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Cretaceous Ecosystems and Their Responses to Paleoenvironmental Changes in Asia and the Western Pacific

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The book contains materials of the reports submitted to the Fourth International Symposium of International Geoscience Programme (IGCP) Project 608. Theoretical, methodical and practical questions of Cretaceous paleogeography, paleontological characteristics and stratigraphy of different regions of Asia and the Western Pacific are discussed. The significant attention is given to the Cretaceous climate and environmental changes, biogeography, biodiversity of terrestrial and marine ecosystems, and vertebrates of Asia and Western Pacific.

This book will be of interest to a wide range of geoscientists who study the Cretaceous Period.

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The mid-Cretaceous swamp plant communities of northeastern Asia

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In eastern Russia, the coal-bearing deposits that were formed during the Barremian–Albian in the high and mid-latitudes are widespread. The former developed in the region of Yakutia and Chukotka, the latter – in the Amur region and Primorye. We studied the fossil floras of the Ainakhkurgen (Aptian) and Chimchememel (Early Albian) formations of the Ainakhkurgen Basin located in the middle reaches of the Anuy River (Chukotka). The lower part of the sequence formed in a marine environment, the upper part – in brackish and continental environments.

The palynological assemblage of the Ainakhkurgen Formation is dominated by ferns having affinity with Cyatheaceae, Dicksoniaceae and Osmundaceae. They are accompanied by ferns close to Polypodiaceae. Spores of Gleicheniaceae are rare and sporadic, while spores of Schizaeaceae occur somewhat more common. Among gymnosperms the conifers (Pinaceae and Podocarpaceae) and *Ginkgocycadophytus* sp. dominate. They are accompanied by taxa close to Taxodiaceae and Podozamitaceae.

The fossil plants of the Ainakhkurgen Formation (Filippova, 1975) are represented by ferns, cycadaleans, bennettitaleans, ginkgoaleans, czekanowskialeans, and conifers (Pinaceae and Podozamitaceae).

The palynological assemblage of the Chimchememel Formation is dominated by the gymnosperms. Among them *Ginkgocycadophytus* sp., Pinaceae, Podocarpaceae and Taxodiaceae prevail. The percentage of pollen of Podozamitaceae decreases and pollen of Cheirolepidiaceae increases. The taxonomic composition of spores is depleted. They are mainly represented by taxa close to Cyatheaceae and Dicksoniaceae, the share of Osmundaceae sharply reduces. The representatives of Gleicheniaceae and Schizaeaceae are rare.

The fossil plants of the Chimchememel Formation (Filippova, 1975) include horsetails, bryophytes, ferns, bennettites, ginkgoaleans, czekanowskialeans and conifers (Pinaceae, Cheirolepidiaceae, Podozamitaceae, and Taxodiaceae).

Both floras have depleted and rather unvaried taxonomic composition. During the Aptian, the plant communities were dominated by cyatheaceous, dicksoniaceous and osmundaceous ferns. Tree and shrub vegetation was represented by pinaceous, podocarpaceous, taxodiaceous and podozamitaceous conifers, ginkgoaleans, czekanowskialeans, cycadaleans, and bennettitaleans. During the Albian, the ferns lose their significance (by reducing of the Osmundaceae), trees and shrubs become more diverse (a new species of pinaceous and cheirolepidiaceous conifers, as well as rare gleicheniaceous ferns and angiosperms appear).

The flora of the more southern coal-bearing basins of the Amur River region (Bureya Basin) and Primorye region (Partizansk and Razdolnaya River basins) was studied.

The Bureya Basin is located in the upper reaches of the Bureya River, a tributary of the Amur River. The Barremian–Aptian coal-bearing deposits of this basin were divided into the Chagdamyn and Chemchukin formations. The palynological assemblage of the Chagdamyn Formation (Barremian) is characterised by high diversity and abundance of cyatheaceous, gleicheniaceous and osmundaceous ferns; among gymnosperms the pinaceous and taxodiaceous conifers dominate, the share of *Ginkgocycadophytus* in palynospectra remains rather high (Markevich and Bugdaeva 2014). The diversity of ferns and cycadophytes is low in the megafossil flora of the Chagdamyn Formation. The horsetails, bryophytes, czekanowskialeans and some ginkgoaleans (*Sphenobaiera*) disappear. The ginkgoaleans *Eretmophyllum glandulosum* (Samyl.) Krassil. and *Ginkgoites longipilosus* Krassil. dominate in the burials (Krassilov, 1972, 1973).

The palynological assemblage of the Chemchukin Formation (Aptian) is dominated by spores *Cyathidites* and *Gleicheniidites*, pollen of taxa close to Taxodiaceae and Pinaceae, locally *Ginkgocycadophytus*. The megafossil flora of the Chemchukin Formation is characterised by an increase in taxonomic diversity (Vachrameev and Doludenko, 1961; Krassilov, 1972, 1973). The ferns and ginkgoaleans hold a role of dominants. The bryophytes, cycadophytes, czekanowskialeans, conifers *Elatides* sp. and *Athrotaxopsis expansa* Font. are locally abundant (Krassilov, 1973).

The significant floristic events took place during the Barremian in the Bureya Basin: the diversity of ferns abruptly reduced, Gleicheniaceae began to play a dominant role in plant communities, Czekanowskiales and cycadophytes disappeared, among Ginkgoales *Eretmophyllum glandulosum* and *Ginkgoites longipilosus* replaced extinct *Baiera* and *Sphenobaiera* (Krassilov, 1973). The swamp plant communities were represented by mainly gleicheniaceous ferns, mosses, and lycopsids, and to a lesser extent by Pinaceae, Ginkgoales, and Cyatheaceae.

The megafossil flora of the Chemchukin Formation is characterised by an increase in taxonomic diversity while ginkgoaleans remain as dominant components. The czekanowskialeans *Hartzia angusta* Krassil. and *Phoenicopsis* sp. appear. This flora has ever-increasing abundance of cycadophytes suggesting a thermophilic feature of vegetation (Krassilov, 1973). In the Chemchukin megaflora, *Athrotaxopsis expansa* (Taxodiaceae) appears. This plant is a typical taxon of the Barremian–Albian floras of Southern Primorye. The introduction of this representative of the more southern floras in the plant communities of Bureya Basin may indicate warming, as well as the creation of conditions for the floristic exchanges between these regions. The predominance of Gleicheniaceae in palynological spectra may also indicate a climatic optimum.

The composition of swamp communities during the time of deposition of the Chemchukin Formation has changed drastically. They were dominated by Gleicheniaceae along with Cyatheaceae, followed by Taxodiaceae and plants produced *Ginkgocycadophytus* pollen. In moister environments, ferns and cycadophytes remain as ground cover beneath a canopy of taxodiaceous trees. The Cyatheaceae lost its leading role in lowland plant communities; it appears that these ferns shifted to the periphery of swamps.

Coeval floras of Partizansk and Razdolnaya River basins of Southern Primorye formed under different conditions: the former existed in environments of the coastal lowlands and influence of the sea, the latter – mainly in environments of intracontinental basin.

The Barremian megafossil flora of Partizansk Basin is dominated by Taxodiaceae and Schizaeaceae. The Polypodiaceae and cycads played an important role in plant communities (Krassilov, 1967). The Aptian plant communities here were dominated by Taxodiaceae and Gleicheniaceae, while Pinaceae, Miroviaceae, Ginkgoales and bennettites appeared as minor ground cover components. During the Albian, Taxodiaceae retains its dominating status in the plant communities, polypodiaceous ferns returned to the status of dominant. The vegetation becomes more diverse (new species of ferns and conifers, as well as the first angiosperms have appeared).

The Barremian flora of Razdolnaya River Basin is characterised by an increase in fern diversity and dominance of Schizaeaceae. The Cyatheaceae and Pteridaceae played a great role in plant communities. Among gymnosperms the Pinaceae, Miroviaceae and cycadophytes dominate. The Aptian plant communities are very diverse. On the foothills or near the watershed, they were dominated by pinaceous and podocarpaceous, and to a lesser extent by taxodiaceous conifers. Cyatheaceous, dicksoniaceous and gleicheniaceous ferns are abundant. The lowland plant communities located in the central part of this basin were dominated by gleicheniaceous and cyatheaceous ferns; followed by dicksoniaceous ferns and plants produced pollen *Ginkgocycadophytus*. Minor components of these communities were Taxodiaceae, Bryophyta, Lycophyta, other groups of ferns, Araucariaceae, Cheirolepidiaceae, and Erdtmanithecaceae. The bisaccate pollen which was produced by Pinaceae, Podocarpaceae and Caytoniaceae is absent in the spectra. Angiosperms appear in this flora.

During the mid-Cretaceous, the wetland ecosystems with their specific vegetation widespread on the eastern margin of the Asian continent. Living in similar habitats, swamp vegetation had similar features, such as the dominance of ferns, conifers and plants produced *Ginkgocycadophytus* (Ginkgoales, Czekanowskiales, Cycadales, and Bennettitales). However, there are differences. The taxonomical composition of plant communities existed at high latitudes was depleted, whereas more southern swamp vegetation was characterised by ever-increasing plant diversity. Among ferns the role of Gleicheniaceae increased to the south; it is possible that this was due to the nature of these light-loving ferns. Cycadophytes have similar distribution, though perhaps it was related to the temperature factor. Near-polar environments formed under conditions of the mid-Cretaceous pronounced global warmth and the absence of cold winters. Winter dormancy plants lasted for no more than four and a half months and were largely controlled by light rather than temperature (Spicer et al., 2002). On the contrary, Czekanowskiales and Podozamitaceae typical of seasonal climate disappeared in the plant communities from north to south.

Thus, the maximum spread of the marshes and the peak of a peat-accumulation in them on the eastern margin of Asia occurred in Barremian–Aptian–Early Albian, the time of climatic optimum and the Oceanic Anoxic Event 1 (OAE 1). Obviously, these events were closely linked: transgression of the sea, flooding and waterlogging of vast areas, the emission of large amounts of greenhouse gases (mainly water vapour, methane and carbon dioxide; the release of the latter could be result of the volcanic eruptions what the occurrences of tuffaceous interlayers in the coal-bearing deposits testify) contributed to warming of climate, an increase of biodiversity and ecosystem productivity. The Barremian–Early Albian peat-formation with the peak in the Aptian was widely manifested in other parts of Asia and North America (Krassilov, 1985).

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