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

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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.

The organization and carrying out of the Symposium are supported by the UNESCO-IUGS-IGCP Committee (IGCP Project 608) and the Russian Foundation for Basic Researches (RFBR Project 16-05-20508).

Cover illustration: *Psittacosaurus sibiricus*. Painting by Andrey A. Atuchin

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Preface

The mechanisms underlying the evolution of the Asia-Pacific Cretaceous ecosystems are far from being fully understood. The IGCP608 project lead by Prof. Hisao Ando (Ibaraki University, Japan) is aimed to reconstruct the Cretaceous ecosystems and the history of their responses to paleoenvironmental changes in Asia and the Western Pacific.

The 4th International Symposium of the IGCP608 is a follow-up of very successful previous meetings in Lucknow (India), Tokyo (Japan) and Shenyang (China). The Trofimuk Institute of Petroleum Geology and Geophysics of Siberian Branch of Russian Academy of Sciences in Novosibirsk (Russia) was elected as a host for international meeting of the project workers in 2016.

IGCP608 symposiums became an effective platform for participants to share their views on the paleoenvironmental changes impacts both on terrestrial and marine ecosystems. The scientific programme of the 4th International Symposium of the IGCP608 in Novosibirsk covers a wide range of topics including paleoclimate, paleogeography, paleontology, stratigraphy, tectonics, and petroleum geology. This symposium is an opportunity for discussion of the latest advances in studies of Asia-Pacific Cretaceous ecosystems. In addition to scientific sessions, the post-symposium field excursion will be organized in Kemerovo Oblast to examine the non-marine Cretaceous deposits yielding dinosaurs and other vertebrates.

The Symposium is dedicated to the 105th anniversary of the birth of Corresponding Member of the USSR Academy of Sciences, Professor Vladimir N. Saks (1911–1979), Soviet geologist and paleontologist, and the founding father of the Mesozoic paleontology and stratigraphy Research Group in Novosibirsk Academy Town.

This special issue is a contribution to UNESCO IUGS International Geoscience Programme (IGCP project 608).

We express our sincere thanks to all of the authors who contributed to this issue.

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Vladimir N. Saks: geologist and paleontologist, and the founding father of the Mesozoic paleontology and stratigraphy Research Group in Novosibirsk Academy Town

(to the 105th anniversary of the birth of V.N. Saks)

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Vladimir Nikolaevich Saks, the founder and the first head of the Laboratory of the Mesozoic and Cenozoic Paleontology and Stratigraphy (Institute of Geology and Geophysics SB AS USSR, currently – Trofimuk Institute of Petroleum Geology and Geophysics SB RAS) would have turned 105 years old on April 22, 2016.

The school of scientific thought initiated by Vladimir Saks is justifiably considered the greatest and the most important achievement of his scientific career and, ultimately, his whole life. A school of thought implies a community of scientists like-minded spiritually connected, united by common goals and objectives, as long as the staple idea of the school founder is handed on and developed further by generations of researchers. V.N. Saks was the mastermind and inspiration in such teams organized by him first in Leningrad and later in Novosibirsk.

He always had his hand in planning the research activities on stratigraphy and assisted in organizing the work of interdepartmental groups for creating the regional stratigraphic schemes for the Mesozoic–Cenozoic deposits of the Boreal type. He would act as a chief scientific arbiter for all regional stratigraphic schemes, regarded as an integrated part of the geological information on most of Siberian regions. Back in the 1960s–70s, the Regional Stratigraphic meetings on approval of the Mesozoic and Cenozoic charts with regional columns were held under his scientific leadership in the cities of Novosibirsk, Tyumen, Magadan, Khabarovsk, Vladivostok, including those for the European platform and the Urals.

As an Earth scientist, Vladimir Saks really had two careers and was equally known as a geologist and geographer. His expertise and research results and findings in these two relatively remote areas of geological knowledge – Quaternary and Mesozoic geology – have gained recognition among the experts in Russia and many countries of the Northern Hemisphere. The intact by time persistent interest in his works is largely attributed to the profound knowledge, deep intuition and wisdom this remarkable geologist and paleontologist.

Vladimir Saks was known for an amazing diversity of his scientific interests, but his primary academic and professional interest was given to stratigraphy. The key idea governing the development of the detailed Mesozoic stratigraphy of Siberia was V.N. Saks' pioneering conjecture that the succession of Jurassic stages traditionally assigned to the West European, including British stratigraphic columns is equally applicable to Siberia (Saks, 1962). It was revealed that in the Mesozoic, the Arctic marine fauna was essentially poorer versus faunas from the paleobasins situated further south. However, in stratigraphic columns of Western Europe and Siberia a whole series of common genera and species, primarily ammonoids, was established, which form the basis for subdivisions of all Mesozoic systems.

When suggesting the possibility of using of the International Stratigraphic Chart for Siberia, it was highlighted that the stages were to be filled with zones from Siberian sections, given that the differences between Siberian and European faunas in certain stratigraphic levels proved fairly essential. That was why Vladimir Saks believed that comparison of the Western Siberian ammonite scale should be based not only on the groups of master stratigraphic columns, but rather defined by homotaxis (similar positions within similar stratigraphic sequences). This approach bridges the major gaps in determinations of geological ages of rocks.

The most outstanding achievement made by Vladimir Saks, his students and fellows in the study of the Mesozoic of the Arctic region was the zonal stratigraphic scale, comprising 140 ammonite zones (Saks et al., 1980). In Western Europe, it took 125 years to develop the Jurassic and Cretaceous zonal scale, while modern parallel zonal scales for the Siberian Jurassic were completed within a 20 years' time span (Zakharov et al., 1997; Shurygin et al., 2000). All the Triassic, Jurassic and Cretaceous zones established in Siberia are widely traceable – in North of USA, Canada, the Arctic Islands.

During V.N. Saks' scientific career, apart from dealing primarily with the ammonite-based stratigraphy, he was involved in the pioneering attempts of developing biostratigraphic scale for other groups of invertebrates – the belemnites, bivalves, brachiopods, etc. Already after his passing away, this work was successfully completed by his disciples. At present, the Mesozoic biostratigraphy of Siberia has at its disposal a series of intercorrelated scales based on different groups of fossils.

The second in order but not minor in significance, direction of his scientific activity was concerned with paleobiogeography of the Panboreal Superrealm, which was geographically equaled with Boreal climatic Belt by V.N. Saks. Analysis of the area extent of several groups of Jurassic and Early Cretaceous marine organisms – ammonites, belemnites, bivalves, brachiopods, foraminifers – resulted in the division of area occupied by this superrealm beyond 50°N into three paleobiogeographic realms: Boreal-Atlantic, Arctic, and Boreal Pacific, with the provinces allocated by the area extent of specific taxa in each of them (Saks et al., 1971). The proposed division has thus far existed in the literature.

V.N. Saks in collaboration with I.S. Gramberg and Z.Z. Ronkina offered one of the first paleogeographic reconstructions for the Mesozoic of the Soviet Arctic (Saks and Ronkina, 1958; Saks et al., 1959; Saks, 1961). During the 'Siberian period' of V.N. Saks' life, a significant part of his work was dedicated to the research into the Mesozoic Arctic paleogeography. His theory on the integrity of the Arctic paleobasin and on its evolution associated with plate tectonics during the Mesozoic got further development in Russia and abroad.

Vladimir N. Saks

In his study of past climates, V.N. Saks proceeded from the best studied later periods (like Pleistocene) to earlier (Jurassic and Cretaceous). It was on his initiative and with his immediate participation that hundreds of definitions of paleotemperatures were obtained for the Arctic territory based on the oxygen isotopic data and the Ca/Mg ratios from belemnite rostra. A wealth of scientific evidence was obtained stating that during the Mesozoic Era (about 70–200 Ma BP) the Arctic climate was moderately warm, however subjected to significant changes over the time. The mean annual surface water temperatures ranged from 11 to 24°C, and the Arctic water temperatures were gradually decreased during the Jurassic and Early Cretaceous.

During his research into geological history of the Arctic region in the Mesozoic, Vladimir Saks' interests often extended beyond the scope of terrestrial geology. This is heavily evidenced by the paleogeographic and tectonic reconstructions of the Arctic Ocean and the surrounding polar seas, built for individual time intervals of the Mesozoic (e.g., Saks, 1958, 1960, 2007).

In the late forties–early fifties of the last century, when the nation was facing the need for searches of hydrocarbons in Siberia, V.N. Saks took an active part in the work of the Glavsevmorput Mining and Geological Bureau in Ust-Yenisei region. The results were summarized in a monograph describing the Mesozoic strata of the Ust-Yenisei and Khatanga basins in northern Siberia (Saks and Ronkina, 1957; Saks et al., 1959). For many years ahead, the books were extremely helpful to petroleum geologists in the exploration and development of hydrocarbon resources of Western Siberia. Relaying on his research in Ust-Yenisei region and on general understanding of the geology of Western Siberia, V.N. Saks expressed his firm belief that Jurassic and Cretaceous deposits of this area are to be highly prospective for hydrocarbons.

Vladimir Saks belonged to the generation of enthusiastic geologists whole-heartedly devoted to their chosen profession. His whole career was dedicated to the study and development of mineral resource base of the Soviet Arctic and to establishing the academic science in Siberia.

References

Saks, V.N., 1958. Stratigraphy of Jurassic and Cretaceous deposits of the middle sector of Soviet Arctic, in: Petroleum potential of the North of Siberia. Gostoptekhizdat, Leningrad, pp. 44–60 (in Russian).

Saks, V.N., 1960. Geological history of the Arctic Ocean during the Mesozoic Era, in: Regional Paleogeography. Gosgeoltekhizdat, Moscow, pp. 108–124 (in Russian).

Saks, V.N., 1961. Paleogeography of the Arctic in the Jurassic and Cretaceous periods, in: Papers at yearly readings in commemoration of V.A. Obruchev. Izd-vo AN SSSR, Moscow-Leningrad, pp. 20–68 (in Russian).

Saks, V.N., 1962. On possibility of application of general stratigraphic scale for structural zoning of Jurassic deposits of Siberia. Geol. Geofiz. 5, 62–75 (in Russian).

Saks, V.N., 2007. Selected works. GEO, Novosibirsk (Vol. 1, 641 p.; Vol. 2, 339 p.).

Saks, V.N., Ronkina, Z.Z., 1957. Jurassic and Cretaceous deposits of the Ust'-Yenisei depression. Gosgeolizdat, Moscow (in Russian).

Saks, V.N., Ronkina, Z.Z., 1958. Paleogeography of the Khatanga depression and the adjacent areas throughout the Jurassic and Cretaceous periods. Collection of articles on the Arctic geology 85(9), 70–89 (in Russian).

Saks, V.N., Gramberg, I.S., Ronkina, Z.Z., Aplonova, E.N., 1959. Mesozoic deposits of the Khatanga depression. Gostoptekhizdat, Leningrad (in Russian).

Saks, V.N., Basov, V.A., Dagis, A.A., Dagis, A.S., Zakharov, V.A., Ivanova, E.F., Meledina, S.V., Mesezhnikov, M.S., Nalnyaeva, T.I., Shulgina, N.I., 1971. Paleogeography of the seas of Boreal Belt in the Jurassic and Neocomian, in: Problems of general and regional geology. Nauka, Novosibirsk (in Russian).

Saks, V.N., Zakharov, V.A., Meledina, S.V., Mesezhnikov, M.S., Nalnyaeva, T.I., Shulgina, N.I., Shurygin, B.N., 1980. Recent understanding of the development of flora and fauna and zonal stratigraphy of the Jurassic and Neocomian of the Boreal Belt. Geol. Geofiz. 1, 9–25 (in Russian).

Shurygin, B.N., Nikitenko, B.L., Devyatov, V.P., Il'ina, V.I., Meledina, S.V., Gaideburova, E.A., Dzyuba, O.S., Kazakov, A.M., Mogucheva, N.K., 2000. Stratigraphy of oil and gas basins of Siberia: The Jurassic System. Geo, Novosibirsk (in Russian with English summary).

Zakharov, V.A., Bogomolov, Yu.I., Il'ina, V.I., Konstantinov, A.G., Kurushin, N.I., Lebedeva, N.K., Meledina, S.V., Nikitenko, B.L., Sobolev, E.S., Shurygin, B.N., 1997. Boreal zonal standard and biostratigraphy of the Siberian Mesozoic. Russ. Geol. Geophys. 38, 965–993.

Session 1
Biodiversity of terrestrial and marine ecosystems. Cretaceous fauna and flora of Asia and the Western Pacific

Fossil woods from the Bykov Formation (Late Cenomanian–Early Campanian) of Sakhalin Island, Russian Far East

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Fossil woods are common in the Upper Cretaceous deposits of Sakhalin, Russian Far East. Numerous fossil wood remains were previously described from the Upper Cretaceous of Sakhalin (Ay, Nayba and Susuya River basins) by Japanese palaeobotanists M. Shimakura (1937), H. Nishida and M. Nishida (Nishida, H. and Nishida, M., 1986; Nishida, M. and Nishida, H., 1986, 1995). They reported 15 coniferous fossil wood taxa (*Araucarioxylon*, *Brachyoxylon*, *Cedroxylon*, *Cupressinoxylon*, *Palaeopiceoxylon*, *Phyllocladoxylon*, *Piceoxylon*, *Pinoxylon*, *Pinuxylon*, *Protocupressinoxylon*, *Planoxylon*, *Podocarpoxylon*, *Taxaceoxylon*, *Taxodioxylon*, and *Xenoxylon*) and one dicotyledonous fossil wood taxon (*Aptiana*).

We described coniferous (*Sequoioxylon* sp.) and dicotyledonous (*Paraphyllanthoxylon* sp.) fossil wood taxa, all new to the Late Cretaceous fossil wood record of Sakhalin, from the Cenomanian–Campanian of Nayba River, Southern Sakhalin (Fig. 1). The fossil woods studied were collected by workers of the Far Eastern Geological Institute FEB RAS (Vladivostok) on the right bank of the Nayba River, in the marine

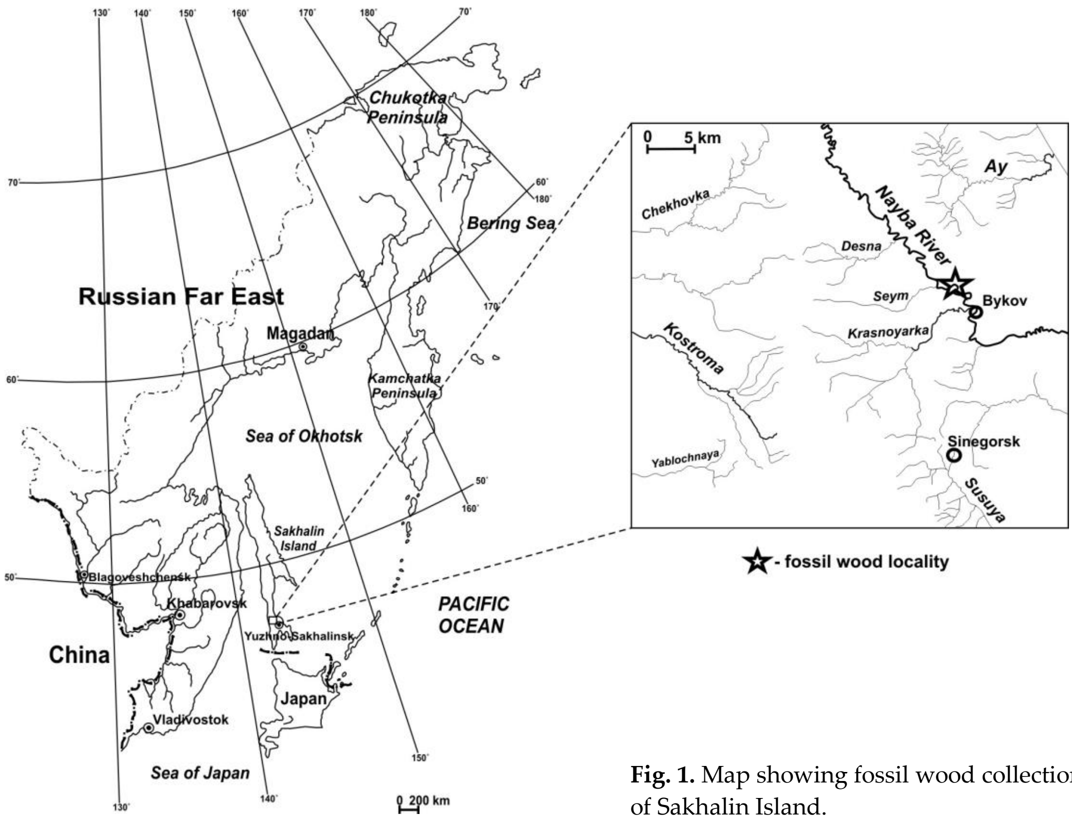
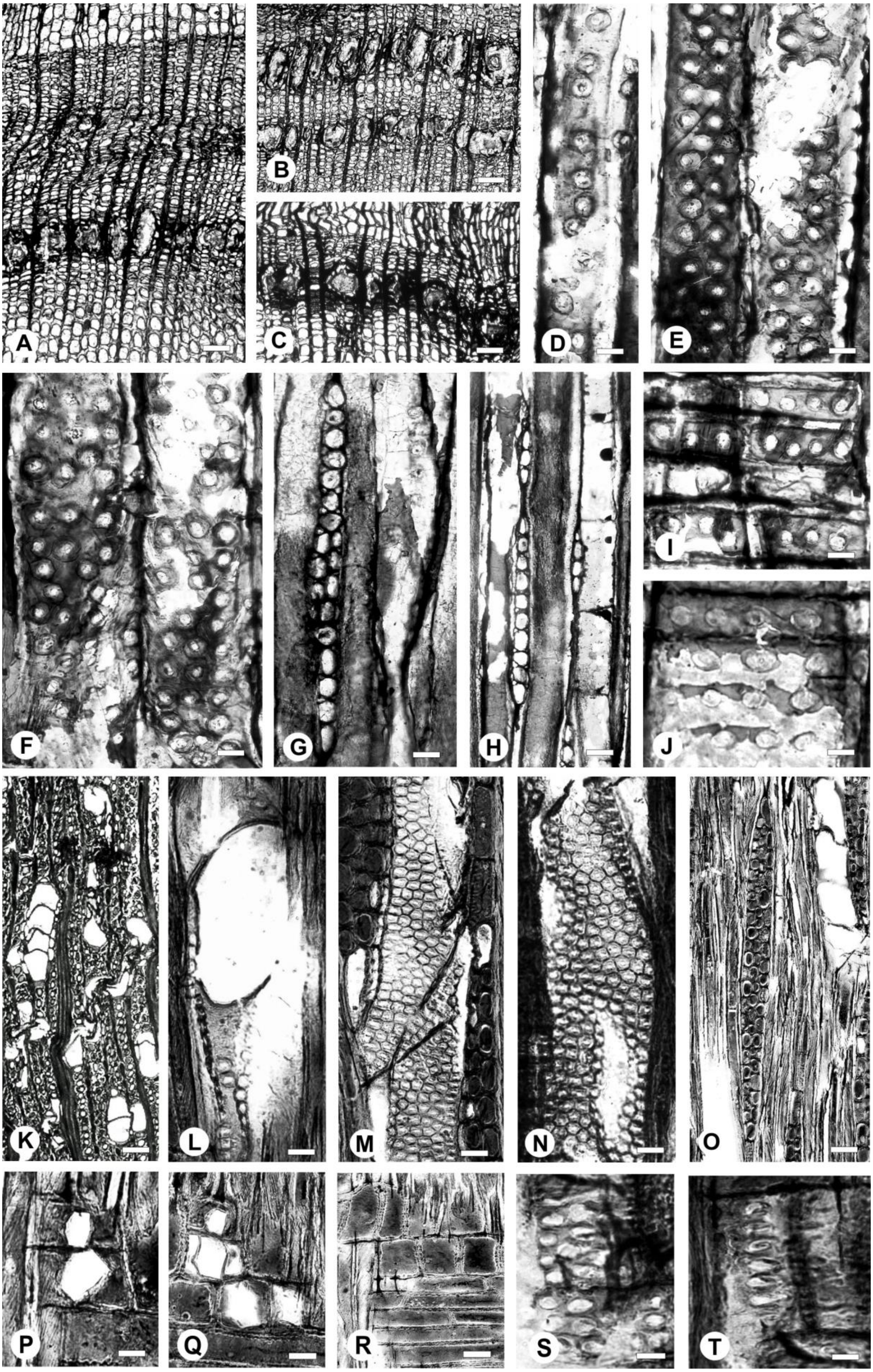


