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The palynological assemblages from the J–K boundary beds of the Bureya Basin, Russian Far East

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Abstract

Palynological assemblages were studied from the coal-bearing Upper Jurassic (Talanja Formation) to the Lower Cretaceous (Dublikan Formation) deposits of the Bureya Basin, Russia. The palynological assemblages from the upper part of the Talanja Formation are dominated by gymnosperms, mainly *Ginkgocycadophytus* (up to 40%) and conifers related to Pinaceae (up to 70%). The contribution of non-seed plants is not great, but their diversity is considerable. The miospore assemblages of the Talanja sequence are characterized by the last appearance of the spore taxa *Staplinisporites pocockii*, *Camptotriletes cerebriformis*, *Camptotriletes nitida*, and *Cingulatisporites sanguinolentus*. The palynological assemblage from the Dublikan Formation is dominated by ferns (up to 84%), represented mainly by *Cyathidites* and *Duplexisporites*. Among gymnosperms the role of *Classopollis* increases (making up about 20%). Another feature is the first appearance of the spore taxa *Stereisporites bujargiensis*, *Neoraistrickia rotundiformis*, *Contignisporites dorsostriatus*, *Appendicisporites tricostatus*, and *Concavissimisporites asper*.

Keywords: Palynology; Stratigraphy; Late Jurassic; Early Cretaceous

1. Introduction

The Geologic Time Scale is based on integrated stratigraphic studies (biologic, chemical, sea-level, magnetic, etc.) of marine deposits. Definitions of the Mesozoic boundary divisions are usually based on taxonomic investigations of ammonites and bivalves and, therefore, the dating and correlation of terrestrial stratigraphic units usually represents a very complicated problem. As early as in 1962, it was expressed that only palynological analysis solved the correlation of marine, brackish-water and non-marine deposits (Menner, 1962). The advantage of using palynological assemblages lies in their usual abundance and their long transportation from land into near shore and even off-shore marine environments. Krassilov (1972b) examined properties of pollen transport in detail, and showed that pollen can generally be carried to a distance of 50–100 km from land and in some instances can even reach as far as thousands of kilometres. Spores and pollen are transported from different geographical areas and deposited in coeval deposits. Thus, palynological analysis is a key in correlating marine and non-marine beds.

In marine deposits of southeastern Russia, the stratigraphic position of the Jurassic–Cretaceous boundary is well established (Konovalov and Konovalova, 1997; Markevich et al., 2000). The Jurassic–Cretaceous stratotype section falls within the Chiganov Formation, located on the eastern coast of the Ussury Bay where late Tithonian and early Berriasian ammonites and bivalves (mainly buchiids) were collected. The joint occurrence of Tethyan ammonites and Boreal buchiids at this locality is of great importance as it is situated within the ecotone between the Tethyan and Boreal Realms. Unfortunately, these sediments are devoid of spores and pollen.

Both the Berriasian marine deposits of the Tauhe Formation and the terrestrial sediments of the Ustinovka Formation are widely distributed in the Sikhote-Alin volcanogenic belt. Several fossil groups have been identified in the sediments of the Tauhe Formation including ammonites (e.g., *Neocomites* aff. *retowskyi* Sar. et Schond) from the Berriasian of Crimea and Caucasia (Markevich et al., 2000), bivalves, gastropods, brachiopods and sea-urchins. Abundant plant fossils were found in the same beds (Krassilov, 1967) and palynological studies were carried out by Markevich revealing characteristic features of the Berriasian

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palynoflora (Markevich, 1980, 1995; Markevich and Parnyakov, 1989).

The Upper Jurassic and Lower Cretaceous sequences of the Bureya Basin were studied intensively during the 1960–1970s because they contain productive coal seams. During the geological explorations, numerous cores were drilled and mines opened, exposing these deposits.

Based on abundant and well-preserved palynological assemblages, the characteristics of every formation in the Bureya Basin were obtained and correlated with palynofloras of adjacent regions. Palynology was further used for dating the units with reference to the palynological biozones of the Russian Far East (Markevich, 1995), and for paleoenvironmental and climatic reconstructions. One aspect of palynological studies in the Bureya Basin is to determine the position of the J–K boundary. Special attention is given to age determination of coal accumulation in this basin.

2. Geological settings

The Bureya Basin is located in the northern part of the Amur River region. The basin was formed during the Jurassic and Early Cretaceous as a pull-apart basin. This tectonic structure represents a series of NE-trending grabens. It is about 300 km long and 60–80 km wide (Fig. 1). The basin infill is composed of Jurassic marine and brackish-water coal-bearing sediments and Cretaceous terrestrial coal-bearing deposits. The sequence is represented by the marine Umalta, Epikan, Elga and Chagany formations of Early and Middle Jurassic ages. Their total thickness is about 5000 m. These sequences are overlain by the Late Jurassic Talanja Formation, which is composed of sandstones, mudstones, tuffs and coals (10 seams) with a thickness of 200–800 m (Sharudo, 1972).

At the base of the Talanja Formation in the section on the right bank of Bureya River, down-stream of Umalta River mouth, limulid fossils were found indicating marine influences on the Bureya Basin during the Late Jurassic (Krassilov, 1973). At this locality, nearly the whole Talanja Formation is exposed. The sediments contain abundant plant remains dominated by conifers, czekanowskialeans and ginkgoaleans (e.g., *Pseudotorellia angustifolia* Dolud., *P. pulchella* (Heer) Vassil.); ferns, cycadophytes and horsetails are common.

The fossil flora of the Bureya Basin was studied by several palaeobotanists. Prynada (1940, 1956), Vachrameev and Doludenko (1961), Lebedev (1965), Lebedev and Paraketsov (1975), Vachrameev and Lebedev (1967) and Krassilov (1972a, 1973) made the most important contributions. Based on these publications, a Late Jurassic age has been inferred for the Talanja Formation.

The Cretaceous sequence commences (Fig. 2) with deposits of the coal-bearing terrestrial Urgal, Chemchukin, Chegdomyn formations (total thickness 900–1400 m) and the terrigenous Kyndal and Yorek formations (about 1300 m).

With local unconformity the Urgal Formation, which is divided into Dublikan and Soloni subformations, overlies the Talanja Formation. Some geologists treat these subformations as formations. The sediments of the Urgal Formation are represented by alternation of conglomerate, gravel, sandstone, siltstone, tuff, tuffite, coals and coaly siltstone with a thickness of 300–700 m. The sediments contain 42 coal seams and up to 22 of them are productive.

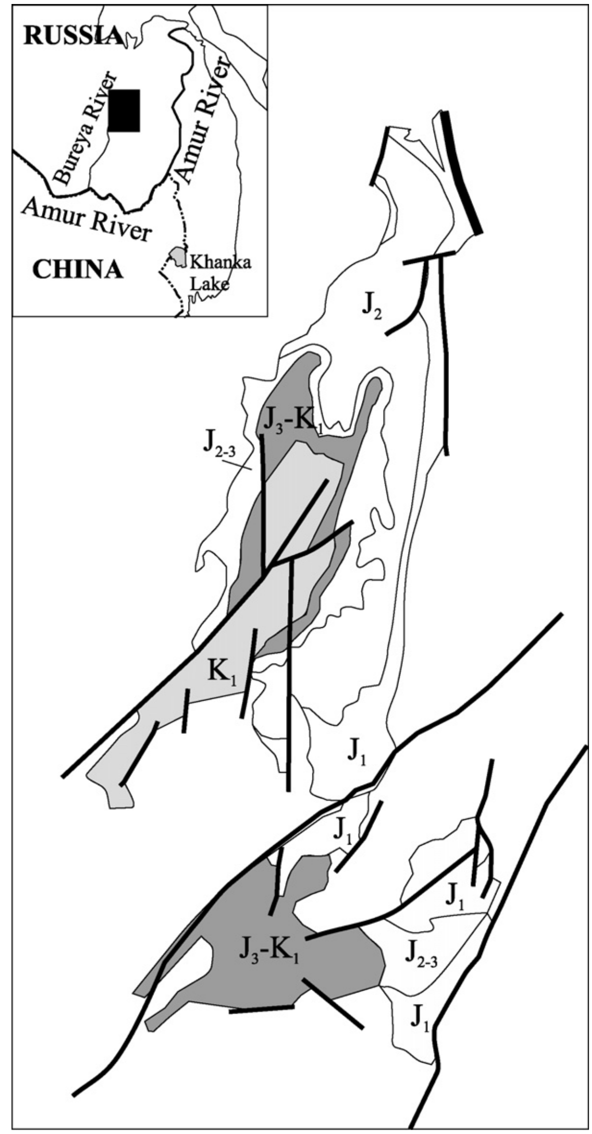

Fig. 1. Schematic geologic map of the Bureya Basin.

Plant remains are abundant in these sediments and the fossil flora of this stratigraphic unit is dominated by narrow-leaved *Pseudotorellia angustifolia*, representing monospecific plant communities. In some cases, this plant is associated with *Pityophyllum* (Krassilov, 1972a). Ferns and cycadophytes are numerous and diverse (Krassilov, 1973).

In the Soloni Subformation, the fossil flora includes conifers, ginkgoaleans and czekanowskialeans. The diversity of cycadophytes is rather high (Krassilov, 1973).

According to Krassilov (1973), the Dublikan flora is similar to the flora of the Tyl River described by Lebedev (Lebedev, 1965; Lebedev and Paraketsov, 1975). The fossil plants of the Tyl River were found at the Oxfordian–Valanginian transition together with marine fauna. Based on this comparison, Krassilov

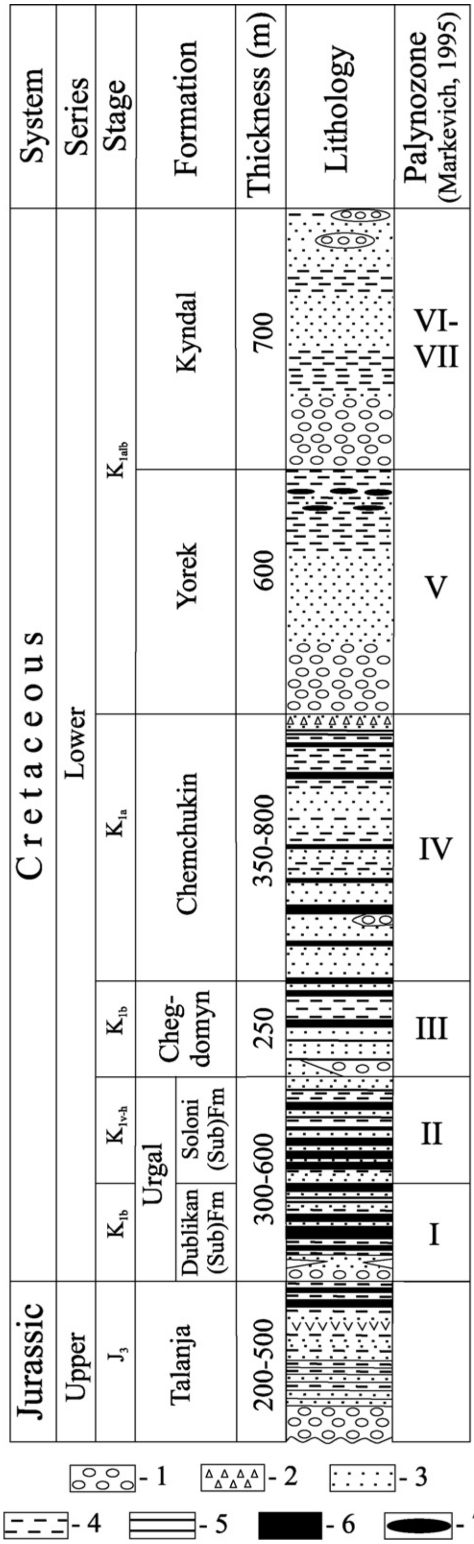

Fig. 2. Sequence of non-marine Upper Jurassic to Lower Cretaceous deposits of the Bureya Basin. 1: conglomerate; 2: breccia; 3: sandstone; 4: siltstone; 5: claystone; 6: coal; 7: lenses of coals.

(1973) concluded that the age of the Dublikan Formation is possibly late Volgian–Berriasian, in contrast to a Neocomian age for the Urgal Formation postulated a decade earlier by Vachrameev and Doludenko (1961).

The sediments of the Early Cretaceous Chegdomyn Formation unconformably over the Urgal Formation and are 150–350 m thick (Sharudo, 1972), represented by sandstones, siltstones and coals (up to 10 seams of productive thickness). The fossil flora includes ginkgoaleans (*Ginkgoites* and *Eretmophyllum glandulosum* (Samyl.) Krassil.). The diversity of cycadophytes drops abruptly and only *Neozamites* was found (Krassilov, 1973).

These beds are covered concordantly by polymictic sandstones and siltstones of the Chemchukin Formation with a thickness of up to 800 m. The fossil flora of this stratigraphic unit is dominated by ginkgoaleans, but czekanowskialeans, taxodiaceous conifers, cycadophytes and bryophytes are also important components of this flora (Krassilov, 1973).

The Chegdomyn–Chemchukin floral assemblage was correlated by Krassilov (1973) with the Eksenyakh assemblage of the Lena Basin and with assemblages from the coal-bearing deposits of Southern Primorye region. The age of these deposits is considered to be Barremian–Aptian (Vachrameev and Doludenko, 1961; Krassilov, 1973).

The coal-bearing deposits are overlain by the terrestrial Yorek and Kyndal formations, with a total thickness about 1.5 km. Fresh water molluscs and dicotyledonous angiospermous pollen were found in the Kyndal Formation (Sharudo, 1972). The angiosperm fossils indicate an Albian age.

Palynology of all stratigraphic units of the Bureya Basin was studied (Shugaevskaya et al., 1975). The age of the Talynzhan Formation was determined as Late Jurassic, Urgal Formation Berriasian–Valanginian, Chegdomyn Formation Barremian, Chemchukin Formation Aptian, and Yorek and Kyndal formations Albian (Markevich, 1995).

3. Material and methods

In the Bureya Basin, 16 drill cores and 14 outcrops were sampled and approximately 1500 palynological samples were processed for analysis. Geographic locations of sample localities are shown in Fig. 3. The samples were processed using the standard methods of Waltz (1941). During maceration of coals, the Luber's mixture was used (Pokrovskaya, 1966). For maceration of the tuffogenic rocks, hydrofluoric acid was used.

4. Results

The Jurassic–Cretaceous boundary was identified in five drill cores (No. 4, 68, 89, 109 and 495) and from one outcrop (U-3) by the Urgal geological exploring Party of "Dalvostuglerazvedka" Trust. Most of them contained abundant and well-preserved palynomorphs.

Spores and pollen were obtained from every stratigraphic unit of the Bureya Basin. The changes in taxonomical composition of miospores throughout non-marine sequences in the basin were recorded (Fig. 4). Stratigraphical key species were recognized, and age determinations were made with reference to palynostratigraphic biozones established for the Russian Far East (Markevich, 1994, 1995).

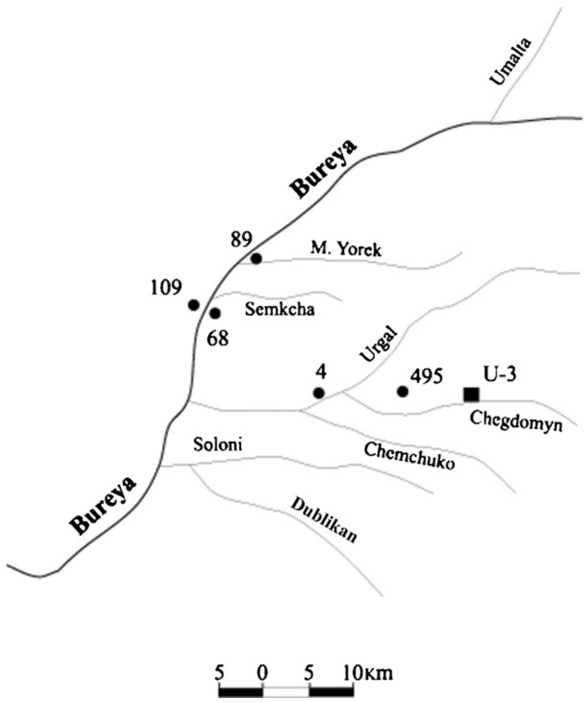

Fig. 3. Location of boreholes and outcrops showing the contact of Upper Jurassic and Lower Cretaceous beds.

Palynological assemblages from the middle part of the Late Jurassic Talanja Formation include bryophyte and pteridophyte spores and gymnosperm pollen. Pteridophyte spores, mainly Cyatheaceae and Osmundaceae, predominate in abundance (up to 90%) and diversity. Among gymnosperms, *Ginkgocycadophytus* and pinaceous pollen prevail.

In palynological assemblages from the upper part of the Talanja Formation, the relative abundance of pteridophyte spores decreases while their diversity increases. There is an increase in the number of gymnosperm pollen represented by pinaceous pollen (up to 70%) and *Ginkgocycadophytus* (up to 40%).

Palynological assemblages from the Dublikan Subformation include bryophyte and pteridophyte spores, with the latter predominating in abundance (up to 84%) and diversity. Among gymnosperms, *Classopollis* prevails (about 20%) together with other conifers. The "cheirolepidiaceous peak" is characteristic of the Berriasian palynofloras of East Asia, in which percentage of *Classopollis* can reach 45% (Markevich, 1995).

Palynological assemblage from the Soloni Subformation is dominated by conifers (up to 60%). *Ginkgocycadophytus* pollen has considerable share in this assemblage. The relative abundance of pteridophyte spores decreases down to 50%. Among them Gleicheniaceae and Schizaeaceae have assumed a higher significance, and the percentage of Osmundaceae decreased.

The palynological assemblage from the Chegdomyn Formation is dominated by spores, mainly belonging to Cyatheaceae. Among gymnosperms, *Ginkgocycadophytus* and conifers prevail.

Assemblages from the Chemchukin Formation are dominated by pteridophyte spores (Cyatheaceae, Gleicheniaceae and Osmundaceae) in abundance and diversity. Among gymnosperms, Pinaceae and Taxodiaceae dominate but, *Ginkgocycadophytus* pollen have a considerable share in this assemblage.

The palynological assemblage from the Yorek Formation is dominated by gymnosperms, mainly pollen close to Pinaceae and Taxodiaceae. Among the ferns, representatives of Schizaeaceae prevail. For the first time in this stratigraphic unit, the very rare pollen of angiosperms (1–2%) appeared.

The palynological assemblages of the Kyndal Formation are characterized by great taxonomical diversity. Ferns (*Cyathidites*, *Laevigatosporites* and *Gleicheniidites*) and bisaccate pollen predominate. The percentage of angiosperms is rather high (up to 8%). Among gymnosperms Pinaceae and Taxodiaceae play an important role.

The distribution of palynomorphs across the Jurassic–Cretaceous boundary at Outcrop U-3 is the most indicative. This small exposure is situated in road cuts on the right bank of the Chegdomyn River (Fig. 4). Here the contact between the sandstone of the Talanja Formation and the conglomerate with sandstone beds and lenses of the Urgal Formation is identified.

Palynological assemblages obtained from the upper part of the Talanja Formation in Outcrop U-3 are dominated by gymnosperms, mainly bisaccate pinaceous and monosulcate *Ginkgocycadophytus*. *Classopollis classoides* Pfl. emend. Poc. et Jans. is rare. The taxonomical diversity of pteridophytes is rather high, but their share in the assemblage is

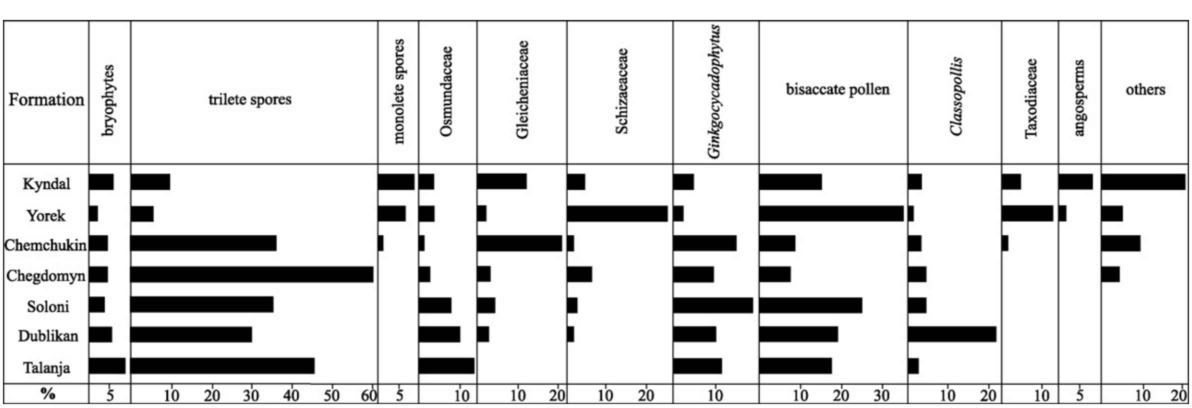

Fig. 4. Relative abundance of major groups of spores and pollen in Late Jurassic and Early Cretaceous palynofloras of the Bureya Basin.

moderate. Among them are trilete, smooth *Cyathidites*; thorned *Osmundacidites*; reticulate *Klukisporites*; and striate *Duplexisporites*. Also characteristic of this interval are the spores *Staplinisporites pocockii* Jans. et Sah., *Camptotriletes cerebriformis* Naum et Jar., *Camptotriletes nitida* (K.-M.) Schug., *Cingulatisporites sanguinolentus* (Sah. et Il.) Markev.

In the assemblages from the sandstone of the lower part of the Dublikan Subformation, the relative abundance of the spores *Cyathidites*, *Duplexisporites* and pollen *Classopollis classoides* rises. The species diversity of *Duplexisporites* increases. However, a sharp decrease occurs in the number of bisaccate and monosulcate pollen *Ginkgocycadophytus*. Spores appear such as *Stereisporites bujargiensis* (Bolch.) Schug., *Neoraistrickia rotundiformis* (K.-M.) Taras., *Contignisporites dorsostriatus* (Bolch.) Fok., *Appendicisporites tricostatus* (Bolch.) Poc., *Concavissimisporites asper* Poc.

5. Discussion

During the Jurassic–Cretaceous transition, the ratio of major groups of spores and pollen remains generally the same in the Bureya Basin (Fig. 5). This is possibly due to sedimentation occurring in similar wetland palaeoenvironments. These coal-forming swamp plant communities subsequently responded to some abiotic event—probably, uplift of marginal areas of basin. The composition of palynofloras from the Jurassic–Cretaceous boundary transition reflects these geologic events by increased role of Cheirolepidiaceae, which could exist under harsh conditions (Markevich, 1980, 1981). In these uppermost Jurassic beds of the Bureya Basin, bisaccate pollen constitutes a considerable percentage of the palynoflora. It provides evidence for the rise of upland plant communities (Fig. 4). The dominance of bisaccate pollen typically corresponds to phases of diminished coal accumulation (for instance, during deposition of the uppermost Talanja Formation and the Soloni and Yorek formations).

The Late Jurassic swamp plant communities included ferns (Cyatheaceae and Osmundaceae), conifers and bryophytes. There were no substantial differences in taxonomic composition of the palynospectra between the coals and the terrigenous sediments. This suggests that similar vegetation occupied both lowlands and uplands. However, in the Cretaceous, the composition of the palynofloras differs between coals and interseam strata. This suggests that lowland and upland plant communities began to differentiate in the Early Cretaceous as regional climates differentiated.

The Upper Jurassic deposits of the Bureya Basin accumulated under deltaic and brackish-water conditions (Sharudo, 1972; Krassilov, 1973). The plant communities were composed of horsetails, lycopsids, ferns, ginkgoaleans, czekanowskialeans and conifers (Vachrameev and Doludenko, 1961; Krassilov, 1972a, 1973). The leaves of ginkgoaleans and czekanowskialeans dominate the assemblages; ferns and cycadophytes are common. The palynological assemblages of both Upper Jurassic and Lower Cretaceous coal-bearing deposits are dominated by trilete spores (Cyatheaceae and *Leiotriletes*) and to a lesser extent by pinaceous bisaccate pollen (Fig. 3), a characteristic that these floras share with Northern European floras (Vajda, 2001; Vajda and Wigforss-Lange, 2006).

The Early Cretaceous sedimentation took place in an intracontinental basin. During that time, the swamp vegetation was represented by Cyatheaceae (Osmundaceae became less important, replaced by Gleicheniaceae and Schizaeaceae), ginkgophytes, cycadophytes, Cheirolepidiaceae and other conifers. Essential features of these plant communities were inherited from the Jurassic vegetation and their conservatism is related to the persistence of similar environments.

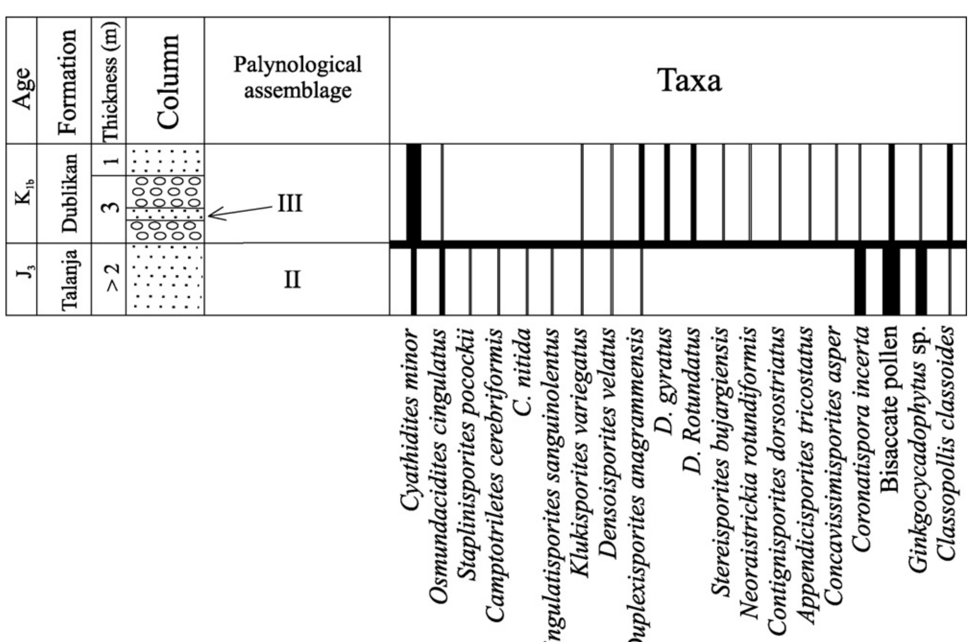

Fig. 5. Distribution of palynomorphs at the J–K boundary identified at the contact between the Talanja and Dublikan formations.

Nevertheless, plants formerly alien to or rare within these ecosystems invaded the swamps during climatic cooling. For instance, earliest Cretaceous coals contain abundant *Duplexisporites* spores and are further characterized by the appearance of taxa such as *Stereisporites bujargiensis*, *Neoraistrickia rotundiformis*, *Contignisporites dorsostriatus*, *Appendicisporites tricostatus*, and *Concavissimisporites asper*. This data supports the opinion of Vachrameev and Kotova (1980) that *Appendicisporites* does not occur in deposits older than the Berriasian, indicating a Berriasian age of the Dublikan Formation. This agrees well with data from northern European pollen assemblages (Vajda and Wigforss-Lange, 2006) and palynological assemblages of the Northern *Cicatricosisporites australiensis-Fixisporites tortus* assemblage of Northern China (Saiki and Wang, 2003; Sha et al., 2003).

6. Conclusion

There are no essential differences in composition of the Late Jurassic and Early Cretaceous palynofloras of the Bureya Basin studied here, but we have revealed a large number of key species LAD and FAD characterizing this boundary transition.

The J–K boundary in the Bureya Basin is identified based on several key species (Fig. 5) with the LAD of *Staplinisporites pocockii*, *Camptotriletes cerebriformis*, *Camptotriletes nitida* and *Cingulatisporites sanguinolentus*, and FAD of the Early Cretaceous taxa *Stereisporites bujargiensis*, *Neoraistrickia rotundiformis*, *Contignisporites dorsostriatus*, *Appendicisporites tricostatus* and *Concavissimisporites asper*. Furthermore, the boundary is met with a decrease in bisaccate and monocolpate pollen. Angiosperm pollen first appeared in the Lower Cretaceous deposits in the Yorek Formation of the Albian age.

The palynological assemblages of Late Jurassic and Early Cretaceous age in the Bureya Basin are further characterized by the following:

The Late Jurassic palynological assemblages are dominated by gymnosperms, mainly Pinaceae (up to 70%) and *Ginkgocycadophytus* (up to 40%). Pteridophytes occur sparsely but are rather diverse. The low relative frequency of pteridophyte spores is probably a result of unfavourable conditions for swamp plant communities caused by uplift of marginal areas of basin, leading to better drainage in combination with a more arid climate. These events resulted in changes of the vegetation pattern in the basin. The Late Jurassic assemblages are further characterized by the last appearances of the spore taxa *Staplinisporites pocockii*, *Camptotriletes cerebriformis*, *Camptotriletes nitida* and *Cingulatisporites sanguinolentus*.

In the Early Cretaceous palynological assemblages, pteridophytes dominate (up to 84%) mainly composed of *Cyathidites* and *Duplexisporites*. Among conifers *Classopollis* dominates. The successions are also characterized by the first appearance of taxa such as *Stereisporites bujargiensis*, *Neoraistrickia rotundiformis*, *Contignisporites dorsostriatus*, *Appendicisporites tricostatus*, and *Concavissimisporites asper*, indicating a Berriasian age for the deposits of the Dublikan Subformation. At this time swamp vegetation rejuvenates leading to significant coal formation.

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