. Among gymnosperms, Ginkgocycadophytus, Podocarpaceae and Araucariaceae (indicators of warm climate) are associated with diverse Gnetaceae (6 species, up to 17%), suggesting that climate became somewhat drier. Among angiosperms, amount of Tricolpites close to Platanaceae and Fagaceae is high, but a role of pollen close to Proteaceae, Santalaceae and Loranthaceae fall. These heat-loving species are replaced by the warm-moderate ones. Climate became less warm, but quite wet. There was no dramatic changes of vegetation. Nevertheless, taxonomic composition of palynoflora evidences it was a little bit colder than previously.

MIDDLE MAASTRICHTIAN FLORA

Although the Middle Maastrichtian is absent in the section described, there are several localities with the deposits containing fossil reptiles and palynoflora of the Middle Maastrichtian age near the Blagoveshchensk City and the Gilchin Village. These palynological data cover the hiatus of the Kundur section.

The palynoflora from the localities above mentioned consists of Ginkgocycadophytus, Araucariaceae and Podocarpaceae predominating among gymnosperms (Figs. 8–9). Diversity and content of the pollen close to Pinaceae was increasing. A role of fern was decreasing since termination of many heat-loving Early Cretaceous species. Among angiosperms, significance of deciduous warm-moderate (including those close to Ulmaceae) species was increasing. Diversity of

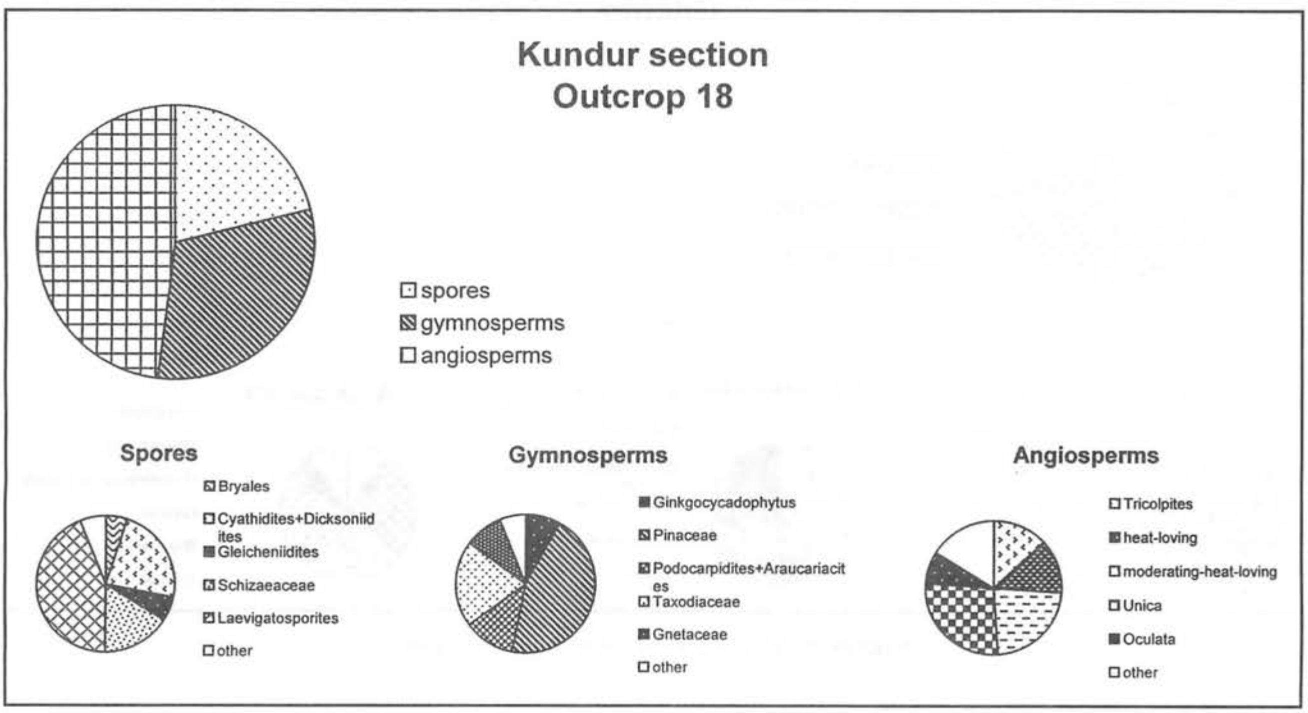

Figure 7. Palynological assemblage, Kundur section, outcrop 18.

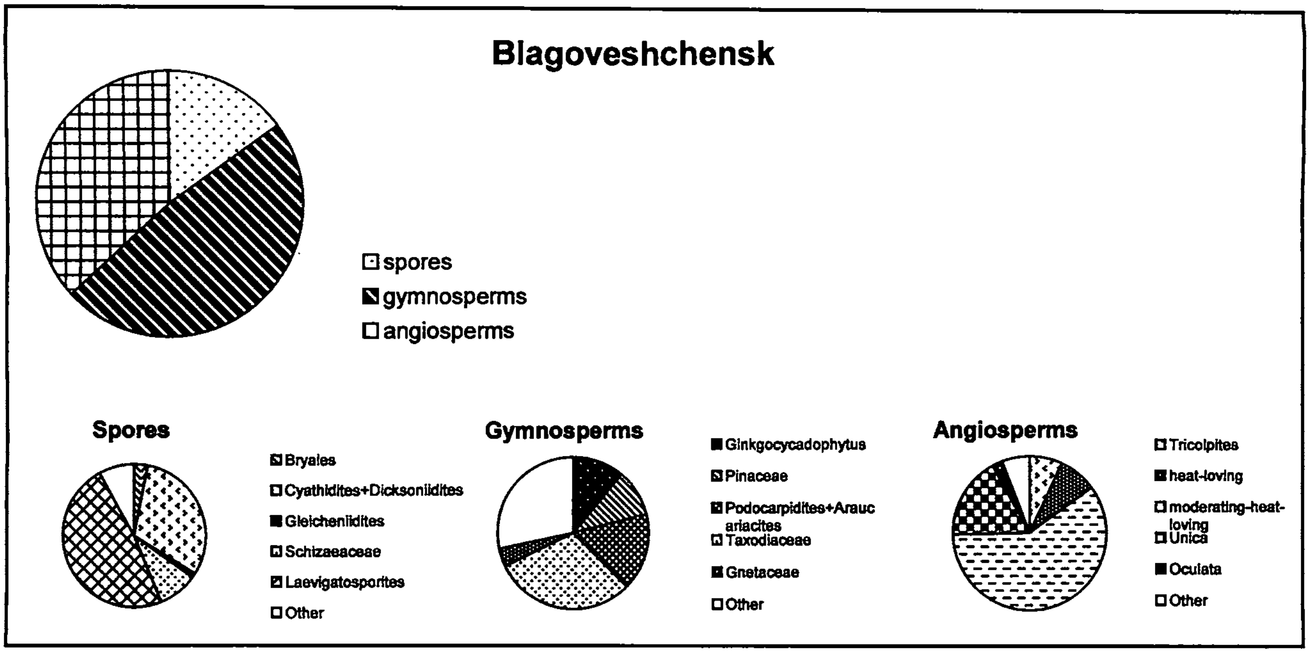

Figure 8. Palynological assemblage, Blagoveshchensk.

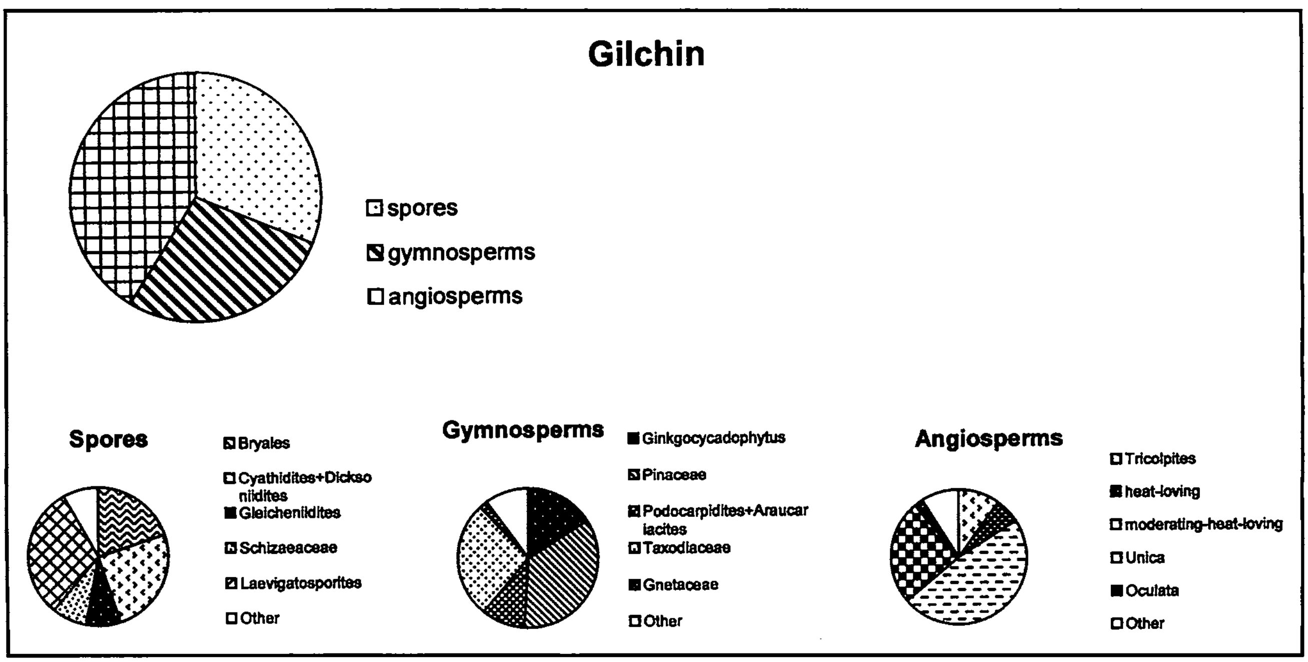

Figure 9. Palynological assemblage, Gilchin.

species close to Santalaceae, Loranthaceae, Proteaceae, as well as the plants with the Tricolpites pollen is lowering. The plants producing the "unica"-type pollen were still predominating. Climate was most likely warm, although somewhat colder than that in the Early Maastrichtian, probably indicating increasing seasoning of the weather.

LATE MAASTRICHTIAN FLORA

The palynological assemblage from the upper part of this section (samples 5, 5a, 6, 7, 9 from section 17; samples 2, 3, 8, 9 from section 28) is characterized by decrease of pteridophyte spores (8 species, up to 26%) and pollen of heat-loving species (Fig. 10). Composition of the angiosperms pollen was also sharply changed. A role of Ulmaceae, Juglandaceae, Platanaceae and Fagaceae was increased. Significance of the "unica"-type pollen decreased, while that of the "oculata"-type ones increased. The latter are one of the dominants, composing up to 23% of the assemblage. They are supposed to be produced by some water plants. A high role of these plants, as well as the plants close to Taxodiaceae allow us to suggest numerous water basins in the area. Thus, taxonomic composition of palynoflora sufficiently changed in the Late Maastrichtian: many heat-loving species of flowering plants had been replaced by the warm-moderate broad-leaved plants.

There, in layer 6 of Section 28, the following fossils were found: Equisetum cf. arcticum Heer, Taxodium sp., "Cephalotaxopsis" sp., Elatocladus aff. talensis Golovn., Czekanowskia (?) sp. nov., Nyssa cf. bureica Krassil., Diplophyllum amurensis Krassil., small-leaved Trochodendroides ex gr. arctica (Heer), "Platanus" raynoldsii Newb. The conifers — Elatocladus and Taxodium — are predominating in taphocoenosis. The fossils were buried abundantly, chaotically, without any orientation.

DINOSAUR FAUNA AND ITS CONNECTION WITH ENVIRONMENT AND VEGETATION

By studying a geological section along Arhara-Obluch'e road, we had an opportunity to observe a sequence of changing of the lithological environments and floral assemblages in detail. The presence here of bone-bearing beds gives us an opportunity for speculation about connection of dinosaur's burial places with fossil flora and palaeoenvironment. It was revealed, that bone-bearing oryctocoenoses, with prevailing of the hadrosaur remains, are typical for the certain layers, so-called mixtites, which are the result of accumulation from mudflows. The remains of bones in the outcrop 17 have been revealed in the

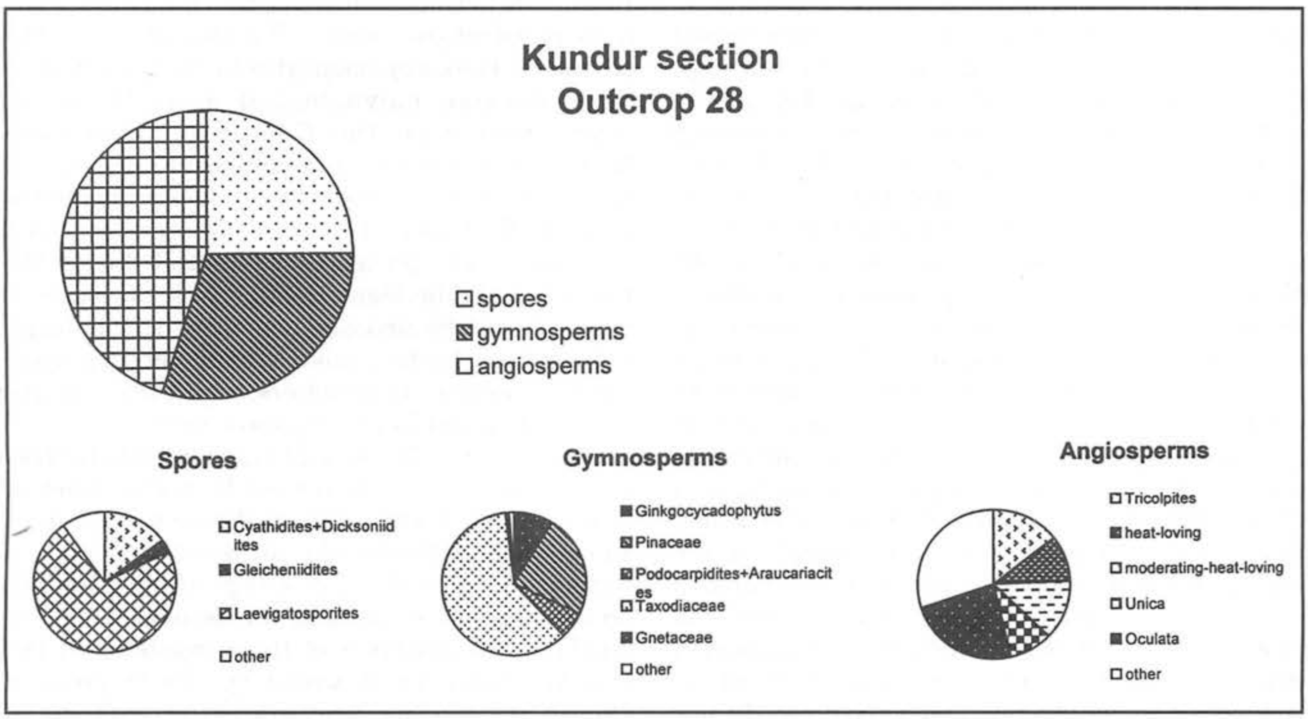

Figure 10. Palynological assemblage, Kundur section, outcrop 28.

lowermost part of mixtite, overlain by from 10 to 20-centimetre thick ironshot layer (ancient weathering crust). In this section the sedimentary complex of a river valley (presence of crossbedding sandstones above and below of the bone-bearing beds) are reconstructed. For a short period this place was surfaced with pausing of the sediment accumulation. Presence of the mixtites with similar remains of reptiles near Blagoveshchensk and Gilchin village evidences for extensiveness of the basin, covered later by sediments of mudflows. Habitat of hadrosaurs was established for North America and Mongolia (Ostrom, 1964; Jerzykiewicz, 1995). In any case, the dinosaurs preferred vast plains with a low relief and a plenty of the meandering rivers, marshes. In case of seaside lowlands there were the valleys of flooding and estuarine deltas. As is seen, the similar conditions are reconstructed for the palaeobiotopes of the Priamurye hadrosaurs. The fact of uniformity of hadrosaurs burials in North of America, in northeast of Russia and Priamurye is important. Everywhere the reptiles were buried as a result of landslips, mudflows or "quick grounds". Their bones in orycticoenoses typically show direct strokes, as result of its dragging by a flows through a hard ground (Nessov, 1995, 1997; Nessov *et al.*, 1990).

It is considered, that hadrosaurs preferred seaside lowlands, but the presence and even domination of their remains in the fossil fauna of Mongolia and Priamurye demonstrate that in Early and Middle Maastrichtian the favorable condition in fodder base, territory (vast plain, large number of fine reservoirs) and temperature conditions (absence of sharp differences of temperatures) existed in intercontinental basins. By the way, lithological sequence in Mongolia and Priamur'ya testifies to an one-orientation of climatic changing in Late Cretaceous. According to Jerzykiewicz (1995), the formations of Djadokhta and Barun-Goyot, including desert and semidesert eolian sandstones, in Maastrichtian were replaced by Nemegt Formation, which is predominantly alluvial in an origin. The Campanian sediments of Priamurye are represented by lacustrine carbonatized sandstones. The carbonatization event evidences for the semiarid environmental conditions. Similar to Mongolia, the Maastrichtian deposits indicate a river origin. Changing of a climate from arid to humid is obvious. Let's remind, that hadrosaurs being terrestrial animals on the biology (proved by their bipedalism), required a water environment, because they had not any protective adaptations (Ostrom, 1964). Campanian deposits in Priamurye are characterized by sediments of the shallow and vast lake. In our opinion, the humid conditions in Campanian changed to drier in Early and Middle Maastrichtian and then again to more humid in Late Maastrichtian. It is possible, that the lake in Amur-Zeya basin had been dried and broken up to set of small reservoirs in the beginning of Maastrichtian, that resulted in surfacing of a vast plain. Then of this lowland the meandering river proceeded. Uplift of the territory in Late Maastrichtian had caused erosion marginal parts of the Middle Maastrichtian mixtite deposits. And only in axial parts of basin the Middle Maastrichtian sediments were mapped (Blagoveshchensk and Gilchin village), while in the Kundur section, it was absent. As it was specified by Krausel (1922) and Ostrom (1964), the basic food resource included seeds, cones, shoots and branches of conifers. By analyzing the taxonomic composition of the palynoflora, we can see the increasing of a variety and quantitative participation of conifers in the interval of the Early and Middle Maastrichtian. We have already pointed to importance of Ginkgocycadophytus pollen in Early Cretaceous, containing the dinosaur's foot prints (for example, formation of Tongfosi in the northeast China). There are no precise linkage between this pollen and any specific plant (as it can belong to ginkgoaleans, bennettites and cycads), but clear positive correlation between dinosaur and this palynomorph in oryctocoenoses are presence. Ginkgocycadophytus pollen could belong to cycadophytes. These plants were specified by Krassilov (1981, 1985) and Krassilov *et al.* (1990) as the basic food for dinosaurs. According to Nessov (1997), troodontids (Troodon occurs in Kundur and Blagoveshchensk localities) gnawed out the seeds from cycadophyte cones. We also observed the peak of the Ginkgocycadophytus in the Early-Middle Maastrichtian palynological assemblages in comparison with the Campanian and Late Maastrichtian ones, that supports the idea of Krassilov (1981). Probably, Ginkgocycadophytus and conifers were the base of dinosaur food allowance. The presence of foodstuff during the Early and Middle Maastrichtian was, obviously, a main factor of the dinosaur's existence in Priamurye. In turn, these herbivorous dinosaurs might provide a fodder resource to predators, which few remains also are founded in the oryctocoenoses.

The Late Maastrichtian palynological assemblages are characterized by replacement of heat-loving forms by warm-moderate broad-leaved ones, that reflects the progressing fall of temperature and increasing of a seasonal prevalence. It is possible to assume, that the regularity in mutation of the ecosystems in the Maastrichtian, accompanied by strong press of abiotic transformations, provoked a chain of consecutive, irreversible, and fast changing of their structures. Probably, in Priamurye the dinosaur's extinction took place at the end of Middle Maastrichtian. The Late Maastrichtian uplift of Amur-Zeya basin, probably, reflects the global tectonic processes which resulted to global regression at the time, about the boundary of the Cretaceous and Paleogene.

CONCLUSIONS

The data obtained allow the following suggestions on palaeoenvironments and palaeofloras of the Late Cretaceous in the Amur-Zeya Basin. During the Campanian the shallow lake was on this territory. The climate was warm and humid. During the Early and Middle Maastrichtian it was vast plain with abundant vegetation, shallow water reservoirs and meandering river. It was favourable biotope for dinosaurs, turtles and crocodiles. The climate during the Maastrichtian gradually became cold. After Earthquakes or catastrophic rains the mudflows came down burying the reptiles. The vegetation and climate of the Late Maastrichtian could not provide existence of dinosaurs. Moreover, the extensive plain, represented favourable dinosaur habitat, disappeared, as general uplift of region. Thus, in Priamurye dinosaurs have extinct to end of the Middle Maastrichtian.

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REFERENCES

BOLOTSKY, YU.L., 1990. Blagoveshchenskoe mestonakhozhdenie melovykh dinosavrov (Blagoveshchensk locality of the Cretaceous dinosaurs). *In:* Krassilov V.A (Ed.), Kontinental'ny mel SSSR (Continental Cretaceous of the U.S.S.R.). *DVO AN SSSR: Vladivostok*, 109–113 (in Russian).

BOLOTSKY, YU.L. AND KURZANOV, S.M., 1991. Hadrosavry Priamurya (Hadrosaurs of Priamurye region). *In:* Moisseyenko, V.G. and Zagruzina, I.A. (Eds.), Geologiya Tikhookeanskogo obramleniya (Materialy mezhdunarodnogo symposiuma "Glubinnoe stroenie Tikhogo okeana i ego kontinental'nogo obramleniya") (Geology of Pacific frame (Materials of International Symposium "Deep structure of Pacific ocean and its continental frame"). *AmurKNII DVO SSSR, Blagoveshchensk*, 94–103 (in Russian).

BOLOTSKY, YU.L. AND MOISEENKO, V.G., 1988. O dinosavrakh Priamur'ya (On dinosaurs of Priamurye). *AmurKNII DVO AN SSSR, Blagoveshchensk*, 37p (in Russian).

BRATZEVA, G.M., 1965. Pyl'tsa i spory maastrikhtskikh otlozheniy Dal'nego Vostoka (Pollen and spores of the Maastrichtian deposits of Far East). Nauka, Moscow, 40p (in Russian).

BRATZEVA, G.M., 1969. Palynologicheskie issledovaniya verkhnego mela i paleogena Dal'nego Vostoka. *Trudy GIN AN SSSR* (Transactions of Geological Institute of Academy of Sciences of USSR) *207*, 56p (in Russian).

CHLONOVA, A.F., 1969. Sporovo-pyl'tsevaya kharakteristica melovykh otlozhenyi Zeya-Bureinskoi vpadiny (Spores and pollen characteristics of the Cretaceous deposits of Zeya-Bureya depression). *In:* Sharudo I.I., Sporovo-pyl'tsevye komplexy Mesosoya Sibiri i Dal'nego Vostoka (Palynological assemblages of the Mesozoic of Siberia and Far East). Nauka, Moscow, 5–64 (in Russian).

FIN'KO, V.I. AND ZAKLINSKAYA, E.D., 1958. K voprosu o stratigraphii rykhlykh otlozheniy Zeisko-Bureinskoy depressii (On a problem of stratigraphy of mellow deposits of Zeya-Bureya River). *Izvestiya AN SSSR, ser. geol. (Proceedings of the Academy of Sciences of USSR, geological series) 2*, 25–43 (in Russian).

HEER, O., 1878. Beitrage zur fossilen Flora Sibiriens und des Amurlandes. *Flora fossilis arctica 5, N2*, 1–58.

JERZYKIEWICZ, T., 1995. Cretaceous vertebrate-bearing strata of the Gobi and Ordos basins — a demise of the Central Asian lacustrine dinosaur habitat. *In:* Ki-Hong Chang, Sun-Ok Park (Eds.), *Environment and tectonic history of East and South Asia with emphasis on Cretaceous correlation (IGCP 350)*. Kyungpook National University, Taegu, 233–256.

KAMAEVA, A.M., 1990. Stratigraphiya i flora pogranichnykh otlozheniy mela i paleogena Zeisko-Bureinskoi vpadiny (Stratigraphy and flora of the Cretaceous-Paleogene boundary deposits of Zeya-Bureya depression). *AmurKNII DVO RAN, Khabarovsk*, 67p (in Russian).

KONSTANTOV, S.V., 1913. Neskol'ko predstaviteley flory miocenovykh otlozheniy nizov'ev r. Burei (Some representatives of flora from the Miocene deposits in the lower reaches of Bureya River). *Izvestiya Geol. Com. (Transactions of Geological Committee) 32*, 2–3 (in Russian).

KONSTANTOV, S.V., 1914. Tretichnaya flora Belogorodskogo obnazheniya v nizov'e r. Burei (Tertiary flora of Belogorod locality in the lower reaches of Bureya River). *Izvestiya Geol. Com. (Transactions of Geological Committee) 113*, 1–27 (in Russian).

KRASSILOV, V.A., 1976. *Tsagayanskaya flora Amurskoi oblasti (Tsagayan flora of Amur region)*. Nauka, Moscow, 92p (in Russian).

KRASSILOV, V.A., 1981. Changes of Mesoxoic vegetation and the extinction of dinosaurs. *Palaeogeogr., Palaeoclimatol., Palaeoecol. 34*, 207–224.

KRASSILOV, V.A., 1985. *Melovoy period* (The Cretaceous period). Nauka, Moscow, 239p (in Russian).

KRASSILOV, V.A., GOLOVNEVA, L.B. AND NESSOV, L.A., 1990. Cykadophyt iz mestonakhozhdeniya pozdnemelovykh dinozavrov v Severnoi Koryakii (Cycadophyte from the Late Cretaceous dinosaur-bearing locality in North Koryakia). *In:* Krassilov V.A. (Ed.), Kontinental'ny mel SSSR (The continental Cretaceous of the U.S.S.R). *DVO AN SSSR, Vladivostok*, 213–215 (in Russian).

KRAUSEL, R., 1922. Die Nahrung von Trachodon. *Palaontol. Ztschr., 4*, 80.

MARKEVICH, V.S., 1995. Melovaya palynoflora severa Vostochnoi Asii (Cretaceous palynoflora of North of East Asia). Dalnauka, Vladivostok, 172p (in Russian).

MARKEVICH, V.S., BOLOTSKY, YU.L. AND BUGDAEVA, E.V., 1994. Kundurskoe mestonakhozhdenie dinozavrov v Priamurye (Dinosaur-bearing Kundur locality in Amur region). *Tikhookeanskaya geologiya (Pacific geology) 6*, 96–107 (in Russian).

MARKEVICH, V.S. AND BUGDAEVA, E.V., 1997. Flora i correlyacia sloyov s ostatkami dinosavrov Rossiyskogo Dal'nego Vostoka (Flora and correlation of dinosaur-bearing beds of Russian Far East). *Tikhookeanskaya geologiya (Pacific Geology), 16(6)*, 114–124 (in Russian).

MOISEYENKO, V.G., SOROKIN, A.P. AND BOLOTSKY, YU.L., 1997. Iskopaemye reptilii Priamur'ya (Fossil reptiles of the Amur region). Magellan, Khabarovsk, 53p (in Russian).

NESSOV, L.A., 1995. *Dinosavry Severnoi Evrasii: novye dannye o sostave compleksov, ecologii i paleobiogeographii (Dinosaurs of North Eurasia: new data on composition of assemblages, ecology and paleobiogeography)*. University of Sankt-Petersburg, Sankt-Petersburg, 156p (in Russian).

NESSOV, L.A., 1997. *Nemorskie pozvonochnye melovogo perioda Severnoi Evrasii (Cretaceous nonmarine vertebrates of Northern Eurasia)*. University of Sankt-Petersburg, Sankt-Petersburg, 218p (in Russian).

NESSOV, L.A. AND GOLOVNEVA, L.B., 1990. Istoriya razvitiya flory, fauny pozvonochnykh i klimata v pozdnem senone na severo-vostoke Koryakskogo nagor'ya (History of development of flora, vertebrate fauna and climate in the Late Senonian on North-East of Koryak Upland). *In:* Krassilov V.A. (Ed.), Kontinental'ny mel SSSR (The continental Cretaceous of the U.S.S.R). *DVO AN SSSR, Vladivostok*, 191–212 (in Russian).

OSTROM, J.H., 1964. A reconsideration of the paleoecology of hadrosaurian dinosaurs. *Amer. Sci., 262*, 975–997.

RYABININ, A.N., 1930a. Mandschurosaurus amurensis gen. et sp. nov. utkonosy dinosavr iz verkhnego mela r.Amur (Mandschurosaurus amurensis gen. et sp. nov. -duck-billed dinosaur from the Upper Cretaceous of Amur River). *Monogr. Russkogo Palaeontol. Obshchestva* (Monographs of Russian Palaeontological Society) 2, 36p (in Russian).

RYABININ, A.N., 1930b. K voprosu o faune i vozraste dinozavrovykh sloyov na r.Amur (On problem of fauna and geological age of dinosaur-bearing beds of Amur River). *Zapiski Russkogo Mineralog. Obshchestva* (Transactions of Russian Mineralogical Society) *59, N 1*, 41–51 (in Russian).

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