Fig. 1. Map showing fossil wood collection site of Sakhalin Island.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terrigenous deposits of the Bykov Formation. The age of the Bykov Formation is Late Cenomanian–Early Campanian, based on diagnostic marine fossils (Zakharov et al., 1981; Poyarkova, 1987). According to Yu.D. Zakharov et al. (1981), these deposits contain ammonoinds, bivalves, gastropods, scaphopods and plant remains (including fossil woods). A detailed overview of the marine fossils from the Bykov Formation in the Nayba River Basin is given in the abovementioned paper. The fossil woods studied are hard, permineralized, grey to almost black, and they represent the remains of trunks or large branches. They were studied using the conventional petrographic technique for preparing thin sections of permineralized wood.

Sequoioxylon sp. (fossil wood samples no. IBSS 37/3, 37/6, 37/7, 37/8, 37/9, 37/10) is characterized by the presence of distinct growth rings, uniseriate, biseriate, triseriate, and sometimes tetraseriate pits on the radial walls of tracheids, crassulae between multiseriate pits on the radial walls of tracheids, uniseriate pits on the tangential walls of tracheids, abundant diffuse axial parenchyma with smooth transverse end walls of cells, uniseriate rays (1–60 cells high) with long biseriate parts, marginal ray tracheids, taxodioid cross-field pits and traumatic vertical resin canals (Fig. 2A–J).

Paraphyllanthoxylon sp. (fossil wood sample no. IBSS 37/12) has diffuse-porous wood, distinct growth rings, tyloses in vessels, simple perforation plates, alternate intervessel pits, distinct circular vessel-ray pits, fiber-tracheids with small, circular, bordered pits, apotracheal axial parenchyma, heterocellular rays width 1 to 5 cells, rarely uniseriate rays, ray cells with prismatic crystals (Fig. 2K–T).

It should be noted that *Sequoioxylon* fossil wood was described from the Cretaceous of Sakhalin for the first time. The record of *Paraphyllanthoxylon* represents the first from Russia. Therefore, the investigation of the Cretaceous woods of Sakhalin will improve our understanding of the vegetation history during the Cretaceous in Northern Asia.

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References

Nishida, H., Nishida, M., 1986. Petrified plants from the Upper Cretaceous of Saghalien (2). Bot. Mag. Tokyo 99, 205–212.

Nishida, M., Nishida, H., 1986. Petrified plants from the Upper Cretaceous of Saghalien (1). Bot. Mag. Tokyo 99, 191–204.

Nishida, M., Nishida, H., 1995. Pinoid woods with resin canals from the Upper Cretaceous of Hokkaido and Saghalien. J. Plant Res. 108, 161–170.

Poyarkova, Z.N. (Ed.), 1987. Reference section of the Cretaceous deposits in Sakhalin (Nayba section). Nauka Publishing House, Leningrad (in Russian).

Shimakura, M., 1937. Studies on fossil woods from Japan and adjacent lands (2). Sci. Rep. Tohoku Imp. Univ. Sendai. Ser. 2 (Geology) 19(1), 1–73.

Zakharov, Yu.D., Grabovskaya, V.S., Kalishevich, T.G., 1981. Succession of marine invertebrates from the Nayba and Bykov formations of the reference Upper Cretaceous section in Sakhalin, in: Naydin, D.P., Krassilov, V.A. (Eds.), Organic evolution and biostratigraphy in the middle of the Cretaceous period. Vladivostok, pp. 47–85 (in Russian).

Fig. 2. (A–J) Photomicrographs of *Sequoioxylon* sp. (sample no. IBSS 37/6). (A–C) Transverse sections showing distinct growth rings, transition from the early wood to the late wood, and traumatic vertical resin canals. (D–F) Radial sections showing one, two and three rows of radial tracheid bordered pits. (G) Tangential section showing uniseriate ray with biseriate part. (H) Tangential section showing uniseriate rays and smooth transverse end walls of axial parenchyma cells. (I, J) Radial sections showing taxodioid cross-field pits and smooth horizontal and end walls of ray cells. (K–T) Photomicrographs of *Paraphyllanthoxylon* sp. (sample no. IBSS 37/12). (K) Transverse section showing diffuse-porous wood. (L) Radial section showing simple perforation plate. (M, N) Radial sections showing alternate intervessel pits. (O) Tangential section showing rays width 1 to 3 cells. (P–R) Radial sections showing ray cells with prismatic crystals. (S, T) Radial sections showing vessel-ray pits.

The change of the Early Cretaceous ecosystems of Gusinoozerskiy Basin (the Buryat Republic)

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The Gusinoozerskiy Basin contains the sedimentary strata united into the Gusinoozyorskaya Group, which is divided into the Murtoy, Ubukun, Selenga and Kholboldzhin formations (Skoblo et al., 2001). They overlay with stratigraphic unconformity the Upper Jurassic and older volcanic rocks. The Murtoy Formation consists mainly of conglomerates and sandstones with remains of fossil vertebrates (theropods, sauropods, ornithopods, and ceratopsians), as well as the abundant remains of limnetic fauna (Skoblo et al., 2001; Nessov and Starkov, 1992; Averianov and Skutschas, 2009). Its thickness is 250–450 m.

In the Murtoy Formation, the numerous remains of conifers *Pityophyllum* ex gr. *nordenskioldii* (Heer) Nath. and *Pityocladus* sp. were found at the Atsay locality. The strobiles *Scarburgia hillii* Harris are common in the burial with them. The horsetail stems, scale-leaved shoots *Cyparissidium gracile* Heer and strobiles of conifers are rare. According to V.A. Vachrameev (1964), the flora of this formation also includes *Coniopteris onychioides* Vassil. et K.-M., *Cladophlebis* aff. *tongusorum* Pryn., *Sphenopteris* (*Ruffordia*) cf. *goeppertii* Dunk., *Carpolithes* sp. Palynological assemblage is dominated by Schizaeaceae (mainly *Concavissimisporites*), the share of the latter in the pollen spectra can reach 36%. A number of club-mosses is high, up to 24%. The percentage of cyatheaceous and dicksoniaceous ferns does not exceed 15%. Among gymnosperms the bisaccate pollen having pinaceous affinity prevails (up to 36%); it is accompanied by *Ginkgocycadophytus* sp. (up to 18%). Only for palynological assemblage of this formation the pollen of unknown affinity, *Pollenites* sp., having elongated shape with longitudinal folds is characterized. Its amount may reach 12% (Kotova, 1964).

The Ubukun Formation is characterized by fine-grained clayey well-bedded deposits with ash-gray massive mudstones having conchoidal fracture. The numerous remains of lacustrine bivalves and ostracods have been found. The thickness of this formation is 140–250 m (Skoblo et al., 2001).

The Selenga Formation is represented by a multi-step alternation of two-three-term transgressive rhythms of deposits. Each of the lower rhythms is formed by the fluvial or lacustrine sandstones, and the overlying rhythm is represented by thicker fine-grained psammite or siltstone beds of floodplain or lacustrine origin with seams of brown coal. In total, 23 coal seams were revealed. In the upper part of this formation, the cross-bedded sandstones become more widespread. The shells of ostracods and mollusks, bones of fish *Lycoptera fragilis* Huss. have been found. The thickness of this formation varies from 575 to 1330 m (Skoblo et al., 2001). The Selenga Formation yields abundant remains of leaves *Pseudotorellia* sp. and *Phoenicopsis* cf. *krassilovii* Kiritch. The findings of *Pityophyllum* ex gr. *nordenskioldii* (Heer) Nath. are common, *Coniopteris setacea* Vachr., *Sphenopteris* (*Ruffordia*) cf. *goeppertii* Dunk., *Cladophlebidium dahuricum* Pryn., *Cyparissidium gracile* Heer, *Podozamites lanceolatus* (L. et H.) F. Braun, *Samaropsis* cf. *aurita* Krassil., *Nilssoniopteris* cf. *prynadae* Samyl., *Baisia* cf. *hirsuta* Krassil., *Umaltolepis* sp., *Ixostrobus* sp., *Swedenborgia* sp. are rare. Palynological assemblage is dominated by club-mosses and bryophytes, their number may reach 46%. Percentage of cyatheaceous and dicksoniaceous ferns increases up to 28%, schizaeaceous ferns become more diverse. Among gymnosperms bisaccate pollen close to Pinaceae dominates, sometimes reaching 55%. The share of *Ginkgocycadophytus* sp. reduces (13%). The rare *Classopollis classoides* Pfl. et Jans. appears. The bulk maceration of coals of this formation has revealed that they are composed mainly of leaves *Pseudotorellia* sp. A. and fossil wood of Pinaceae.

In the Kholboldzhin Formation, the cross-bedded, light gray quartz-feldspathic sandstones widely spread. About 16–17 coal seams having the thickness from 2–4 to 30 and even

53 m occur here. The thickness of this stratigraphic unit is 1000–1200 m (Skoblo et al., 2001). The numerous leaves of *Pseudotorellia* sp. and *Ginkgo coriacea* Florin were revealed in this formation. Next in abundance in the burials are the remains of *Pityophyllum* ex gr. *nordenskioldii* (Heer) Nath., *Pityocladus* sp., *Cyparissidium gracile* Heer, and *Podozamites lanceolatus* (L. et H.) F. Braun. Palynological assemblage is dominated by club-mosses and bryophytes (36%), as well as by cyatheaceous and dicksoniaceous ferns (up to 30%). The share of osmundaceous ferns is significant (about 12%). As compared with the previous assemblage, the number of schizaeaceous ferns drastically reduced; they are rare. The bisaccate pollen of Pinaceae maintains its quantitative part (48%), the percentage of *Ginkgocycadophytus* sp. (20%) and *Classopollis classoides* (2–3%) slightly increases. The palynological assemblage of this formation is characterized by the appearance of the taxodialeans (1.5%). The plant basis of coals comprises mainly leaves *Pseudotorellia* sp. B. and wood of Pinaceae in this formation.

V.A. Vachrameev (1964) and I.Z. Kotova (1964) believed that the composition of the megafossil flora of the formations in Gusinoozerskiy Basin almost does not change and they considered the geological age of Gusinoozerskaya Group as the Early Cretaceous, while V.M. Skoblo et al. (2001) dated this group as the Berriasian–Aptian. Our findings of guide taxa of fossil plants, characteristic for the Barremian–Aptian floras of Transbaikalia, Mongolia and north-eastern China (Bugdaeva, 1989; Bugdaeva and Markevich, 2012; Krassilov, 1982; Krassilov and Bugdaeva, 1982; Prynada, 1962; Sun et al., 2001), allow us to assume that the sedimentary sequence of this basin was formed within the Barremian–Early Albian.

Thus, at the beginning of formation of the basin the conditions favorable for habitation and burial of herbivorous dinosaurs (mostly psittacosaurs, but also sauropods) appeared. Psittacosaurs had self-sharpening teeth well adapted to browse rude fare and crush it. The diet of psittacosaurs, like modern parrots, could consist of seeds, fruits, branches, buds and leaves. There is paleontological evidence that they used gastroliths (stones in the stomach) for grinding, as some recent birds. The gregarious behavior was inherent for them. A not large size of bodies of herbivorous dinosaurs existed in this basin may indicate that vegetation of dinosaur ecosystems was not abundant, highly productive and easily restored. According to the paleobotanical data we can assume the existence of lighted coniferous-cheirolediaceous forests with abundant undergrowth, consisting of shrubby cycadophytes, club-mosses, mosses, and various ferns (mostly schizaeaceous, to a lesser cyatheaceous and dicksoniaceous ferns). A recent representatives of Schizaeaceae are herbaceous or liana plants; usually they inhabit the moist biotopes.

As the Gusinoozerskiy Basin developed and broadened, the lakes and meandering rivers have formed. The environment and vegetation changed. The lacustrine ecosystem with abundant limnetic fauna begins to form. The shells of ostracods and mollusks were buried under ash fall as a result of the some distant volcano eruption. Since the time of deposition of the Selenga Formation an intensive swamping of this area occurred. The abundant vegetation provides a massive phytomass in burial and gives rise to the coals. Swamp plant community was dominated by conifers and ginkgoaleans (*Pseudotorellia*), lower plants, cyatheaceous and dicksoniaceous ferns. During the time of deposition of the Kholboldzhin Formation, the diversity of the community increased by appearance of taxodialeans and ferns having affinity with Osmundaceae. Lack of dinosaur burials in the deposits of lacustrine and swamp origin can evidence of such conditions were not favorable for the habitat of these animals.

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References

Averianov, A.O., Skutschas, P.P., 2009. Additions to the Early Cretaceous Dinosaur Fauna of Transbaikalia, Eastern Russia. Proc. Zoological Institute RAS 313 (4), 363–378.

Bugdaeva, E.V., 1989. Correlation of the Lower Cretaceous isolated depressions of Transbaikalia based on flora, in: Stage and zonal scales of the Boreal Mesozoic of the USSR. Nauka, Moscow, pp. 162–168 (Proc. IGG SB AN SSSR 722) (in Russian).

Bugdaeva, E.V., Markevich, V.S., 2012. The age of Lycoptera beds (Jehol biota) in Transbaikalia (Russia) and correlation with Mongolia and China, in: Godefroit, P. (Ed.), Bernissart Dinosaurs and Early Cretaceous Terrestrial Ecosystems. Indiana University Press, Bloomington, pp. 452–464.

Kotova, I.Z., 1964. The age of the continental deposits of the Gusinoozerskaya depression and features of the Early Cretaceous floras of Transbaikalia. Izv. Akad. Nauk, Ser. Geol. (8), 84–93 (in Russian).

Krassilov, V.A., 1982. Early Cretaceous flora of Mongolia. Palaeontographica B 181, 1–43.

Krassilov, V.A., Bugdaeva, E.V., 1982. Achene-like fossils from the Lower Cretaceous of the Lake Baikal area. Rev. Palaeobot. Palynol. (36), 279–295.

Nessov, L.A., Starkov, A.I., 1992. The Cretaceous vertebrates from Gusinoozerskiy Basin of Transbaikalia and their significance for age definition and conditions of formation of deposits. Geology and Geophysics (6), 10–18 (in Russian).

Prynada, V.D., 1962. Mesozoic flora of Eastern Siberia and Transbaikalia. Gosgeoltekhizdat, Moscow (in Russian).

Sun, G., Zheng, S.-L., Dilcher, D., Wang, Y.-D., Mei, S.-W., 2001. Early Angiosperms and their associated Plants from Western Liaoning, China. Scientific and Technological Education Publishing House, Shanghai.

Skoblo, V.M., Lyamina, N.A., Rudnev, A.F., Luzina, I.V., 2001. The Continental Upper Mesozoic of the Pribaikalia and Transbaikalia (stratigraphy, depositional environments, correlation). Publishing House of the SB RAS, Novosibirsk (in Russian).

Vachrameev, V.A., 1964. The Jurassic and Early Cretaceous floras of Eurasia and paleofloristic provinces of this time. Nauka, Moscow (Proc. Geological Institute AS USSR 102, 1–263) (in Russian).

Taxonomy and morphological diversity of infructescences co-occurred with *Trochodendroides* leaves

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The remains of distinctive follicular fruits with subparallel longitudinal ridges and transverse striation often occur in the Late Cretaceous and Tertiary deposits in the Northern Hemisphere. They were first detected from the Paleocene deposits of Atanekerdluk in West Greenland, and then named as *Nyssa arctica* Heer (1869).

Leaves associated with these follicular fruits are usually assigned to the genus *Trochodendroides*, which was a common component of the Late Cretaceous and Paleogene floras from middle and high latitudes. The investigation of their cuticular features reveals the similarity of *Trochodendroides* leaves with those of living genus *Cercidiphyllum* (Golovneva and Alekseev, 2010).

Later, such fruits were assigned to a wide range of extinct and extant genera: *Leguminosites* (Lesquereux, 1873, 1878), *Nyssidium* (Heer, 1870; Schmalhausen, 1890; Hollick, 1936; Iljinskaya, 1974; Crane, 1984), *Berrya* (Knowlton, 1930), *Jenkinsella* (Reid and Chandler, 1933), *Trochodendrocarpus* (Kryshtofovich, 1958), *Joffrea* (Crane and Stockey, 1985). Most part of these names is inappropriate. The form genus *Leguminosites* was erected by Bowerbank (1840) for fruits and seeds of fossil Fabaceae from London Clay. The name *Berrya* can not be used for this type of fructification, because earlier this name was established for another plant from family Malvaceae. The genus *Trochodendrocarpus* is also invalid, because name *Jenkinsella* had priority before *Trochodendrocarpus*. Iljinskaja (1974) suggested using generic name *Nyssidium* Heer as the earliest appropriate generic name for this kind of fruits. However, these fruits differ from those of *Nyssa arctica* by smaller sizes and some other features (Budantsev and Golovneva, 2009).

Abundant specimens from the Upper Paleocene Paskapoo Formation, the Joffre Bridge locality, Alberta, Canada, allowed describing the most complete *Cercidiphyllum*-like plant (Crane and Stockey, 1985). *Joffrea speirsii* Crane et Stockey is known from shoots, leaves, pistillate inflorescences, infructescences, winged seeds and seedlings. Associated staminate inflorescences were described later as *Alasia* (Golovneva, 2006).

Although the name *Nyssidium* is now widely used, it should be rejected for isolated follicles and racemes, associated with *Trochodendroides* leaves. In other case delimitation of this kind of fructification from other similar remains will be problematic. The earliest generic name originally designated for fruits of *Cercidiphyllum*-like plants with distinguishable morphology and critical details of inner structures is *Jenkinsella*. We suggested applying the name *Jenkinsella* to dispersed follicular fruits or to fruits attached to the axis (raceme).

In the genus *Jenkinsella* we recognized three species: *J. apocynoides* Reid et Chandler, *J. arctica* (Heer) Bell and *J. filatovii* (Samylina) Golovneva et P. Alekseev. The first of these is applied to the permineralized fruits from the London Clay Formation for which many morphological and anatomical details were revealed. Second name we suggested to use as broadly defined species to accommodation of fruits preserved mostly as impression without anatomical details. Variations in shape and size usually do not provide sufficient basis for separation of morphological species.

For present time several types of follicular racemose infructescence, attached to shoots, were described: *Joffrea speirsii* from the Paskopoo Formation (Paleocene, Canada), "*Trochodendrocarpus arcticus*" from the Upper Tsagayan Formation (Paleocene, Russia), "*Nyssidium arcticum*" from the British Lower Tertiary and "*Berrya racemosa*" from the Dawson arkose (Paleocene, USA). The same kind of infructescences were documented in detail from the Paleocene of north-east China as *Nyssidium jiayinense* G.P. Feng, C.S. Li, Zhilin, Y.F. Wang et Gabrielyan (Feng et al., 2000). N.M. Makulbekov (1988) described *Trochodendrocarpus asiaticus* Makulbekov from the Paleocene of Mongolia.

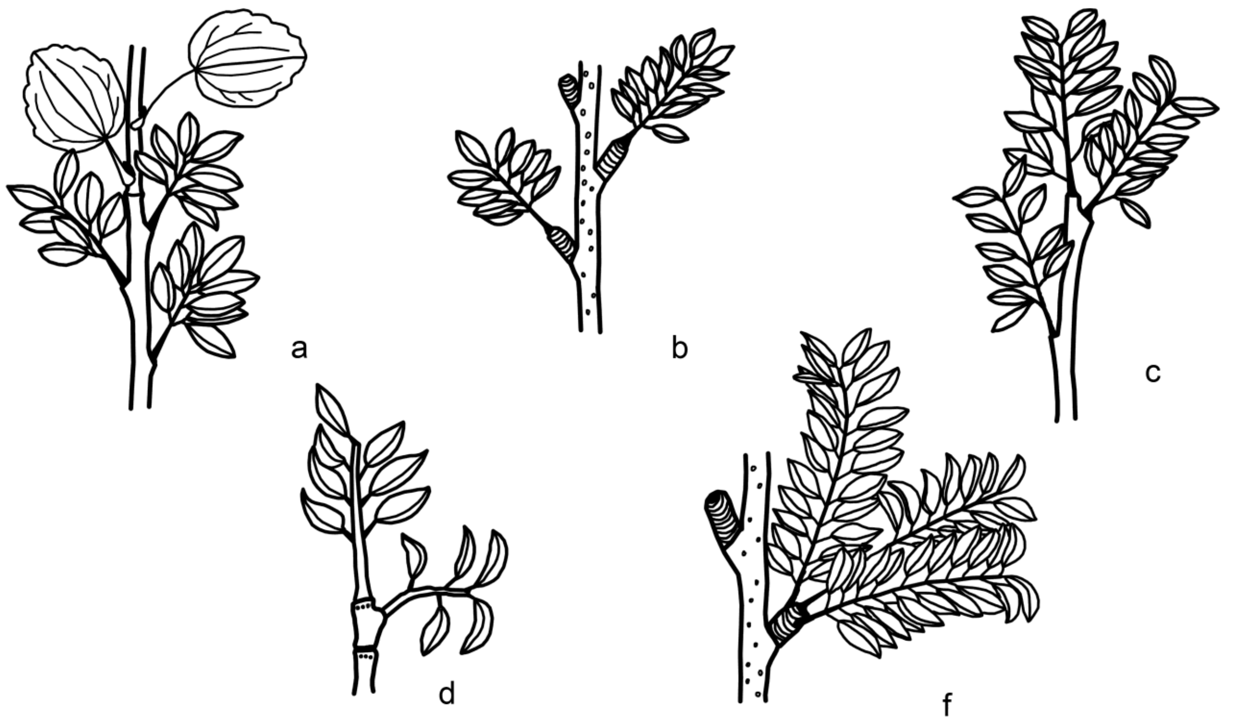

Fig. 1. Schematic reconstructions of fertile shoots of different species of *Jenkinsella* (a–d) and *Joffrea speirsii* (f): a – long shoot with alternate lateral infructescences in terminal position and vegetative shoot developing from apical bud (*Jenkinsella krassilovii*); b – long shoot with alternate short shoots, bearing singly infructescences in terminal position (*Jenkinsella confertus* and *J. makulbekovii*); c – long shoot with alternate lateral and one apical infructescences (*Jenkinsella jiayinensis*, *J. knowltonii* and *J. vilyuensis*); d – terminal short with one lateral and one apical infructescences (*Jenkinsella gardnerii*); f – long shoot with alternate short shoots, bearing three alternate lateral infructescences (*Joffrea speirsii*).

Two more types of these infructescences were found recently in the Coniacian deposits of the Sym Formation in Western Siberia and in the Turonian–Coniacian deposits of the Timmerdyakh Formation in Eastern Siberia.

The general construction of racemose infructescences and fruits of all known specimens is practically identical. This similarity allows supposing that these plants were closely related and differences are not sufficient for separate generic designation. To avoid further confusion, we recommend to consider all known findings under one generic name and differentiate them specifically. For this aim we suggest to use the name *Jenkinsella* to accommodate also racemose infructescense of follicular fruits, attached to the shoots. Now we include another seven species in this genus: *Jenkinsella krassilovii* Golovneva et P. Alekseev, *J. gardnerii* (Chandler) Golovneva et P. Alekseev, *J. knowltonii* Golovneva et P. Alekseev, *J. jiayinensis* (G.P. Feng, C.S. Li, Zhilin, Y.F. Wang et Gabrielyan) Golovneva et P. Alekseev, *J. confertus* P. Alekseev et Golovneva, *J. makulbekovii* Golovneva et P. Alekseev, and *J. vilyuensis* Golovneva et P. Alekseev (Fig. 1).

General organization of infructescences is similar in all species of *Jenkinsella*. This is a raceme with numerous follicles that were borne on short side branches of infructescence axis. Each side branch bears one or two short-stalked follicles. There is the junction between the follicle stalk and the side branch of the infructescence. The follicles or pairs of follicles are often broken away at this joint. This similarity indicates close relationship of all species in spite of differences in position of infructescences. The differences between species in infructescence and follicles features are insignificant. The infructescences were developed from lateral flower buds without leaves. Production of infructescences from the apical bud terminates the growth of shoot. Because the long shoots of *Jenkinsella* with infructescences usually shed as a unit, it is possibly to suggest that most part of them had apical infructescence.

The reproductive structures of *Jenkinsella confertus* resemble those in *Joffrea speirsii*. This plant also exhibits long and short shoot differentiation. General construction of the racemose infructescences in both species is also similar. However, short shoots of *J. confertus* bore one terminal infructescence, while short shoots of *Joffrea speirsii* had at least two infructescences.

The fossil records of *Jenkinsella* range from Early–Middle Albian to Oligocene and occur mostly in temperate and subtropical areas of the Siberian-Canadian paleofloristic realm. Majority of findings of this genus comes from the Paleocene and Eocene deposits.

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References

Bowerbank, J.S., 1840. A history of the fossil fruits and seeds of the London Clay. John Van Voorst, London.

Budantsev, L.Y., Golovneva, L.B., 2009. Fossil Flora of Arctic II—Palaeogene Flora of Spitsbergen. Marafon, Saint Petersburg.

Crane, P.R., 1984. A re-evaluation of *Cercidiphyllum*-like plant fossils from the British early Tertiary. Bot. J. Linn. Soc. 89, 199–230.

Crane, P.R., Stockey, R.A., 1985. Growth and reproductive biology of *Joffrea speirsii* gen. et sp. nov., a *Cercidiphyllum*-like plant from the Late Paleocene of Alberta, Canada. Can. J. Bot. 63(2), 340–364.

Feng, G.P., Li, C.S., Zhilin, S.G., Wang, Y.F., Gabrielyan, I.G., 2000. *Nyssidium jiayinense* sp. nov. (Cercidiphyllaceae) of the Early Tertiary from north-east China. Bot. J. Linn. Soc. 134, 471–484.

Golovneva, L.B., 2006. *Alasia*, gen. nov. – male inflorescences, associated with *Trochodendroides* leaves (Cercidiphyllaceae). Bot. J. 91(12), 1898–1906 (in Russian).

Golovneva, L.B., Alekseev, P.I., 2010. The genus *Trochodendroides* Berry in the Cretaceous floras of Siberia. Palaeobotany 1, 120–166 (in Russian).

Heer, O., 1869. Contributions to the fossil flora of North Greenland, being a description of the plants collected by Mr. Edward Whymper during the summer of 1867. Philos. Trans. R. Soc. London 159, 445–488.

Heer, O., 1870. Die Miocene Flora und Fauna Spitzbergens. Kongl. Svenska Vetensk. Akad. Handl. 8 (7), 1–98.

Hollick, A., 1936. The Tertiary floras of Alaska. U. S. Geol. Surv. Prof. Pap. 182, 1–185.

Iljinskaja, I.A., 1974. *Nyssidium* Heer, in: Takhtajan, A.L. (Ed.), Magnoliophyta Fossilia URSS. Vol. 1. Nauka, Leningrad, pp. 123–124 (in Russian).

Knowlton, F.H., 1930. The flora of the Denver and associated formations of Colorado. U. S. Geol. Surv. Prof. Pap. 155, 1–135.

Kryshtofovich, A.N., 1958. Fossil floras of Penjin Bay, Tastakh Lake and Rarytkin Range. Trans. Bot. Inst., Ser. 8, 3, 74–121 (in Russian).

Lesquereux, L., 1873. Enumeration and description of fossil plants from the Western Tertiary formations. Description of species of fossil plants from the Cretaceous of Kansas. U. S. Geol. Geogr. Surv. Terr., Ann. Rep., pp. 371–427.

Lesquereux, L., 1878. Contributions to the fossil flora of the Western Territories. Pt. II. The Tertiary flora. U. S. Geol. Surv. Terr., Rep. 7, pp. 1–366.

Makulbekov, N.M., 1988. Paleogene flora of Southern Mongolia. Nauka, Moscow (in Russian).

Reid, E.M., Chandler, M.E., 1933. The London Clay flora. British Museum Natural History, London.

Schmalhausen, J., 1890. Wissenschaftliche Resultate der von der Kaiserlichen Akademie der Wisswnschaften zur erforschung des Janalandes und der Neusibirischen Inseln in der Jahren 1885 und 1886 ausgesandten Expedition. Abt. II. Tertiäre pflanzen der Insel Neusibirien. Mém. Acad. Imp. Sci. St.-Pétersbourg. VII Sér. 37(5), 1–22.

The composition and dynamics of the Late Cretaceous and Paleocene Arctic plant communities

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The Arctic is rich with Late Cretaceous and Paleocene plant fossils evidencing a thriving, diverse, but now extinct polar ecosystem that sequestered vast amounts of carbon (Herman, 2013; Spicer and Herman, 2010). The polar climate and light regime were key constraints on floral composition and dynamics (Herman et al., 2016). By combining field and museum studies across North America and Northern Asia a picture has emerged of a highly productive polar ecosystem surrounding a warm Arctic Ocean and shrouded in an almost permanent cover of cloud and mist. High rainfall, warm temperatures and 24 hours of diffuse sunlight led to high summer productivity (Spicer and Herman, 2010). Cool wet winters favoured the translation of autumnal leaf fall and above ground biomass dieback into deep time storage, thus making these forests highly effective systems for sequestering carbon. By using collections and observations made over large numbers of field seasons working in different geographic areas and on rocks of different ages it has been possible to gain insights into palaeofloral associations, and even seral successions.

The sedimentologically dynamic Arctic floodplains captured a patchwork of plant communities at different stages of development. Detailed examination of the distributions of plant remains in time and space, and repeated associations that occur between particular plant taxa and particular sedimentary facies, allows the reconstruction of changes in Arctic vegetation composition and dynamics throughout the Late Cretaceous and into the Paleocene (Herman, 2013; Herman et al., 2016; Spicer and Herman, 2010). Based on many thousands of leaf and leafy shoot remains, fossil wood and reproductive organ assemblages from Northeastern Russia and Northern Alaska we identify a number of successional plant communities (SPCs) representing seral development from early (primary colonisers, pioneer), through middle to late (mature, 'climax') SPCs. By looking at taxon/facies relationships in successive taphofloras through longer intervals of time we have been able to study the evolution of seral succession.

Successional plant communities (SPCs) are those aggregations of taxa that repeatedly occur in stages as a bare substrate is initially colonised and the composition of the vegetation changes until a relatively stable state is attained, often, but not always, comprising a mature forest. In our case we divide the SPCs into three categories: Early, Middle and Late (Fig. 1). The boundaries between these stages are not rigid, but are transitional as the composition changes by the addition or loss of individual taxa.

We recognise that (1) horsetails *Equisetites* and some ferns (typically *Birisia*, but after the beginning of the Maastrichtian, *Onoclea*) were obligatory components of the early SPCs; (2) the first rare angiosperms (e.g., the dicot *Vitiphyllum multifidum*) appeared in the middle SPCs of the Arctic in the Early–Middle Albian and occupied disturbed near-channel habitats; (3) from Late Albian times onwards angiosperms became abundant in the middle SPCs of the Arctic, but were still rare in the earlier and later SPCs; (4) monocots appeared in the Maastrichtian in early, predominantly aquatic, SPCs; (5) all Arctic Cretaceous late SPCs (and 'climax' vegetation) were dominated by conifers; (6) Arctic SPCs were taxonomically more diverse under warm climate intervals than cold; (7) during the Albian and Late Cretaceous, advanced (Cenophytic, angiosperm-dominated) plant communities co-existed with those of a more relictual (Mesophytic, dominated by ferns and gymnosperms) aspect, and plants in these communities tended not to mix; (8) coal-forming environments (mires) remained conifer, fern and bryophyte dominated throughout the Late Cretaceous and Paleocene with little penetration of woody angiosperm components and so are conservative and predominantly Mesophytic in character;

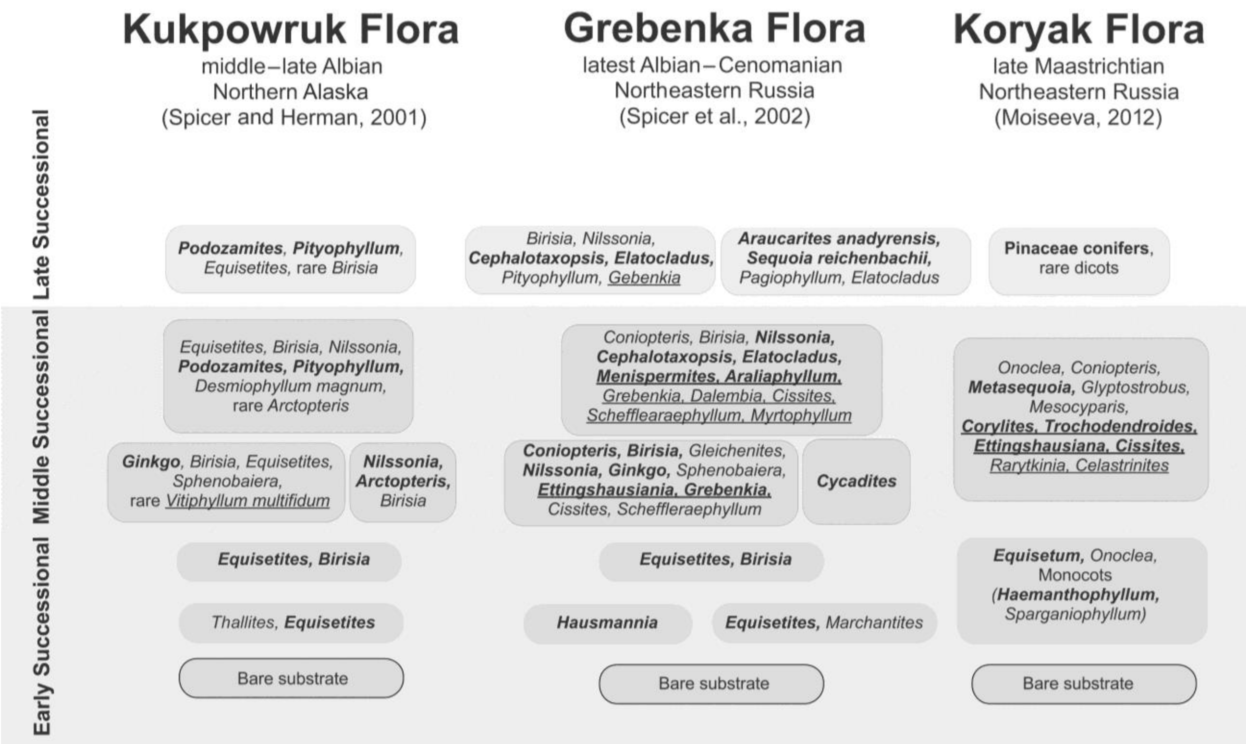

Fig. 1. Idealised successional plant communities based on three exemplar fossil floras: the Middle to Late Albian Kukpowruk Flora (Spicer and Herman, 2001), the latest Albian–Cenomanian Grebenka Flora (Spicer et al., 2002) and the Late Maastrichtian Koryak Flora (Moiseeva, 2005, 2012). Ecologically dominant taxa are shown in bold and angiosperms are underlined.

(9) bryophytes and ferns, with some subordinate conifers, make up a persistent raised mire climax community that is most widely developed in Late Albian, Cenomanian and Campanian times, with the Campanian exhibiting particularly high levels of bryophyte diversity; (10) general Cretaceous SPC characteristics were maintained into the Paleocene due to migrations from Northeastern Russia into the more northerly Northern Alaska and (11) there was no significant extinction across the K/Pg boundary.

These observations attest to Arctic vegetation displaying persistent structure and dynamics despite a general Late Cretaceous cooling trend and events at the Cretaceous–Paleogene transition.

References

Herman, A.B., 2013. Albian–Paleocene flora of the North Pacific: Systematic composition, palaeofloristics and phytostratigraphy. Stratigr. Geol. Correl. 21(7), 689–747.

Herman, A.B., Spicer, R.A., Spicer, T.E.V., 2016. Environmental constraints on terrestrial vertebrate behaviour and reproduction in the high Arctic of the Late Cretaceous. Palaeogeogr. Palaeoclimatol. Palaeoecol. 441, 317–338.

Moiseeva, M.G., 2005. Koryak floristic assemblage of Northeastern Russia: Systematic composition, ecological, taphonomical and palaeoclimatic characteristics, in: Akhmetiev, M.A., Herman, A.B. (Eds.), Modern problems of palaeofloristics, palaeophytogeography and phytostratigraphy. GEOS, Moscow, pp. 212–223 (in Russian).

Moiseeva, M.G., 2012. The Maastrichtian Flora of the Amaam Lagoon Area (Northeastern Russia). Stratigr. Geol. Correl. 20(7), 579–679.

Spicer, R.A., Herman, A.B., 2001. The Albian–Cenomanian flora of the Kukpowruk River, western North Slope, Alaska: stratigraphy, palaeofloristics, and plant communities. Cretaceous Res. 22, 1–40.

Spicer, R.A., Herman, A.B., 2010. The Late Cretaceous environment of the Arctic: A quantitative reassessment based on plant fossils. Palaeogeogr. Palaeoclimatol. Palaeoecol. 295, 423–442.

Spicer, R.A., Ahlberg, A., Herman, A.B., Kelley, S.P., Raikevich, M.I., Rees, P.M., 2002. Palaeoenvironment and ecology of the middle Cretaceous Grebenka flora of northeastern Asia. Palaeogeogr. Palaeoclimatol. Palaeoecol. 184, 65–105.

Late Jurassic to Early Cretaceous oysters (Bivalvia, Ostreoidea) from Siberia: Taxonomy, palaeoecology, distribution and variations of carbon and oxygen isotopes

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The present contribution is an analysis of more than 300 specimens of Upper Jurassic–Lower Cretaceous oysters collected by V.A. Zakharov during the 1960s and currently stored in Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of RAS (Novosibirsk, Russia). They were sampled in the northwestern margin of Western Siberia (Yatriya, Maurynya, Tol'ya, and Lopsiya rivers) and the north of Eastern Siberia (Boyarka, Bol'shaya Romanikha, and Dyabaka-Tari rivers) (Zakharov, 1966; Saks, 1972; Zakharov and Mesezhnikov, 1974; Kosenko, 2014). During the last five years, they were examined with taxonomic and palaeoecological purposes.

Taxonomic study included classical morphofunctional and biometrical analyses. A large number of Cretaceous oysters from Crimea as well as of modern Pacific oysters, *Crassostrea gigas*, have been involved in this study to understand the range of modification variability between different species (Kosenko, 2016). Oysters identified previously as *Liostrea* are attributed now to four genera: *Praeexogyra*, *Helvetostrea* (Flemingostreidae), *Pernostrea* (Gryphaeidae), and one new genus (Gryphaeidae) including only species "*Liostrea*" *roemeri* (Quenstedt). The latter genus is characterised by peculiar ethology, being attached to floating ammonites, and morphology outlined by a beak-shaped umbo on the right (!) valve. Endemic Siberian species from the genus *Pernostrea* have recently been included into the subgenus *Boreiodeltoideum* Kosenko, 2016. Genera *Pernostrea* and *Deltoideum* have been included into the new tribe (under description) from the subfamily Gryphaeinae. Model of phylogenetic relationships between species of this tribe has been proposed.

Siberian oyster complexes are compared with complexes from Western Europe, Poland and East European Platform (Table 1). Two stages of oyster development, Jurassic stage and Cretaceous stage, are recognised in western Boreal and Subboreal domains (England, northern France and Poland). In Siberia, Jurassic and Early Cretaceous oysters formed a unique complex. This may be explained by the absence of good communications between west European and Polish basins and Siberian basins during the earliest Cretaceous.

Based on carbonate material of oyster shells the stable isotope analyses were performed, and palaeotemperatures were calculated. Seven oyster shells of *Pernostrea* (*Pernostrea*) *uralensis* (Zakharov) from the Jurassic–Cretaceous boundary interval (Upper Volgian–lowermost Ryazanian) of Maurynya River have been used to obtain $\delta^{13}C$ and $\delta^{18}O$ data (Kosenko et al., 2013). The preservation of the carbonate material was controlled by the following methods: cathodoluminescence analyses; control of content of Fe, Mn, Sr; control of absence of correlation between $\delta^{13}C$ and $\delta^{18}O$ and content of Fe and Mn. The obtained $\delta^{13}C$ and $\delta^{18}O$ data were compared with isotopic data based on belemnites from the same section (Dzyuba et al., 2013) and were used to estimate palaeotemperatures. A general trend towards negative $\delta^{18}O$ values was recognised in the Maurynya section, from the lower part of the Upper Volgian to the middle part of the Ryazanian *Chetaites sibiricus* ammonite Zone. The same trend was also established in the Nordvik section (Dzyuba et al., 2013). The higher palaeotemperatures (2°C in average) determined from oyster shells indicate that belemnites likely migrated laterally and lived part of their lives in cooler waters.

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Table 1

Comparison of Upper Jurassic and Lower Cretaceous complexes of oysters from northwestern part of Western Siberia, northern Eastern Siberia and Europe (author's names are kept)

	Northern and Subpolar Urals (north-western part of Western Siberia)	**Northern Eastern Siberia**	**European part of Russia** (Gerasimov, 1955)	**Poland** (Pugaczewska, 1971, 1975)	**Western Europe (Switzerland)** (Koppka, 2015)
Kimmeridgian	*Pernostrea* (*Pernostrea*) sp. n. 1, *Helvetostrea exotica* (Kosenko), *Gryphaea* (*Gryphaea*) *curva* (Ger.), *Nanogyra* (*Nanogyra*) *nana* (Sow.)	*Pernostrea* (*Pernostrea*) sp. n. 1, *"Liostrea" roemeri* (Quenstedt)	*Ostrea plastica* (Trautsch.), *Exogyra virgula* (Defrance)	*Alectryonia gregarea* (Sow.), *A. solitaria* (Sow.), *A. rastellaris* (Münster), *A. pulligera* (Goldfuss), *A. vallata* (Étallon), *A. flabelliformis* (Nilsson), *Arctostrea hastellata* (Schl.), *Liostrea delta* (Smith), *L. oxfordiana* (Rollier), *L. quadrangularis* (Arkell), *L. gryphaeata* (Schl.), *L. sequana* (Thurm.), *L. moreana* (Buv.), *L. monsbeliardensis* (Cont.), *L. brasili* Chavan, *L. polymorpha* (Münster), *L. multiformis* (Koch et Dunker), *Gryphaea dilatata* (Sow.), *Nanogyra nana* (Sow.), *Exogyra virgula* (Defrance), *E. reniformis* (Goldf.), *E. welseni* (Jourdi), *E. intricata* (Cont.)	*Circunula cotyleodon* (Cont.), *Nanogyra* (*Nanogyra*) *nana* (Sow.), *N.* (*Palaeogyra*) *reniformis* (Gold.), *N.* (*P.*) *virgula* (Deshayes), *Helvetostrea sequana* (Thurm. et Étallon), *Praeexogyra dubiensis* (Cont.), *P. monsbeliardensis* (Cont.), *Actinostreon gregarium* (Sow.)
Volgian	*Pernostrea* (*Pernostrea*) sp. n. 2, *P.* (*P.*) *gibberosa* (Zakharov), *P.* (*P.*) *uralensis* (Zakharov), *Pernostrea?* sp. n. 3, *Praeexogyra siberica* (Zakharov), *"Liostrea"roemeri* (Quenstedt), *Nanogyra* (*Nanogyra*) *thurmanni* (Étallon), *N.* (*N.*) *nana* (Sow.)	*Pernostrea* (*Boreiodeltoideum*) *praeanabarensis* (Zakharov)	*Ostrea plastica* (Trautsch.), *Gryphaea curva* (Ger.), *Ostrea expansa* (Sow.), *O. unciformis* (Buv.), *O. kharashovensis* (Roullier), *O. dibiensis* (Cont.), *Exogyra nana* (Sow.)	*Liostrea dubisensis* (Cont.), *L. unciformis* (Buv.), *L. plastica* (Trautsch.), *L. virguloides* (Lew.), *Exogyra michalskii* Lew., *E. decipiensis* Lew.	no data
Ryazanian	*Pernostrea* (*Pernostrea*) *uralensis* Zakharov, *Praeexogyra lyapinensis* (Zakharov), *P. siberica* (Zakharov)	*Pernostrea* (*Boreiodeltoideum*) *anabarensis* (Bodyl.)	*Ostrea limaciforme* Ger.	*Ceratostreon tuberculiferum* (Koch et Dunker), *Rhynchostreon etalloni* (Pictet et Campiche), *Ostrea sanctae crucis* (Pictet et Campiche)	no data
Valanginian	no data	*Pernostrea* (*Boreiodeltoideum*) *anabarensis* (Bodyl.), *Pernostrea* (*Pernostrea*) *cucurbita* (Zakharov), *Gryphaea borealis* Zakharov	no data	*Aetostreon latissimum* (Lam.), *A. neocomiensis* (Orb.), *Ceratostreon minos* (Coq.), *Rhynchostreon tombeckianum* (Orb.), *Gryphaeostrea* cf. *lateralis* (Nilss.), *G. arduennensis* (Orb.), *Ostrea sanctae cricis* (Pictet et Campiche), *O. germaini* (Coq.), *Lopha* cf. *cotteaui* (Coq.), *L.* cf. *eos* (Coq.)	no data

References

Dzyuba, O.S., Izokh, O.P., Shurygin, B.N., 2013. Carbon isotope excursions in Boreal Jurassic-Cretaceous boundary sections and their correlation potential. Palaeogeogr. Palaeoclimatol. Palaeoecol. 381–382, 33–46.

Gerasimov, P.A., 1955. Index fossils of the Mesozoic of the central regions of the European part of the USSR. Gosgeoltekhizdat, Moscow (in Russian).

Koppka, J., 2015. Revision of the Bivalvia from the Upper Jurassic Reuchenette Formation, Northwest Switzerland – Ostreoidea. Zootaxa 3927, 1–117.

Kosenko, I.N., 2014. On Late Jurassic and Early Cretaceous oysters (Bivalvia, Ostreidae) from northern Siberia. Paleontol. J. 48(4), 380–388.

Kosenko, I.N., 2016. On Late Jurassic and Early Cretaceous oysters of the genus *Deltoideum* Rollier (Bivalvia, Ostreoidea) from Siberia. Paleontol. J. 50(4), 336–346.

Kosenko, I.N., Izokh, O.P., Dzyuba, O.S., Shurygin, B.N., 2013. Variatsii izotopov ugleroda i kisloroda v rakovinakh ustrits iz prigranichnykh otlozhenii yury i mela reki Maurynya (Zapadnaya Sibir'), in: XX simpozium po geokhimii izotopov imeni akademika A.P. Vinogradova (12–14 noyabrya 2013 g.): Tezisy dokladov. Akvarel', Moscow, pp. 185–188 (in Russian).

Pugaczewska, H., 1971. Jurassic Ostreidae of Poland. Acta Palaeontol. Polon. 16(3), 193–311.

Pugaczewska, H., 1975. Neocomian oysters from Central Poland. Acta Palaeontol. Polon. 20(1), 47–72.

Saks, V.N. (Ed.), 1972. The Jurassic–Cretaceous boundary and the Berriasian Stage in the Boreal Belt. Nauka, Novosibirsk (in Russian).

Zakharov, V.A., 1966. Late Jurassic and Early Cretaceous bivalves (order Anisomyaria) of northern Siberia and the conditions of their existence. Nauka, Moscow (in Russian).

Zakharov, V.A., Mesezhnikov, M.S., 1974. The Volgian Stage in the Subpolar Urals. Nauka, Novosibirsk (in Russian).

The neuropteran assemblage (Insecta) of the mid-Cretaceous Burmese amber confirms transitional character of its biota

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The biological inclusions of Burmese amber represent a sample of a tropical forest community in equatorial southeastern Asia at ~12°N paleolatitude (Grimaldi et al., 2002; Poinar et al., 2008). The volcaniclastic matrix of the amber is estimated as ~98.79±0.62 million years old, i.e., near the Albian–Cenomanian (Early–Late Cretaceous) boundary (Shi et al., 2012), but the amber is considered to be slightly older, Late Albian.

Fossils of the order Neuroptera have been found as old as the early Permian. Today, this order is comprised of 16 families. A preliminary analysis of published and unpublished materials reveals the presence of 18 neuropteran families in Burmese amber, 13 of which are extant and 5 extinct. To date, 25 neuropteran species have been described from Burmese amber, and more specimens in existing collections remain undescribed.

The vast majority of extant families are found in Burmese amber. Polystoechotidae is the only extant family known from the Cretaceous that is still not recorded from it. It is noteworthy, however, that only a few representatives of some Coniopterygidae, Nevrorthidae, Osmylidae and Dilaridae are similar to extant taxa, certainly or probably (Nevrorthidae, Osmylidae) belonging to their crown groups. All other extant families are represented in Burmese amber by unusual and/or distantly related supergeneric taxa (extinct subfamilies and tribes) that belong to their stem groups.

Burmese amber has the oldest fossil records for the extant families Sisyridae, Dilaridae and Nevrorthidae, but they are undoubtedly older, originating at least as far back as the Jurassic. All other extant families in Burmese amber except Nemopteridae are recorded from the Jurassic (its oldest known record is in the Late Aptian Crato Formation of Brazil). Unusual larvae similar to those of Crocinae (Nemopteridae) are rather common in Burmese amber, represented by at least two species (e.g., Xia et al., 2015, see figs. on pp. 99, 100).

The Nevrorthidae is recorded from Burmese amber (and the Mesozoic) for the first time, based on the photograph of Xia et al. (2015, right upper fig. on p. 101). Judging from this, this undescribed species does not strongly differ from Baltic amber and extant taxa.

The Coniopterygidae are relatively rare in Burmese amber. Two species assigned to two extinct genera have been described (Engel, 2004a), and there is at least one undescribed genus and species. One genus belongs to extant tribe Fontenelleini.

All known adult specimens of Burmese amber Osmylidae belong to the extant relict subfamily Gumillinae (Myskowiak et al., 2016; pers. obs.), whose single extant species is distributed in Brazil. Two possible larvae of Osmylidae would be very unusual for that group (Engel and Grimaldi, 2008, figs. 9–11; Xia et al., 2015, upper fig. on p. 95).

The Berothidae are the most abundant and diverse neuropterans in Burmese amber, with more than 100 known specimens and thirteen species and one unnamed larva described (Engel, 2004b; Engel and Grimaldi, 2008; Makarkin, 2015; Shi et al., 2015). The subfamily affinities of most of these are unclear (expect the Cretaceous subfamily Paraberothinae), but they probably do not belong to extant subfamilies.

One Burmese amber species assigned to the Mantispidae (Poinar and Buckley, 2011) is, however, not conclusively a member of this family; in any case, its subfamily affinity is entirely unclear.

Some larvae of Chrysopidae from Burmese amber are in general similar to those of some extant taxa, in particular in bearing short lateral tubercles (processes) (e.g., Xia et al., 2015, figs. on p. 96). They are extremely elongated on a few undescribed chrysopoid trash/debris-carrying larvae that are similar to *Hallucinochrysa* Pérez-de la Fuente from the Albian of Spain. No adult chrysopids are known from Burmese amber.

Stem group Hemerobiidae and Ithonidae are present in private collections, with at least one undescribed species each.

Larval Nymphidae are common in Burmese amber, implying that they were probably arboreal. They represent several species, all of which are generally similar to those of Nymphinae. Adults of the family are scarce; one species has been described based on an incomplete specimen (Engel and Grimaldi, 2008).

The larvae of a few species of Psychopsidae are quite common in Burmese amber, consistent with the arboreal habit of their modern species. At least three adults are known, one of which has been described (Engel and Grimaldi, 2008).

All known specimens of Burmese amber Sisyridae belong to the extinct subfamily Paradoxosisyrinae (Makarkin, 2016; pers. obs.). They are remarkable in possessing extremely long, siphonate mouthparts.

The Dilaridae are rather common, and very diverse in Burmese amber, with three species described to date (Huang et al., 2015; Lu et al., 2016). The majority of the species have long siphonate mouthparts, but some are similar to the extant *Dilar* Rambur and have the mandibute mouthparts that are usual for the family.

Of its five extinct families, Burmese amber has the youngest record for four, the Kalligrammatidae, Araripeneuridae, Babinskaiidae, and Mesochrysopidae; the Dipteromantispidae are known in younger (Turonian) New Jersey amber. Undescribed Kalligrammatidae and one species of Araripeneuridae were reported from Burmese amber by Huang et al. (2016), and Dipteromantispidae by Liu et al. (2016a). The Babinskaiidae are reported here for the first time based on photographs provided by Xia et al. (2015, fig. on p. 94). The Mesochrysopidae are represented in Burmese amber by one species similar to the Barremian genus *Allopterus* Zhang (Liu et al., 2016b).

The middle Cretaceous was a time of most intensive transformation of terrestrial ecosystems, shifting from those dominated by ancient gymnosperm groups to those dominated by angiosperms, Pinaceae and polypod ferns (‘the mid-Cretaceous biocenotic crisis’ of Zherikhin, 1978). In the Burmese amber forest, confident records of extinct gymnosperm groups (e.g., Bennettitales) are so far unknown (except for possible pollen of Bennettitales: Peñalver et al., 2015), but angiosperms were already diverse, and all known ferns are polypods (Schneider et al., 2016). At the same time, extant families dominate the neuropteran assemblage, and extinct families are rare.

The transitional character of the Burmese amber neuropteran assemblage is most clearly seen in the coexistence of three neuropteran groups with siphonate mouthparts, i.e., large Kalligrammatidae, moderately-sized Dilaridae, and small Sisyridae. Most of the Mesozoic kalligrammatid species had a long proboscis. They are assumed to have fed on pollination drops and pollen of extinct gymnosperms, mainly Bennettitales and Caytoniales (Labandeira et al., 2016), and became extinct along with most of their presumptive host plants in early Late Cretaceous. On the other hand, species of Dilaridae and Sisyridae with siphonate mouthparts probably fed on nectar and pollen of flowers, as their proboscis was short, suitable to the shallow calyx (often less than 1 mm) of known Burmese amber flowers. It may be assumed that these Burmese amber sisyrids and dilarids were among the first specialized groups of insect pollinators, which occupied the newly formed niche provided by flowers as a source of food. However, these groups may have also become extinct through an inability to compete as other more active and successful flower visitors appeared, mainly bees.

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References

Engel, M.S., 2004a. The Dustywings in Cretaceous Burmese Amber (Insecta: Neuroptera: Coniopterygidae). J. Syst. Palaeontol. 2(2), 133–136.

Engel, M.S., 2004b. Thorny lacewings (Neuroptera: Rhachiberothidae) in Cretaceous amber from Myanmar. J. Syst. Palaeontol. 2(2), 137–140.

Engel, M.S., Grimaldi, D.A., 2008. Diverse Neuropterida in Cretaceous amber, with particular reference to the paleofauna of Myanmar (Insecta). Nova Suppl. Entomol. 20, 1–86.

Grimaldi, D.A., Engel, M.S., Nascimbene, P.C., 2002. Fossiliferous Cretaceous amber from Myanmar

(Burma): its rediscovery, biotic diversity, and paleontological significance. Am. Mus. Novit. 3361, 1–72.

Huang, D.Y., Azar, D., Cai, C.Y., Garrouste, R., Nel, A., 2015. The first Mesozoic pleasing lacewing (Neuroptera: Dilaridae). Cretaceous Res. 56, 274–277.

Huang, D.Y., Azar, D., Engel, M.S., Garrouste, R., Cai, C.Y., Nel, A., 2016. The first araripeneurine antlion in Burmese amber (Neuroptera: Myrmeleontidae). Cretaceous Res. 63, 1–6.

Labandeira, C.C., Yang, Q., Santiago-Blay, J.A., Hotton, C.L., Monteiro, A., Wang, Y.J., Goreva, Y., Shih, C.K., Siljeström, S., Rose, T.R., Dilche, D.L., Ren, D., 2016. The evolutionary convergence of mid-Mesoizoic lacewings and Cenozoic butterflies. Proc. R. Soc. B 283: 20152893.

Liu, X.Y., Lu, X.M., Zhang, W.W., 2016a. *Halteriomantispa grimaldii* gen. et sp. nov.: A new genus and species of the family Dipteromantispidae (Insecta: Neuroptera) from the mid-Cretaceous amber of Myanmar. Zoological Systematics 41(2), 165–172.

Liu, X.Y., Zhang, W.W., Winterton, S.L., Breitkreuz, L.C.V., Engel, M.S., 2016b. Early morphological specialization for insect-spider associations in Mesozoic lacewings. Current Biol. (in press).

Lu, X.M., Zhang, W.W, Liu, X.Y., 2016. New long-proboscid lacewings of the Early Cretaceous provide insights into ancient plant-pollinator interactions. Sci. Rep. 6: 25382. doi:10.1038/srep25382

Makarkin, V.N., 2015. A new genus of the mantispid-like Paraberothinae (Neuroptera: Berothidae) from Burmese amber, with special consideration of its probasitarsus spine-like setation. Zootaxa 4007(3), 327–342.

Makarkin, V.N., 2016. Enormously long, siphonate mouthparts of a new, oldest known spongillafly (Neuroptera: Sisyridae) from Burmese amber imply nectarivory or hematophagy. Cretaceous Res. 65: 126–137.

Myskowiak, J., Huang, D., Azar, D., Cai, C.Y., Garrouste, R., Nel, A., 2016. New lacewings (Insecta, Neuroptera, Osmylidae, Nymphidae) from the Lower Cretaceous Burmese amber and Crato Formation in Brazil. Cretaceous Res. 59, 214–227.

Peñalver, E., Arillo, A., Pérez-de la Fuente, R., Riccio, M.L., Delclòs, X., Barrón, E., Grimaldi, D.A., 2015. Long-proboscid flies as pollinators of Cretaceous gymnosperms. Current Biol. 25, 1917–1923.

Poinar Jr., G., Buckley, R., 2011. *Doratomantispa burmanica* n. gen., n. sp. (Neuroptera: Mantispidae), a new genus of mantidflies in Burmese amber. Hist. Biol.: Int. J. Paleobiol. 23(2/3), 169–176.

Poinar Jr., G., Buckley, R., Brown, A.E., 2008. The secrets of Burmite amber. MAPS Digest 20, 20–29.

Schneider, H., Schmidt, A.R., Heinrichs, J., 2016. Burmese amber fossils bridge the gap in the Cretaceous record of polypod ferns. PPEES 18, 70–78.

Shi, G.H., Grimaldi, D.A., Harlow, G.E., Wang, J., Wang, J., Yang, M.C., Lei, W.Y., Li, Q.L., Li, X.H., 2012. Age constraint on Burmese amber based on U–Pb dating of zircons. Cretaceous Res. 37, 155–163.

Shi, C.F., Ohl, M., Wunderlich, J., Ren, D., 2015. A remarkable new genus of Mantispidae (Insecta, Neuroptera) from Cretaceous amber of Myanmar and its implications on raptorial foreleg evolution in Mantispidae. Cretaceous Res. 52, 416–422.

Xia, F.Y., Yang, G.D., Zhang, Q.Q., Shi, G.L., Wang, B., 2015. Amber: Lives through time and space. Science Press, Beijing (in Chinese).

Zherikhin, V.V., 1978. Development and changes in Cretaceous and Cenozoic faunistic complexes (tracheates and chelicerates). Nauka, Moscow (in Russian).

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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References

Filippova, G.G., 1975. Flora of the Lower Cretaceous deposits of the Umkuveem and Ainakhkurgen Depressions, in: Materials on Geology and Mineral Resources of the North-East USSR 22. Magadanskoe knizhnoe izdatelstvo, Magadan, pp. 23–35 (in Russian).

Krassilov, V.A., 1967. Early Cretaceous flora of Southern Primorye and its stratigraphic significance. Nauka, Moscow (in Russian).

Krassilov, V.A., 1972. Mesozoic flora of the Bureya River (Ginkgoales and Czekanowskiales). Nauka, Moscow (in Russian).

Krassilov, V.A., 1973. Materials on stratigraphy and palaeofloristics of coal-bearing deposits in the Bureya Basin, in: Krassilov, V.A. (Ed.), Fossil floras and phytostratigraphy in the Far East. DVNTs AN SSSR, Vladivostok, pp. 28–51 (in Russian).

Krassilov, V.A., 1985. The Cretaceous Period: Evolution of the Earth's Crust and Biosphere. Nauka, Moscow (in Russian).

Markevich, V.S., Bugdaeva, E.V., 2014. Late Jurassic–Early Cretaceous coal-forming plants of the Bureya Basin, Russian Far East. Stratigr. Geol. Correl. 22 (3), 239–255.

Spicer, R.A., Ahlberg, A., Herman, A.B., Kelley, S.P., Raikevich, M.I., Rees, P.M., 2002. Palaeoenvironment and ecology of the middle Cretaceous Grebenka flora of northeastern Asia. Palaeogeogr. Palaeoclimatol. Palaeoecol. 184, 65–105.

Vachrameev, V.A., Doludenko, M.P., 1961. The Late Jurassic and Early Cretaceous flora of the Bureya Basin and its stratigraphic significance. AN SSSR, Moscow (in Russian).

Upper Cretaceous palynology (spores, pollen and dinoflagellate cysts) of the Yakovlevskaya-2 borehole, Ust-Yenisei region

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Palynological studies of the Upper Cretaceous sediments in the section of Yakovlevskaya-2 borehole located in the Yakovlev River Basin in the north of Ust-Yenisei region of northern Siberia (Fig. 1) permit the biostratigraphic subdivision of the sediments for definition of age, boundaries of formations and for reconstruction of paleogeography. The present report is based on a study of core materials containing a varied and highly rich coastal and marine microflora. Spores, pollen and dinoflagellates have been identified. The diverse taxonomic composition and stratigraphic distribution of microphytofossils are analyzed. Five palynological assemblages are revealed here in the Upper Cretaceous on the basis of their comparison with standard assemblages characterizing a zonal palynostratigraphic scale of northern Siberia (Bochkarev, 1981; Bondarenko, 2001; Gurari, 2004; Nikitenko et al., 2013). By means of the cores a very rich microflora (spores of ferns and mosses, pollen of gymnosperms and angiosperms, and algae) could be collected from various stratigraphic levels. Studied palynological assemblages indicate the following stratigraphic units: Cenomanian (820.0–890.0 m depth), Upper Turonian–Coniacian (270.0–280.0 m depth), Santonian–Campanian (190.0–270.0 m depth), Upper Campanian–Maastrichtian (150.0–190.0 m depth), and Upper Maastrichtian (70.0–130.0 m depth) (Fig. 2).

Cenomanian. Abundant spores (up to 59.2%); the subdominant: dinoflagellates (up to 16.6%), *Cyathidites* spp. (up to 12.9%), *Ginkgocycadophytus* (10.0%), *Leiotriletes* spp. (up to 19.5%), and Disaccites (up to 10.8%); many *Polypodisporites* sp. (6.7%). Related: *Foveosporites cenomanicus* (Chl.) Schvez., *Stenozonotriletes* sp., *Lycopodiumsporites marginatus* Singh., *Sphagnum* spp. (up to 4.7%), *Appendicisporites macrohysus* (Bolch.) Pot., *Balmeisporites glenelgensis* Cook. et Dett., pollen Taxodiaceae, *Cedrus* spp., *Pinuspollenites minimus* (Coup.) Kemp., *Tetraporina* sp., single *Lycopodiumsporites* spp., Dicksoniaceae, *Marattisporites* sp., *Auritulina* sp., Salviniaceae, *Densoisporites microrugulatus* Brenner., *D. velatus* Weyl. et Krieg., *Kuylisporites lunaris* Cook. et Dett., *Aequatriradites verrucosus* Cook. et Dett., *Camptotriletes ambigens* Fradk., *Osmundacidites* spp., *Selaginella* spp., *Gleicheniidites senonicus* Ross., *Appendicisporites* spp. (*A. tricostatus* Bolch., *A. exilioides* (Mal.) Bolch., etc.), *Cicatricosisporites dorogensis* R. Pot. et Gell., *Lygodiumsporites subsimplex* Bolch., *L. asper* Bolch., *Trilobosporites mirabilis* Bolch., *Klukisporites pseudoreticulatus* Coup., *Leptolepidites major* Coup., *Foraminisporites asymmetricus* (Cook. et Det.) Det., *Rouseisporites reticulatus* Poc., *Cycadopites dilucidus* (Bolch.) Il., *Araucariacites pexus* Sach. et Kosenk., *Podocarpidites* spp., *Pseudopicea* sp., *Picea complanatiformis* Bolch., *Piceapollenites variabiliformis* (Bolch.) Petr., *Sciadopityspollenites multiverrucosus* Sach. et Il., *Classopollis*, *Alisporites* sp., *A. similis* (Balme) Dett., *Phyllocladidites* spp., typical *Pteris cretacea* Chlon., *Ruminatisporites* sp. (0.3%), *Taurocusporites reduncus* (Bolch.) Stov., and *Pinus aralica* Bolch., dinocysts *Chlamidophorella neyei* Cook. et Eis., *Chlonoviella agapica* Leb., *Chatangiella* spp., *Amphydiadema* sp., and *Oligospheridium* sp., prasinophyte *Leiospheridia* spp., and algae *Ovoidites* sp.

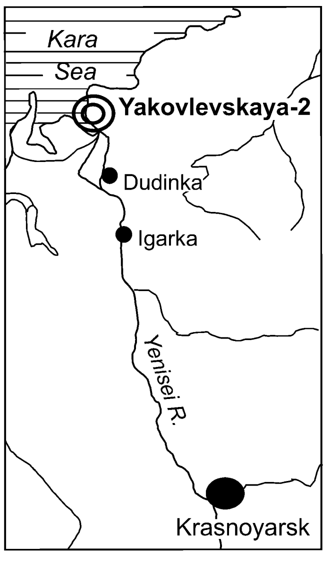
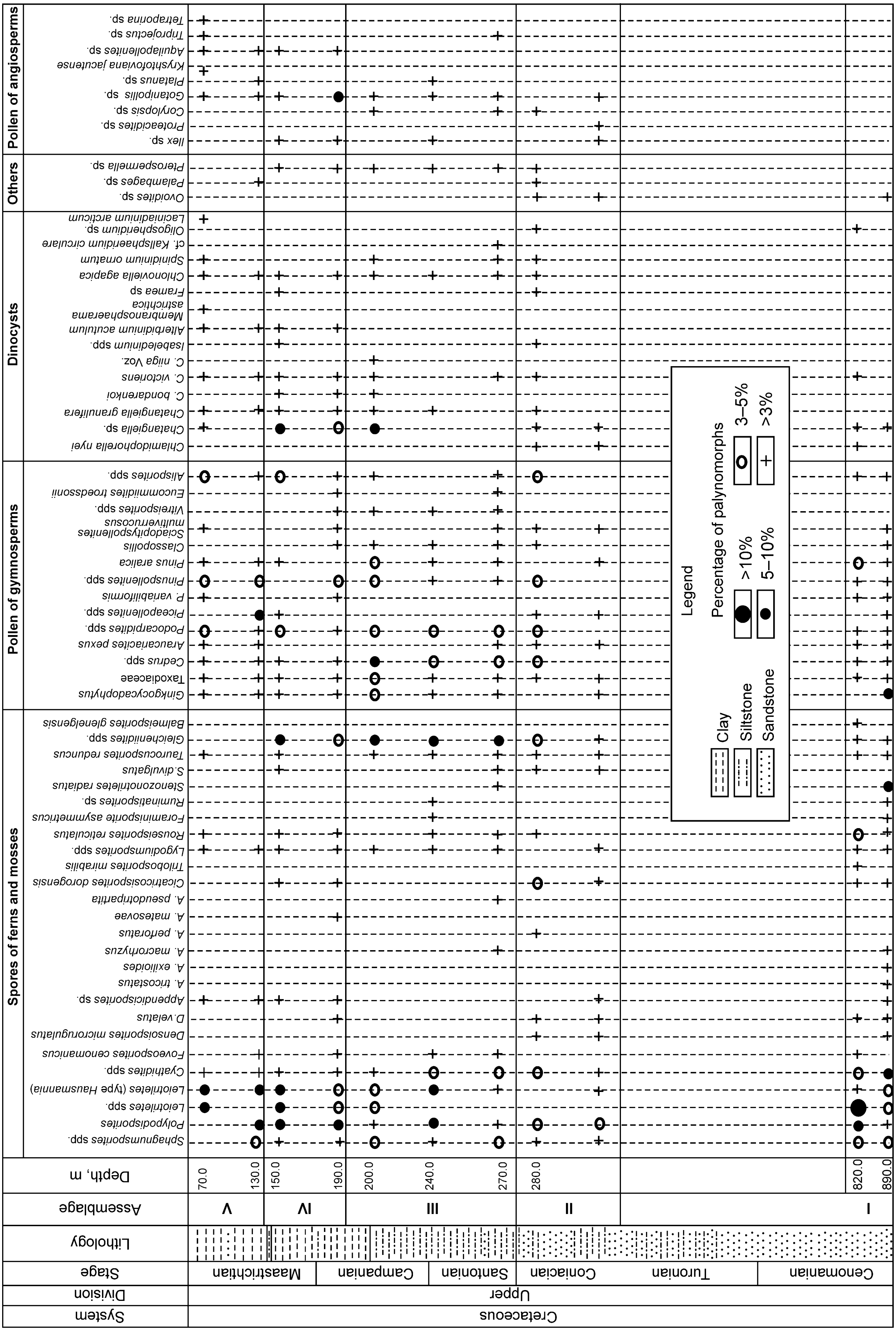


Fig. 1. The location of the Yakovlevskaya-2 borehole in Ust-Yenisei region.


System
Division
Stage
Lithology
Assemblage
Depth, m
Cretaceous
Upper
Maastrichtian
Campanian
Santonian
Coniacian
Turonian
Cenomanian
V
IV
III
II
I
70.0
130.0
150.0
190.0
200.0
240.0
270.0
280.0
820.0
890.0
Spores of ferns and mosses
Sphagnumsporites spp.
Polypodisporites
Leiotriletes spp.
Leiotriletes (type Hausmannia)
Cyathidites spp.
Foveosporites cenomanicus
Densoisporites microrugulatus
D. velatus
Appendicisporites sp.
A. tricostatus
A. exilioides
A. macrorhyzus
A. perforatus
A. matesovae
A. pseudotripartita
Cicatricosisporites dorogensis
Trilobosporites mirabilis
Lygodiumsporites spp.
Rouseisporites reticulatus
Foraminisporite asymmetricus
Ruminatisporites sp.
Stenozonotriletes radiatus
S. divulgatus
Taurocusporites reduncus
Gleicheniidites spp.
Balmeisporites glenelgensis
Pollen of gymnosperms
Ginkgocycadophytus
Taxodiaceae
Cedrus spp.
Araucariacites pexus
Podocarpidites spp.
Piceapollenites spp.
P. variabiliformis
Pinuspollenites spp.
Pinus aralica
Classopollis
Sciadopityspollenites multiverrucosus
Vitreisporites spp.
Eucommiidites troedssonii
Alisporites spp.
Dinocysts
Chlamidophorella nyei
Chatangiella sp.
Chatangiella granulifera
C. bondarenkoi
C. victoriens
C. niiga Voz.
Isabelidinium spp.
Alterbidinium acutulum
Membranosphaerama astrictica
Framea sp
Chlonoviella agapica
Spinidinium ornatum
cf. Kallsphaeridium circulare
Oligosphendium sp.
Laciniadinium arcticum
Others
Ovoidites sp.
Palambages sp.
Pterospermella sp.
Pollen of angiosperms
Ilex sp.
Proteacidites sp.
Corylopsis sp.
Gotanipollis sp.
Platanus sp.
Kryshtofoviana jacutense
Aquilapollenites sp.
Triprojectus sp.
Tetraporina sp.
Legend
Clay
Siltstone
Sandstone
Percentage of palynomorphs
>10%
5–10%
3–5%
>3%

Upper Turonian–Coniacian. Abundant spores (46.1%); the subdominant: dinoflagellates (16%). Related: *Pilasporites marcidus* Balme, *Polypodisporites* sp., *Sphagnum* spp., *Lycopodiumsporites* spp., *Leiotriletes* spp., *Cyathidites* spp., *Foveosporites cenomanicus*, Pteridaceae, *Dictyophyllidites* sp., *Clathropteris obovata*, *Densoisporites* spp., *Pteris cretacea*, *Kuylisporites lunaris*, *Aequatriradites spinulosus* Cook. et Dett., *Osmundacidites* spp., *Gleicheniidites* spp., *Appendicisporites* spp., *Cicatricosisporites* spp., *Lygodiumsporites* spp., *Klukisporites variegates* Coup., *Stenozonotriletes divulgatus* Chlon., *Rouseisporites reticulatus*, *Taurocusporites reduncus* (Bolch.) Stov., pollen *Ginkgocycadophytus*, *Glyptostrobus* sp., Taxodiaceae, *Cedrus* spp., *Araucariacites pexus*, *Podocarpidites* spp., *Pseudopicea* sp., *Piceapollenites* spp., *Pinus aralica*, *Sciadopityspollenites multiverrucosus*, *Classopollis*, *Alisporites* sp., and *Phyllocladidites* spp., typical dinocysts *Chlamidophorella nyei* Cook. et Eis., and *Chatangiella* spp., Angiosperms (5.7%): *Proteacidites* sp., *Ilex* sp., *Corylopsis* sp., Ericaceae, *Inaperturepollenites* sp., and *Gotanipollis* sp.

Santonian–Campanian. Abundant spores (up to 56.2%); the subdominant: dinocysts (up to 17.3%); many *Polypodisporites* sp. (up to 6.0%), *Leiotriletes* spp., *Gleicheniidites laeta* Bolch. (up to 6.0%), *G. senonicus* Ross. (up to 6.0%), Disaccites (up to 5.2%), *Phyllocladidites* spp. Related: *Clavifera rudius* Bolch., *Pilasporites marcidus* Balme, *Sphagnum* spp., *Stereisporites psilatus* (Ross.) Pfl., *S. regium* Drozh., *Lycopodiumsporites* spp., *Cyathidites* spp., *Ruminatisporites* sp. (0.2%), *Stenozonotriletes radiatus* Chlon., *Foveosporites cenomanicus*, Pteridaceae, *Dictyophyllidites* sp., Dipteridaceae, *Clathropteris obovate* var. magna Tur.-Ket., *Obtusisporites junctus* (K.-M.) Pocock., *Tripartina variabilis* Mal., *Concavisporites juriensis* Balme, *Densoisporites velatus*, *Camptotriletes ambigens*, *Osmundacidites* spp., *Appendicisporites* spp., *Cicatricosisporites* spp., *Lygodiumsporites* spp., *Stenozonotriletes divulgatus*, *Leptolepidites* spp., *Foraminisporites daijli*, *F. asymmetricus*, *Rouseisporites reticulatus* Poc., *Ginkgocycadophytus*, *Cycadopites dilucidus*, *Glyptostrobus*, Taxodiaceae, *Cedrus* spp. (4.2%), *Araucariacites pexus*, *Podocarpidites* spp., *Quadraecullina limbata* Mal., *Pinuspollenites* spp., *P. aralica* Bolch., *Sciadopityspollenites multiverrucosus*, *Classopollis*, *Alisporites* sp., *Eucommiidites troedssonii* Erdtm., *Callialasporites* sp., and *Vitreisporites* spp. Typical angiosperms: *Triprojectus* sp., *Gnetaceapollenites* sp., *Ilexs* sp., *Pterocarya* sp., *Platanus* sp., *Myrica* sp., *Corylopsis* sp., Ericaceae, *Gothanipollis* sp., *Tricolpites* sp., Hamamelidaceae, *Rhamnus glabra* Bolch., and *Inaperturepollenites* sp.; dinocysts: *Chatangiella granulifera* (Manum) Len. et Wil., *C. victoriens* (Cook. et Man.) Len. et Wil., *C. bondarenkoi* (Voz.) Len. et Wil., *C. niiga* Voz., *C. chetensis* (Voz.) Len. et Wil., *Isabeledinium* spp., *Spinidinium* sp., *Altertia* sp., *A. daveyi* (Stover et Evitt) Lentin et Williams, ?*Deflandria magna* Davey., and cf. *Kallsphaeridium circulare* (Cookson et Eisenack) Helby; microphytofossils: *Pterospermella* sp., cf. *Veryhachius reductus*, *Botriococcus* sp., *Aletes striatus*, and *Ovoidites* sp.

Upper Campanian–Maastrichtian. Abundant spores (up to 54.6%), the subdominant: dinocysts (up to 16.1%); many *Polypodisporites* sp. (up to 9.4%), *Leiotriletes* spp. (up to 7.2%), *Gleicheniidites senonicus* (up to 6.5%), *Phyllocladidites* spp., *Piceapollenites* sp., *Chatangiella* spp. (6.5%), *Gothanipollis* sp. (up to 7.2%). Related: *Pilasporites marcidus*, *Sphagnum* spp., *Cyathidites* spp., *Foveosporites cenomanicus*, *Concavisporites juriensis*, *Hymenozonotriletes bicycla* (Mal.) Sach. ex Fradk., Salviniaceae, *Densoisporites velatus*, *Camptotriletes* spp., *Gleicheniidites* spp., *Appendicisporites* spp., *Cicatricosisporites* spp., *Lygodiumsporites* spp., *Stenozonotriletes divulgatus*, *Foraminisporites daijli*, *Rouseisporites reticulatus*, *Taurocusporites reduncus*, pollen *Ginkgocycadophytus*, *Glyptostrobus*, Taxodiaceae, *Sequoia* sp., *Cedrus* spp., *Podocarpidites* spp., *Piceapollenites* spp., *Abies* sp., *Pinuspollenites* spp., *Sciadopityspollenites multiverrucosus*, *Classopollis*, *Alisporites* spp., *Eucommiidites troedssonii*, *Piceites* sp., *Vitreisporites pallidus* (Reis.) Nils., and Disaccites. Typical angiosperms: *Gnetaceapollenites* sp., *Ilex* sp., *Quercus* sp., *Myrica* sp., Ericaceae, *Tricolpites* sp., *Aquilapollenites* sp., and *Tetraporina* sp.; dinocysts: *Chlonoviella agapica*, *Isabilidinium* spp., *Spinidinium echinoideum* (Cook.et Eis.) Lentin et Wil., *Alterbidinium acutulum* (Wilson) Lentin, *Deconodinium* spp., ?*Deflandria magna*, and *Framea* sp.; prasinophyte *Pterospermella* sp.

Fig. 2. The subdivision of the Cretaceous deposits in the Yakovlevskaya-2 borehole based on palynological data.

Upper Maastrichtian. Abundant spores (up to 55.5%); the subdominant: dinocysts (up to 15,8%); many *Laevigataesporites ovatus* (up to 9.4%), *Leiotriletes* spp., *Gleicheniidites senonicus*, *Piceapollenites* sp., *Phyllocladidites* spp. Related: *Sphagnum* spp., *Lycopodiumsporites* spp., *Cyathidites* spp., *Foveosporites cenomanicus*, Pteridaceae, *Auritulina* sp., *Camptotriletes ambigens*, *Osmundacidites* sp., *Selaginella* spp., *Gleicheniidites* spp., *Appendicisporites* sp., *Cicatricosisporites* sp., *Lygodiumsporites* spp., *Rouseisporites reticulatus*, *Ginkgocycadophytus*, Taxodiaceae, *Cedrus* spp., *Araucariacites pexus*, *Podocarpidites* spp., *Abies* sp., *Sciadopityspollenites multiverrucosus*, *Alisporites* spp., *Vitreisporites pallidus*, and Disaccites. Typical angiosperms: *Aquilapollenites* sp., *Triprojectus* sp., *Platanus* sp., Ericaceae, *Gothanipollis* sp., Hamamelidaceae, *Kryshtofoviana jacutense* Samoil., and *Tetraporina* sp.; dinocysts: *Membranosphaerama astrichtica* Samoil., *Chatangiella* spp., *Amphydiadema* sp., *Spinidinium ornatum* (May) Lentin et Williams, *Alterbidinium acutulum*, and *Laciniadinium arcticum* (Manum) Lentin et Williams; green algae *Palambages* sp.

Analysis of abundant palyonological data revealed a high share of various species of dinocysts that indicates a marine condition of accumulation of the Late Cretaceous sediments.

References

Bochkarev, V.S. (Ed.), 1981. Regional stratigraphic charts of the Mesozoic and Cenozoic sediments of the West Siberian Plain. ZapSibNIGNI, Tyumen' (in Russian).

Bondarenko, N.M., 2001. Early Cretaceous spores of Schizeaceae ferns in the core of Yakovlevskaya 1-P borehole (the north part of Ust-Yenisei region), in: Biostratigraphy of Mesozoic and Cenozoic in some regions of the Arctic and the oceans. VNII-Oceangeologia, St. Petersburg, pp. 34–52 (in Russian).

Gurari, F.G. (Ed.), 2004. A decision of the 6th Interdepartmental stratigraphic meeting on consideration and arrival of the improved stratigraphic scales of the Mesozoic deposits of West Siberia. SNIIGGiMS, Novosibirsk (in Russian).

Ilyina, V.I., Kul'kova, I.A., Lebedeva, N.K., 1994. Microphytofossils and detail stratigraphy of marine Mesozoic and Cenozoic of Siberia. UIGGM SB RAS, Novosibirsk (in Russian).

Nikitenko, B.L., Shurygin, B.N., Knyazev, V.G., Meledina, S.V., Dzyuba, O.S., Lebedeva, N.K., Peshchevitskaya, E.B., Glinskikh, L.A., Goryacheva, A.A., Khafaeva, S.N., 2013. Jurassic and Cretaceous stratigraphy of the Anabar area (Arctic Siberia, Laptev Sea coast) and the Boreal zonal standard. Russian Geology and Geophysics 54, 808–837.

Conifer fossils from the Lower Cretaceous of Inner Mongolia, North China and their geologic significance

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Some conifer fossils collected from the Lower Cretaceous of the Huolinhe and Guyang Basins (Inner Mongolia, North China) are described. These fossils are three *Schizolepis* species, *S. longipetiolus* Xu X.H. et Sun B.N., *S.* cf. *heilongjiangensis* Zheng et Zhang and *S. neimengensis* Deng, and one *Taxus* species, *T. guyangensis* Xu X.H et Sun B.N.

Schizolepis longipetiolus is a well-preserved female cone, slender and cylindrical in shape. The seed-scale complexes have long petioles and are arranged on the cone axis loosely and helically. The seed scales are divided into two lobes from the base. The seed is borne on the adaxial surface at the base or middle of each lobe. *Schizolepis* was established in 1847. Although more than twenty species have been discovered and reported, its phylogenetic position is controversial because of the imperfection of fossils. The present result indicates that the genus probably has a distant evolutionary relationship with extant Pinaceae. In the Early Cretaceous most species existed in China's three northeastern provinces and the Inner Mongolia Autonomous Region and adjacent areas. Combining the paleogeographic distribution of the genus with ancient climatic factors, authors deduced that *Schizolepis* began to decline and became extinct in the Early Cretaceous, and the reason for its extinction is closely related to the icehouse climate during the Early Cretaceous.

Taxus guyangensis Xu X.H et Sun B.N is described from the Lower Cretaceous of Guyang Basin, Inner Mongolia, northern China, based on an excellently preserved leafy branch with attached leaves and seed-bearing structures. Three ovules can be found on the leafy branch. It is the first fossil record of *Taxus* in Guyang Basin, China. The species has been compared with living and other previously published fossil species of *Taxus*. The present fossil evidence also appears to suggest that the multi-ovulate shoots of extant *Taxus* are probably not the result of plant evolution or the gene mutation. Otherwise, a warm and humid climate is indicated in the Guyang Basin during the late Early Cretaceous on the basis of the fossil remains and lithology. Furthermore, majority living *Taxus* species are distributed in tropical-subtropical regions of the Northern Hemisphere, and the leaf cuticle of *T. guyangensis* is too thin to separate that maybe suggest a moist environment.

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Keywords

Schizolepis, *Taxus*, Early Cretaceous, paleoclimatic significance, China.

References

Bobrov, A.V.F.Ch., Melkian, A.P., Mikhail, S., Romanov, S., Sorokin, A.N., 2004. Seed morphology and anatomy of *Austrotaxus spicata* (Taxaceae) and its systematic position. Bot. J. Linn. Soc. 145, 437–443.

Chang, S.C., Zhang, H.C., Renne, P.R., Fang, Y., 2009. High-precision $^{40}Ar/^{39}Ar$ age for the Jehol biota. Palaeogeogr. Palaeoclimatol. Palaeoecol. 280, 90–104.

Deforce, K., Bastiaens, J., 2007. The Holocene history of *Taxus baccata* (Yew) in Belgium and neighbouring regions. Belg. J. Bot. 140 (2), 222–237.

Hao, D.C., Xiao, P.G., Huang, B.L., Ge, G.B., Yang, L., 2008a. Interspecific relationships and origins of Taxaceae and Cephalotaxaceae revealed by partitioned Bayesian analyses of chloroplast and nuclear DNA sequences. Plant Syst. Evol. 276, 89–104.

Hao, D.C., Huang, B.L., Yang, L., 2008b. Phylogenetic relationships of the genus *Taxus* inferred from chloroplast intergenic spacer and nuclear coding DNA. Biol. Pharm. Bull. 31(2), 260–265.

Kusuhashi, N., Hu, Y.M., Wang, Y.Q., Hirasawa, S., Matsuoka, H., 2009a. New triconodontids (Mammalia) from the Lower Cretaceous Shahai and Fuxin formations, northeastern China. Geobios 42, 765–781.

Kusuhashi, N., Hu, Y.M., Wang, Y.Q., Setoguchi, T., Matsuoka, H., 2009b. Two eobaatarid (Multituberculata; Mammalia) genera from the Lower Cretaceous Shahai and Fuxin formations, northeastern China. J. Vert. Paleontol. 29, 1264–1288.

Zhang, J., D'Rozario, A., Yao, J., Wu, Z., Wang L., 2011. A new species of the extinct genus *Schizolepis* from the Jurassic Daohugou Flora, Innner Mengolia, China with special reference to the fossil diversity and evolutionary implications. Acta Geol. Sin., Engl. Ed. 85(2), 471–481.

First flowering plants in Primorye region (Russia)

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The interaction between biotic and abiotic processes during the Cretaceous was best pronounced in Primorye region located at the boundary of temperate and subtropical zones. The mid-Cretaceous deposits here are widely distributed in the Alchan River, Partizansk and Razdolnaya River basins. Their sedimentary sequences were formed under different conditions. In the eastern part of this area, since the Aptian time the largest sea transgression began. Marine biota was of the Tethyan type. In North-West Pacific region, the first Ocean Anoxic Event (OAE1), which was recorded both in the ocean and epicontinental basins, occurred in the Aptian–Albian time. The beginning of the Albian was marked by maximum transgression. The predominant biota of epicontinental basins was represented by bivalves (*Aucella* and *Inoceramus*) and ammonites typical of North-Pacific Province. The sediments of Alchan River, Partizansk and southern part of Razdolnaya River basins accumulated under influence of sea; the northern part of the latter was developed as intracontinental basin.

Any variation in deposition and climatic conditions resulted in abrupt changes in the taxonomic composition of fossil floras. The Aptian fossil flora of the Primorye region was characterized by high diversity, considerable share of thermophilic elements, and maximum values of cycadophyte index suggesting obvious trend to increase in temperature. Since the Early Albian a volcanic activity within this region gradually increased, being maximum in the mid-early Late Albian. At this time, the sea regression and expansion of continental environments were recorded. The vegetation typical of humid climate deteriorated. The diversity of terrestrial floras decreased; the number of thermophilic elements dropped, and values of cycadophyte index reduced. Intensification in a volcanic activity caused the formation of specific floras. The Late Albian flora was taxonomically most diverse including subtropical elements. At the Early–Late Cretaceous boundary, the significant geological events (a lull in volcanic activity of the Sikhote-Alin volcanic belt, a change in nature of sedimentation) and climatic changes (climate became warmer and more humid) occurred.

The events that occurred in both marine and continental ecosystems are believed to be synchronous and are considered as reflecting climatic evolution and tectogenesis.

Flowering plants in the geological record of Primorye region first appeared in the Aptian of the Razdolnaya River Basin. The angiosperm remains are almost entirely restricted to sandstone or sandy beds with cross-bedding or cross-lamination, or light-gray mudstone beds representing weathered volcanic ash. In contrast, only conifer, cycadophyte and fern remains are found in equivalent finer-grained, parallel-bedded units. It is possible to recover their remains from tuffaceous mudstone, because that ash fall covered all area of basin. The environmental interpretation of these deposits can evidence about the early angiosperm ecology. These plants apparently colonized disturbed surfaces of the land such as riparian settings or place of accumulations of fallen volcanic ash.

Most recently, we have found new remains of the flowering plants in the Late Aptian (probably, Late Aptian–Early Albian) deposits in the Razdolnaya River Basin, belonging to the Lipovtsy Formation (Bugdaeva et al., 2014; Kovaleva et al., 2016). The earliest angiosperms of Primorye region are represented by leaves of *Dicotylophyllum* sp. (Podgorodnenka coal field – Sokol Bay, nearly Vladivostok City) and by dispersed cuticle of indeterminable platanoids (Porechye coal mine and nearly Dongning City, China). The extremely rare Aptian angiosperm leaves are generally small, have disorganized venation, and are largely restricted to sandy and coaly stream margin lithofacies.

Throughout the Aptian and probably Lower Albian corresponding to the Lipovtsy Formation, palynoflora consists almost entirely of pteridophyte spores and gymnosperm pollen. In other localities of the Lipovtsy Formation, such as Porechye mine and outcrop nearly Dongning City, the Dongning Formation, the Chinese part of the Razdolnaya River Basin, the upper part of the Staryi Sutschan Formation of the Partizansk Coal Basin, tricolpate, tricolporoidate, and monosulcate pollen grains of recognizably angiospermous affinities occur. The earliest angiosperm pollen is represented by *Clavatipollenites hughesii* Coup., *Tricolpites micromunus* (Groot. et Penny) Singh, *T. vulgaris* (Pierce) Sriv., *T. variabilis* Burg., *Tricolpites* spp., *Quercites sparsus* (Mart.) Samoil., *Retitricolpites vulgaris* Pierce, *R. georgiensis* Brenn., and *Fraxiniopollenites variabilis* Stanl. in Razdolnaya River Basin. *Asteropollis asteroides* Hedl et Norris and *Cyclusphaera psilata* Volkh. et Sepul. were found in Partizansk Coal Basin.

It may be noted that there is co-occurrence of the above-mentioned morphotypes, although in the Potomac Group of North America monosulcates appear earlier and were described as older pollen types (Hickey and Doyle, 1977). They include small, finely columellar grains with granular sulcus membranes (*Clavatipollenites hughesii*).

We did not reveal megafossils of flowering plants in the Aptian of the Alchan River and Partizansk basins. The sediments of this age accumulated in environments of seaside plains under marine influence.

During the Albian, the thermophilic bennettitaleans lose their importance and vacate ecological niches in the brushwood and under a canopy of coniferous forests; these niches were actively colonized by angiosperms. The Albian palynofloras in the Alchan and Partizansk River basins contain rapidly diversifying tricolpate pollen and several new assemblages of locally abundant angiosperm leaves.

In the Cenomanian the flowering plants dominate in the plant communities of Razdolnaya River, Alchan River, and Partizansk River basins. Aquatic plants *Potamogeton*, *Quereuxia*, and *Cobbania* appeared in the Alchan River Basin.

The first morphotypes of dicot leaves were Laurifolia and Rosifolia. Ranunculifolia and Platanifolia were added to them in the Albian. Morphotype Nymphaefolia appears in the Cenomanian, the importance of Platanifolia increases (Volynets, 2005).

There is an opinion that the early flowering plants were "weeds". This fact was supported by findings of angiosperms in the Partizansk (Krassilov and Volynets, 2008) and Alchan River (Bugdaeva et al., 2006; Volynets, 2005) basins. V.A. Krassilov and E.B. Volynets (2008) described a new plants *Achaenocarpites capitellatus* and *Ternaricarpites floribundus* (morphotype Ranunculifolia) from the Late Albian of Primorye. These plants composed the pioneer communities colonizing a surface of volcanic ash.

An important aspect of our study has been an attempt to draw inferences on the paleoecology of early angiosperms from the types of sediment in which their remains are preserved. Depositional settings for sedimentary sequences containing the first flowering plants included river valleys and area after volcanic ash falls. The appearance, invasion and wide spread of these plants in the plant communities took place during the deterioration of climatic and environmental conditions.

Morphological, stratigraphic, and sedimentological analyses of the Early Cretaceous pollen and leaf sequences from Alchan River, Partizansk and Razdolnaya River basins of Primorye region show an approximate scheme of the adaptive radiation of the early angiosperms and suggest the ways of their initial ecological and systematic diversification.

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References

Bugdaeva, E.V., Markevich, V.S., Volynets, E.B., Kovaleva, T.A., Nechaev, V.P., 2014. The Early Cretaceous coal-forming plants from the Razdolnaya Basin (Southern Primorye), in: Baraboshkin, E.Yu., et al. (Eds.), Cretaceous System of Russia and the near abroad: problems of stratigraphy and paleogeography. Proc. Seventh Russian scientific conference with international participation. Dalnauka, Vladivostok, pp. 70–71 (in Russian).

Bugdaeva, E.V., Volynets, E.B., Golozubov, V.V., Markevich, V.S., Amelchenko, G.L., 2006. Flora and geological events of the mid-Cretaceous time (Alchan River Basin, Primorye). Dalnauka, Vladivostok.

Hickey, L.J., Doyle, J.A., 1977. Early Cretaceous fossil evidence for angiosperm evolution. Bot. Rev. 43(1), 3–104.

Kovaleva, T.A., Markevich, V.S., Bugdaeva, E.V., Volynets, E.B., Afonin, M.A., 2016. New data on palynostratigraphy of the Lipovtsy Formation in the Razdol'naya Coal Basin (Southern Primorye). Russ. J. Pac. Geol. 10(1), 50–62.

Krassilov, V.A., Volynets, E.B., 2008. Weedy Albian angiosperms. Acta Palaeobotanica 48(2), 151–169.

Volynets, E.B., 2005. The Aptian–Cenomanian Flora of Primorye, Part 1: Floral Assemblages. Stratigr. Geol. Correl. 13(5), 613–631.

Session 2
Cretaceous paleogeography and paleobiogeography

Late Cretaceous paleobiogeography of peninsular India: An overview of constraints from fossil tetrapods

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A Late Cretaceous phase of the geodynamic history of the peninsular India is marked by two major tectonic events, the break-up of India-Seychelles block from Madagascar at ~88 Ma and the Deccan flood basalt volcanism and separation of India from Seychelles around 65 Ma. Both dispersal and vicariance shaped the paleobiogeographic patterns in time and space during India's rapid northward drift in the Late Cretaceous. As the Indian plate separated from Madagascar, it became a continental island initially, resulting in increased opportunities for allopatric speciation and biodiversity peaks.

The tetrapod record, including dinosaurs and mammals, from horizons postdating Indo-Madagascar rifting is yet to be discovered in India. However, the common presence of several family-level taxa in India, Madagascar and South America during the latest Cretaceous (Maastrichtian) has opened up several hotly debated paleobiogeographic issues. Possible explanations involving filter bridges connecting Africa, Antarctica, Indo-Madagascar, South America at different times (Chatterjee et al., 2013) need to be reconciled with the geological and geophysical evidence.

A number of hypothesized ephemeral biotic filter bridges connecting India with other Gondwana landmasses need a serious consideration: i) the Kohistan-Ladakh–Oman Arc that allowed faunal interchanges between India and northern Africa during the Late Cretaceous, ii) the Laxmi Ridge–Seychelles Island that bridged the gap between India and Madagascar, and iii) the emergent Ninetyeast Ridge–Kerguelen Plateau–Antarctica that formed a circumpolar biotic filter bridge between India and South America.

References

Chatterjee, S., Goswami, A., Scotese, C.R., 2013. The longest voyage: tectonic, magmatic, and paleoclimatic evolution of the Indian plate during its northward flight from Gondwana to Asia. Gondwana Res. 23, 238–267.

Terminal Maastrichtian–Danian marine incursion in Central India: Myth or Reality?

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Wisdom and intellectual integrity is the backbone of reliable knowledge built on a variety of meticulously collected empirical and testable data (Mario, 2013). It is instructive to be aware of distinct rifting events which carved the outline of India out of the supercontinent Pangaea for understanding the possible nature of exceptionally deep incursion of sea during the Maastrichtian–Danian.

Extensive volcanism in East Africa, Antarctica and Madagascar coupled with rifting of Madagascar–Seychelles–India–Australia–New Zealand–Antarctica combined continent from continents of Africa–South America led to the creation of Proto-Indian Ocean during the Early Jurassic (ca. 185 Ma). Significant Early Cretaceous (ca. 145 Ma) rifting and subsequent Rajmahal volcanism carved Eastern Indian Ocean with prominent aulacogens and triple junctions at marginal basins of Cauvery, Palar, Krishna-Godavari and Mahanadi. India overlying solid marine crustal support, tilted eastward causing easterly flow of rivers except Narmada and Tapti which continue to flow today westward. It is noteworthy that during this time Madagascar reached current position relative to Africa and India–Madagascar separated from Antarctica–Australia–New Zealand and none of the lineaments permitted any deep incursion of the sea.

As juvenile Indian Ocean continued to grow, rifting separated Australia–New Zealand from Antarctica (ca. 105 Ma). One of the most dramatic plate tectonic event was the rifting causing separation of India–Seychelles from Madagascar, episode of sub-aerial Large Igneous Province (LIP at ca. 92 Ma), the Mahajanga Flood Basalt of Madagascar possibly inducing concomitant Late Turonian deep incursion of sea (>800 Km) along Narmada Valley into central India (Jafar, 2015). Shallow seas generally inundated most continents of the world during the Late Cretaceous as the sea level rose up to 200 m higher than today, but surprisingly, none of the lineaments on the east and west of India received any deep incursion of sea, with notable and unique exception of Narmada Valley. Creation of new rifts, record speed with which India approached Eurasian continent coupled with local Large Igneous Province episodes led to the deep flooding of continents by warm marine waters. Réunion hotspot induced eruption of massive Deccan Flood Basalt sub-aerial Large Igneous Province (LIP at ca. 66 Ma) during the terminal Cretaceous covering over 500.000 sq. km area of India and attracted world attention for exceptionally well preserved fossil fauna and flora in intertrappean lacustrine sediments straddling Cretaceous–Palaeogene boundary. No concrete evidence of deep sea incursion is forthcoming during this time slice either via Narmada valley or Krishna-Godavari lineament, except in the northern collision facing East-West trending Subathu-Dogadda lineament now designated as Lesser Himalaya (Jafar and Singh, 1992). After colliding with Eurasian continent (ca. 50 Ma) the northern portion of India (Greater India) started subducting giving rise to raised Tibetan Plateau (Fig. 1).

The Tethys finally closed after displaying last signs of marine waters in Lesser Himalaya in the Early Miocene.

Deep incursion of sea along Narmada Valley

Contrary to the earlier assumption of some workers (Keller et al., 2009; Keller, 2014), it is noteworthy that during K/T transition time there was absolutely no marine incursion as evidenced by the following observations: (1) K/T transition marine sediments are missing from the western margin of India; (2) critical evaluation of various fossil records suggests an age not older or younger than Late Turonian for marine/estuarine sediment package in the Lower

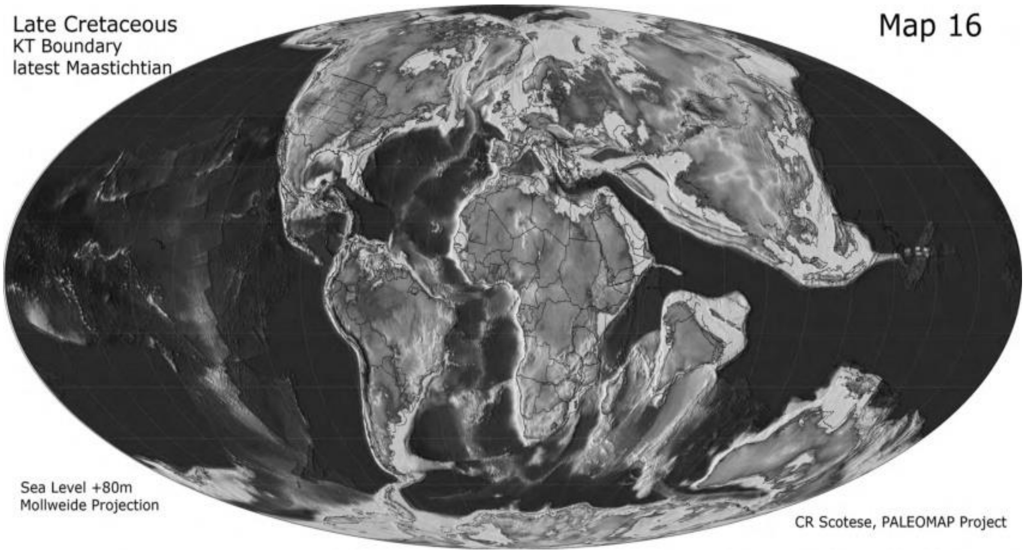

Fig. 1. K/T boundary palaeogeographic map showing rapid northward and anticlockwise movement of Indian block which received significant deep marine incursion from the East along Subathu-Dogadda lineament before colliding with Eurasian continent in the Late Ypresian (ca. 50 Ma).

Narmada Valley, comprising of Nimar Sandstone (dinosaur bearing, fully marine) – Bagh Beds – Nodular Limestone – Coralline Limestone, in ascending order. In Upper Narmada Valley, well known Lameta beds of Maastrichtian age (dinosaur bearing) signify predominant deposition under sub-aerial conditions, despite several spurious counter claims of marine origin.

Deep incursion of sea along Krishna-Godavari Valley

K/T transition marine sediments are developed all along eastern margin of India but notably with intertrappean beds of Rajahmundry area. Based on the presence of certain fossil mangrove / coastal elements like *Nypa*, *Cocos* and *Acrostichum* etc. in several intertrappean sections, it was postulated some 150 years ago that deep sea incursion could have occurred via Krishna-Godavari Valley. More recently, discovery of a thin horizon (ca. 60 cm) yielding diminutive sized planktonic foraminifera of Danian age in Jhilmili intertrappean area also led to rather strange speculation of the deep entry of short lived sea via Narmada or Krishna-Godavari valley (Keller, 2014).

Deep incursion of sea along Subathu-Dogadda Lineament

Autochthonous Late Maastrichtian–?Danian marine sediments based on dinoflagellates are recently reported from the Kakra section (Thakur et al., 2013), but Maastrichtian–Danian global calcareous nannofossils were detected as tectonically sandwiched within Precambrian Krols and frequently detected as reworked in the Early Eocene Subathu Formation (Jafar, 2013), signifying unroofing and collision event of India against Eurasia (Late Ypresian ca. 50 Ma). Noteworthy is the complete absence of marine siliceous plankton and extremely scarce Cretaceous megafossils.

So, what is the most plausible postulate?

Envisage a large ephemeral Athalassic saline Lake (Deckker, 1981) which had all geomorphic features of a miniature sea and in contrast with "**brackish**" waters, was not contiguous with sea water. It would not be entirely misleading to assume that some kind of seeding mechanism including contamination by wind and birds (Palaeocene records of birds are known from major continents except India) prevailed and coastal / mangrove elements including ostracods and planktonic foraminifera could be transported to **"adapt"** and flourish for a short spell. Similar occurrence of varied marine elements (Xi et al., 2011; Boonstra et al., 2015) deep into the heart of continents is reported from several regions but has not been interpreted without a flaw. We need a complete biotope and sedimentary facies link up to strongly support full-fledged deep sea incursion like the one seen along Narmada Valley during the Late Turonian. Also, it is absurd to assume that catastrophic events like Deccan volcanism or Chicxulub Impact had anything to do with mass extinction at the K/T boundary (Jafar, 2014).

References

Boonstra, M., Ramos, M.I.F., Lammertsma, E.I., Antoine, P.-O., Hoorn, C., 2015. Marine connections of Amazonia: Evidence from foraminifera and dinoflagellate cysts (early to middle Miocene, Colombia/Peru). Palaeogeogr. Palaeoclimatol. Palaeoecol. 417, 176–194.

Deckker, P.D., 1981. Ostracods of athalassic saline lakes. Hydrobiol. 81, 131–144.

Jafar, S.A., 2013. Unfinished Symphony in Lesser Himalaya: Calcareous nannofossils strive to fill the gaps, in: XXIV Indian Colloq. Micropal. Stratigr. Dehradun, India. Dehradun, pp. 39–41.

Jafar, S.A., 2014. Dynamics of Terminal Cretaceous global biotic turnover, in: 2nd Int. Symp. IGCP608 "Land-Ocean Linkages and Biotic Evolution during the Cretaceous: Contribution from Asia and Western Pacific", Waseda, Japan: Abstract volume. Tokyo, pp. 87–90.

Jafar, S.A., 2015. Episodes of subaerial Large Igneous Provinces (LIPs) linked to late Turonian/Late Maastrichtian deep incursions of Sea on Indian continental block, in: Zhang, Y., Wu, S.Z., Sun, G. (Eds.), Abstracts of the 12th Symposium on Mesozoic Terrestrial Ecosystems, Shenyang, China. Shenyang, pp. 37–39.

Jafar, S.A., Singh, O.P., 1992. K/T boundary species with early Eocene nannofossils discovered from Subathu Formation, Shimla Himalaya, India. Curr. Sci. 62(5), 409–413.

Keller, G., 2014. Deccan volcanism, the Chicxulub impact, and the end-Cretaceous mass extinction: Coincidence? Cause and effect? Geol. Soc. Am. Spec. Pap. 505, 57–89.

Keller, G., Adatte, T., Bajpai, S., Mohabey, D.M., Widdowson, M., Khosla, A., Sharma, R., Khosla, S.C., Gertsch, B., Fleitmann, D., Sahni, A., 2009. K–T transition in Deccan Traps of central India marks major marine Seaway across India. Earth Planet. Sci. Lett. 282, 10–23.

Mario, L., 2013. Brilliant Blunders. Simon and Schuster, New York.

Thakur, O.P., Sarkar, S., Dogra, N.N., 2013. A Late Maastrichtian palynofloral assemblage from Nahan area of the Himachal Pradesh, India: Palaeoenvironmental and age implications. Himalayan Geol. 34(2), 148–157.

Xi, D.P., Wan, X.Q., Feng, Z.Q., Li, S., Feng, Z.H., Jia, J.Z., Jing, X., Si, W.M., 2011. Discovery of Late Cretaceous foraminifera in the Songliao Basin: Evidence from SK-1 and implications for identifying seawater incursions. Chinese Sci. Bull. 56(3), 253–256.

The discovery of the CORB in the Southern Tethyan Himalaya and its paleogeographic implication

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The Cretaceous oceanic red beds (CORB) are widespread in the Northern Tethyan Himalaya (NTH) but never reported in the Southern Tethyan Himalaya (STH). In this study, red beds (CORB, composed of 5 m thick cherry-red thin-bedded marl) are firstly discovery from the Upper Cretaceous of the Jinshansibei section, Tüna, Yadong, STH. The litho- and biostratigraphy of upper Gambacunkou Formation and lower Zongshan Formation (containing the CORB) of the Jinsangsibei section were investigated. Micropaleontologic study of the strata led to the discovery of abundant planktic foraminifers in marl, limestone and shale. The foraminifer preservation is mostly satisfactory, and sixty-seven species from 22 genera were identified. These allow recognition of six planktic foraminiferal zones: ① *Dicarinella concavata* Zone (Kj1–6), ② *Dicarinella asymetrica* Zone (Kj7–44), ③ *Globotruncanita elevata* Zone (Kj45–60), ④ *Globotruncana ventricosa* Zone (Kj61–108), ⑤ *Radotruncana calcarata* Zone (Kj109–129), and ⑥ *Globotruncanella havanensis* Zone (Kj130–134). The planktic foraminiferal assemblage provides a Late Cretaceous age for the Gambacunkou and Zongshan formations and an early Late Campanian age for the CORB (corresponding to the upper *R. calcarata* Zone) in the Jinsangsibei section.

In contrast to those in NTH, the CORB in STH is characterized by monotonous cherry-red marl with smaller thickness and shorter age. The discovery of the CORB in STH challenges the previous view that the CORB in the Tethyan Himalaya should be restricted to the NTH (slope to basin) and entirely miss in STH (shelf). This discovery contributes to the paleogeographic interpretation of the CORBs in southern Tibet and the Tethyan Himalaya.

Keywords

CORB, planktic foraminifera, palaeogeography, Late Cretaceous, Southern Tethyan Himalaya.

References

Li, G.B., Jiang, G.Q., Hu, X.M., Wan, X.Q., 2009a. New biostratigraphic data from the Cretaceous Bolinxiala Formationin Zanda, southwestern Tibet of China, and their paleogeographic and paleoceanographic implications. Cretaceous Res. 30(4), 1005–1018.

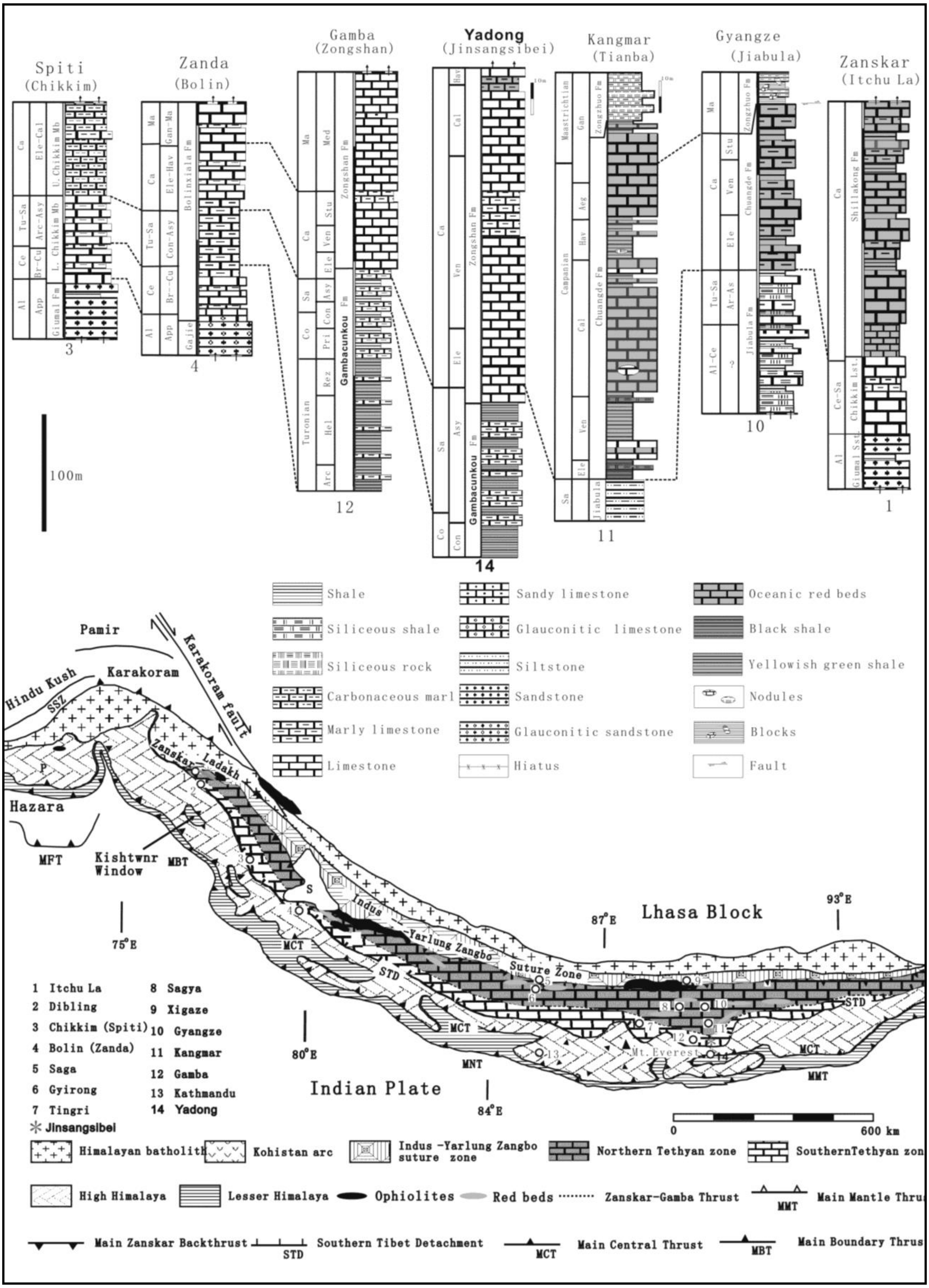
Li, G.B., Xie, D., Wan, X.Q., Han, H.D., Chen, P.L., 2009b. Discovery of Radiolaria from the Zongzhuo Formation in Tianba, Kangmar and its age implication. Acta Geol. Sin. 83(5), 853–859.

Li, G.B., Jansa, L., Wan, X.Q., Pan, M., Xiu, D., Xie, D., 2011a. Discovery of radiolaria from Upper Cretaceous Oceanic Red Beds in Daba, Kangmar and its paleogeographic implication. Palaeogeogr. Palaeoclimatol. Palaeoecol. 312(1–2), 127–137.

Li, G.B., Jiang, G.Q., Wan, X.Q., 2011b. The age of the Chuangde Formation in Kangmar, southern Tibet of China: Implications for the origin of Cretaceous oceanic red beds (CORBs) in the northern Tethyan Himalaya. Sediment. Geol. 235(1–2), 111–121.

Li, G.B., Wan, X.Q., Pan, M., 2011c. Planktic foraminiferal biostratigraphy of the Cretaceous oceanic red beds in Kangmar, Southern Tibet, China. Acta Geol. Sin. 85(6), 1238–1253.

Fig. 1. Correlation of the Gambacunkou and Zongshan formations at Jiansangsibei, Yadong (14) to late Early–Late Cretaceous successions in (1) Itchu La, northern Zanskar (Fuchs, 1982); (3) Chikkim, Spiti (Bertle and Suttner, 2005); (4) Bolin, Zanda (Li et al., 2009a); (11) Tianba, Kangmar (Li et al., 2009a,b, 2011a,b,c); (12) Zongshan, Gamba (Wan, 1985; Wan et al., 2000; Zhao and Wan, 2003; Li et al., 2003); and (10) Jiabula, Gyangze (Zhao and Wan, 2003). Stages and biozones: Al – Albian, Ce – Cenomanian, Tu – Turonian, Co – Coniacian, Sa – Santonian, Ca – Campanian, Ma – Maastrichtian, Tic – Ticinensis Zone, App – Appenninica Zone, Bro – Brotzeni Zone, Rei – Reicheli Zone, Cus – Cushmani Zone, Arc – Archaeocretacea Zone, Hel – Helvetica Zone, Con – Concavata Zone, Asy – Asymetrica Zone, Ele – Elevata Zone, Ven – Ventricosa Zone, Cal – Calcarata Zone, Hav – Havanensis Zone, Aeg – Aegyptiaca Zone, Gan – Gansseri Zone, May – Mayaroensis Zone.


Spiti
(Chikkim)
Zanda
(Bolin)
Gamba
(Zongshan)
Yadong
(Jinsangsibei)
Kangmar
(Tianba)
Gyangze
(Jiabula)
Zanskar
(Itchu La)
100m
Shale
Siliceous shale
Siliceous rock
Carbonaceous marl
Marly limestone
Limestone
Sandy limestone
Glauconitic limestone
Siltstone
Sandstone
Glauconitic sandstone
Hiatus
Oceanic red beds
Black shale
Yellowish green shale
Nodules
Blocks
Fault
Pamir
Hindu Kush
Karakoram
Karakoram fault
Hazara
MFT
Kishtwnr Window
MBT
Lhasa Block
Indus-Yarlung Zangbo Suture Zone
Indian Plate
Mt. Everest
75°E
80°E
84°E
87°E
93°E
1 Itchu La
2 Dibling
3 Chikkim (Spiti)
4 Bolin (Zanda)
5 Saga
6 Gyirong
7 Tingri
8 Sagya
9 Xigaze
10 Gyangze
11 Kangmar
12 Gamba
13 Kathmandu
14 Yadong
Jinsangsibei
0
600 km
Himalayan batholith
Kohistan arc
Indus-Yarlung Zangbo suture zone
Northern Tethyan zone
SouthernTethyan zon
High Himalaya
Lesser Himalaya
Ophiolites
Red beds
Zanskar-Gamba Thrust
Main Mantle Thru
Main Zanskar Backthrust
Southern Tibet Detachment
Main Central Thrust
Main Boundary Thrus

Palaeobiogeographic implications of the late Aptian–Albian polyconitid rudist fauna

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Rudists are a group of thermophilic shallow water benthic bivalves ranging from the Late Jurassic to the end of the Maastrichtian and spanning tropical and subtropical latitudes during the "Greenhouse" Aptian–Albian interval. They were organic builders and sediment constituents of neritic carbonates, and thus they are significant indicators of stratigraphy, palaeogeography and palaeoenvironmental indicators.

The late Aptian–Albian polyconitid rudist fauna is remarked by *Horiopleura* (including *H. haydeni* Douvillé, *H. lamberti* Hébert, and *H. almerae* Paquier) and *Polyconites* (including *P. verneuili* Coquand, *P. hadriani* Skelton et al., and *P. africanus* Tavani) that give rise to diverse assemblages with radiolitid rudists, nerineid gastropods, corals and benthic orbitolinid forams. The general external morphology of these two taxa is marked by a low cupuloid upper valve and an umbo projected towards the external side in *Horiopleura*, while in *Polyconites* the upper valve is flat. The inner features are marked by the different development of the ectomyophoral cavity between the two valves and the arrangement of the cardinal apparatus that is more developed in *Horiopleura* (Fig. 1).

This fauna was globally distributed along the margins of Tethys: in the Lhasa terranes, including Lameila Mt., Ngari area, Nyer Lake, Zabuye Lake, Duba region, east of Xigaze (Tibet, China); Kohistan-Ladakh (K-L) volcanic arc, including Yasin (Northern Pakistan), Shukur and Khalsi (Northern India); Pontides platform (Northern Turkey); Iberia; Ouenza platform (Northern Africa); Apulia; Southeast Arabia (Fig. 2); and even it extended eastwards to the Pacific area from the Iberia region via the Himalayas (Sha and Cestari, 2016).

However, fossil assemblages with both *Horiopleura* and *Polyconites* were widely distributed in the south Tethyan margin, from southern Iberia to southeast Arabia, and in the European north Tethyan margin (northwestern margin of Tethys). Assemblages are marked by the presence of *Horiopleura* in the Asian north Tethyan margin (northeastern margin of Tethys) (e.g., the Mega-Lhasa intra-oceanic platform) and in the Kohistan–Ladakh (Kohistan-Dras) intra-oceanic volcanic arc. Such different assemblages have indicated two distinct bioprovinces: Mediterranean Province yielding *Horiopleura* and *Polyconites* assemblages and South West Asian Province remarked by the presence of *Horiopleura* assemblage (or "Yasin-type" *Horiopleura haydeni* fauna), without the *Polyconites* one.

Such rudists could have had a very high larval productivity and thus were able to migrate along the continental margins and islands, and drift or passively swim with the ocean currents, like the other sessile bivalves, particularly the cemented thermophilous bivalves including ostreids (Sha, 2003; Sha et al., 2014). The distribution pattern of polyconitid rudist fauna (Fig. 2) has implied that larvae dispersal of the Late Aptian–Albian rudists were mainly controlled by the westward Tethys Circumglobal Current (Bush et al., 1997) and by recirculation gyres in epicontinental seas such as in the Bangong–Nujiang. The influx of cooler boreal waters from the Russian engulfment (Fig. 2) were probably a major factor, like a thermal barrier, separating the European North Tethyan margin from the Asiatic North Tethyan margin, forming different bioprovinces. The microplates forming the Kohistan–Ladakh or Oman-Kohistan-Dras arc had separated from Indian Plate and drift into the tropic (Gibbons et al., 2015) area during the late Aptian–Albian as they are documented by the late Aptian–Albian neritic carbonates with rudists.

Acknowledgements

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Keywords

Rudists, Early Cretaceous, palaeobiogeography.

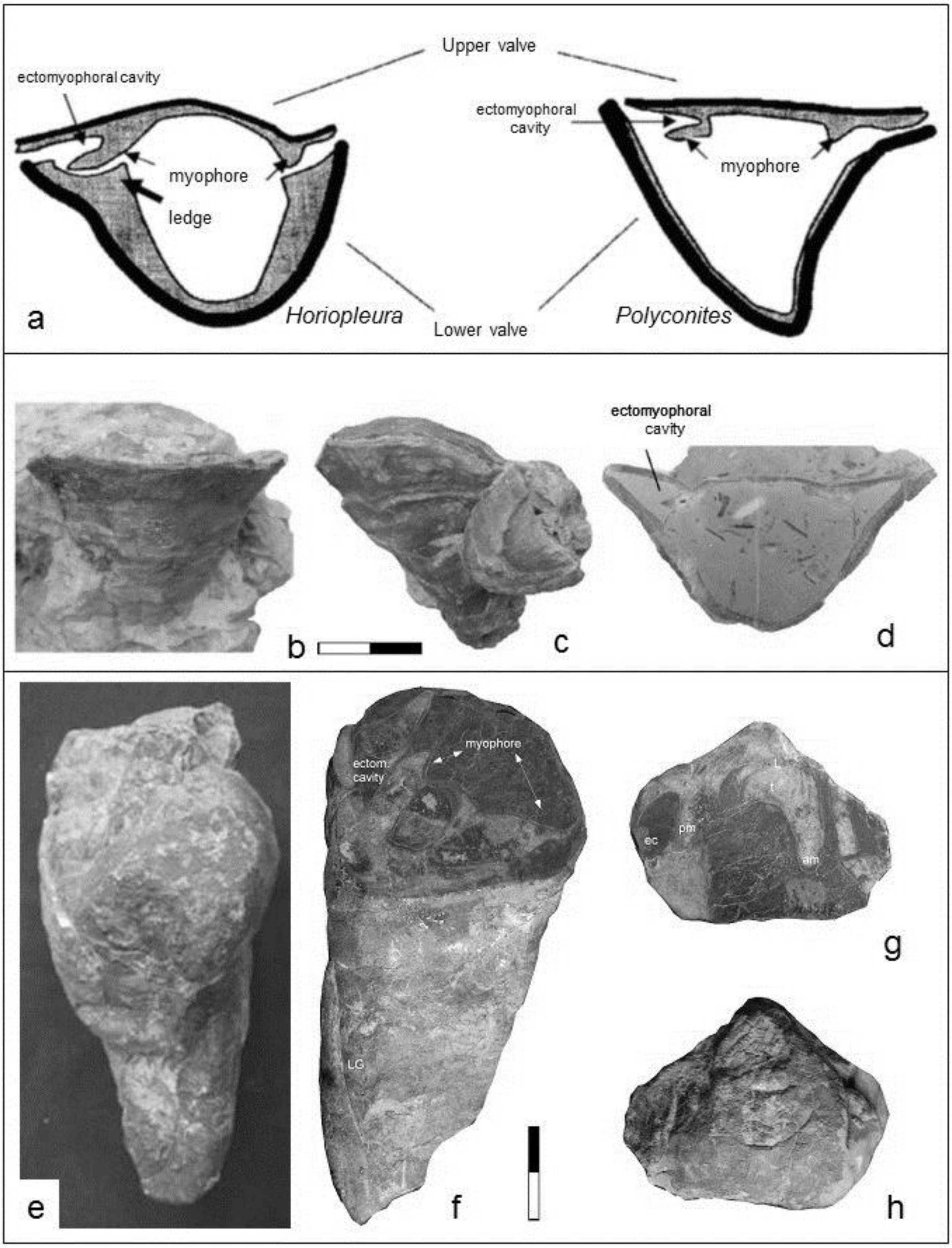

Fig. 1. General shell shape and features of *Horiopleura* and *Polyconites* rudists: (a) drawing of the transverse section showing the main features of the two valves (modified from Fig. 1 of Skelton et al., 2010); (b) *Polyconites hadriani* seen from the ventral side (after Skelton et al., 2010: Fig. 5a); (c) *P. hadriani* postero-ventral view (after Skelton et al., 2010: Fig. 6i); (d) *P. hadriani* antero-posterior section of the valves (after Skelton et al., 2010: Fig. 5d); (e) *Horiopleura haydeni* seen from the dorsal side (type no. MPUM 11381 of *H. desioi* emended to be *H. haydeni* in Sha and Cestari, 2016); (f) lower valve of *H. haydeni* cut near the commissure, showing the inner features; (g) transverse section of the upper valve (L – ligamentary ridge, ec – ectomyophoral cavity, pm – posterior myophore, am – anterior myophore); (h) same specimens, upper valve seen from above (after Sha and Cestari, 2016: Fig. 5f–h). Scale bar equals 2 cm.

Fig. 2. Configuration of the Tethys Ocean during Indian plate drifting (arrow). The *Horiopleura* assemblage is common on the northern shore of Tethys while the *Polyconites* and *Horiopleura* assemblages are common on the southern shore. The Russian engulfment could act as a thermal barrier. 1 – Lhasa terranes, including Lameila Mt., Ngari area, Nyer Lake, Zabuye Lake, Duba region, east of Xigaze (Tibet, China); 2 – Kohistan–Ladakh (K–L) volcanic arc, including Yasin (Northern Pakistan), Shukur and Khalsi (Northern India); 3 – Pontides platform; 4 – Iberia; 5 – Ouenza platform, Northern Africa; 6 – Apulia; 7 – South-east Arabia. KP – Kerguelen Plateau; B–N – Bangong-Nujiang sea (modified from Aptian base map 120 Ma, Blakey, 2010; © Ron Blakey, Colorado Plateau Geosystems) (after Sha and Cestari, 2016: Fig. 10).

References

Blakey, R.C., 2010. Paleogeographic Maps. Colorado Plateau Geosystems. AZ, