

## The Late Jurassic-Early Cretaceous Coal-forming Plants (Russian Far East)

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The coal-bearing deposits of Transbaikalia (Goose Lake, Chita-Ingoda, Bukachacha, Turga-Kharanor basins), Amur River region (Bureya basin) and Primorye region (Razdolnensky and Partizansky basins) were studied. On this territory the Tithonian-Valanginian, and Barremian-Albian stages of coal formation can be distinguished. During this time favorable conditions for existence of mire vegetation occurred. The abundant plant material was feedstock for peat accumulation and coal origin. Coal-forming plants were buried in close proximity to their habitats. We tried to reveal their composition, processing coal from the thick and thin coal seams. The very thin cuticles of ferns do not remain after chemical maceration of coal, but their spores, having exine resistant to acids and alkali, can evidence about existence of ferns in mire vegetation. Both palaeobotanical and palynological data revealed plants contributed in coal formation.

The Bureya Basin located in upper part of the Bureya River has been the best subject of study of the Upper Jurassic to Lower Cretaceous coal-bearing deposits, because the sequence of this tectonic structure includes productive coals of the Tithonian, Berriasian, Barremian, and Aptian ages. The coals of other ages are thin and do not have commercial significance.

The Upper Jurassic strata were deposited in brackish coastal environments. Characteristic of the Late Jurassic epoch are homogeneous composition, not clearly defined differentiation, low diversity and smoothed zonation of vegetation. The main coal-forming plants were cyatheaceous ferns, ginkgoaleans, and conifers. This stage is most conspicuous in Bureya basin. The coal-bearing Upper Jurassic (Talyndzhan Formation) to Lower Cretaceous (Dublikan, Soloni, Chegdomyn, and Chemchukin formations) deposits have thickness about 200-3000 m.

Palynological assemblage from middle part of the Talyndzhan Formation characterized by predominance of fern spores, mainly have been assigned to osmundaceous and cyatheaceous ferns (up to 90%). The participation of diverse mosses is considerable. Gymnosperms are dominated by pollen close to Pinaceae and *Ginkgocycadophytus*. In palynological assemblages from upper part of Talyndzhan Formation fern spores decreases in abundance with increase of taxonomical diversity. Amount of gymnosperms rises.

Their pollen is represented by close to Pinaceae (up to 70%) and *Ginkgocycadophytus* (up to 40%).

Horsetails, bryophytes, ferns, cycadophytes, ginkgoaleans, czezanowskialeans, and conifers made up plant communities of this age (Vachrameev, Doludenko, 1961; Krassilov, 1972, 1973, 1978). The burials are dominated by ginkgoaleans and czezanowskialeans, the role of ferns and cycadophytes is high. The representative of ginkgoaleans (*Pseudotorellia angustifolia* Dolud.) sometimes forms monospecific burials; their cuticle remains are common in coals. Perhaps, this arboreal plant prevailed in mire vegetation, osmundaceous and cyatheaceous ferns were in understory. *Sphenobaiera huangii* (Sze) Krassil. and *S. umaltensis* Krassil. are of considerable importance in the Late Jurassic swamp vegetation of Bureya Basin. Cycadophytes are often abundant in the clastic beds, but coals entirely lack remains of these plants. Consequently, cycadophytes were not constituent of mire vegetation.

The Lower Cretaceous (the Berriasian-Valanginian) strata accumulated in vast swampy lowland. The peculiarity of palynological assemblage from Dublikan Formation (the Berriasian) is considerable amount of fern spores (up to 84%). Among gymnosperms as well as *Classopollis* prevails in parallel with conifers. The floristic changes at the Jurassic-Cretaceous boundary have consisted in the increase of ferns and cheirolepidiaceus gymnosperms, which might be related to the marginal uplift and drier climate (Markevich, 1981, 1995; Markevich and Bugdaeva, 2008). Palynological assemblage of Soloni Formation (the Valanginian) is dominated by conifers (up to 60%) and *Ginkgocycadophytus*. Ferns reduce up to 50%. The gleicheniaceus and schizaeaceous ferns have assumed great importance.

In the middle Cretaceous the sea retreats from this area and the coal are accumulated in the interior depressions. The Chegdomyn Formation (the Barremian) is typified by dominance mainly of spores *Cyathidites*. *Ginkgocycadophytus* and conifers prevail among gymnosperms. The diversity and amounts of ferns are high in palynological assemblage of Chemchukin Formation (the Aptian); they are represented by cyatheaceous, gleicheniaceus and osmundaceous ferns. The Pinaceae and Taxodiaceae predominate among gymnosperms. The involvement of *Ginkgocycadophytus* remains rather high.



The cyatheaceous ferns, ginkgoaleans (*Pseudoto-rellia angustifolia* Dolud., *P. longifolia* Dolud., *Sphenobaiera uralica* Krassil., *S. ikorfatensis* (Sew.) Florin), cheirolepidiaceae plants, and conifers provided a basis for the Early Cretaceous mire plant communities. The osmundaceous ferns lost their significance and gleicheniaceae and schizaeaceae replaced them. Essential features of these plant communities are inherited from the Jurassic vegetation.

Based on a number of criteria, such as the abundance of bryophytes, cycadophytes index and replacement of ecological dominance, V.A. Krassilov has suggested a warming trend during the Talyndzhan and Dublikan time, followed by a cooling trend in Soloni and Chegdomyn time. The czekanowskialeans are reduced whereas cheirolepidiaceae plants increase during the Chemchukin climatic warming (Krassilov, 1973).

The Barremian-Albian stage was in a great part. Coal accumulation was manifested on vast areas of Siberia and Far East. During the Barremian-Aptian main coal-forming plants varied in composition depending on environments: in sea-side marshy plains they were represented by cyatheaceous and gleicheniaceae ferns, Miroviaceae and taxodialeans, in intracontinental basins — ginkgoaleans (mainly *Pseudoto-rellia* and *Sphenobaiera*), czekanowskialeans, Pinaceae, and Cheirolepidiaceae.

The Jurassic mire plant communities significantly consisted of cyatheaceous and osmundaceous ferns, ginkgoaleans, conifers, as well mosses. We emphasize that considerable distinctions between taxonomical composition of palynospectra from coal seams and terrigenous sediments between coals were not revealed, which is meant that vegetation occupied both lowland and upland was similar. On the contrary, the palynological spectra from the Early Cretaceous coals and clastic sediments diverged substantially. It seems reasonable to say that since the Cretaceous period the differentiation of lowland and upland vegetation begin to form. Perhaps it resulted from increase of contrast of

climatic conditions.

The conservatism of taxonomic composition of mire plant communities is related to similar environments. It is well known that coal accumulation is controlled by tectonics, climatic conditions, and the structures of ecosystems that provided the organic material for the coal.

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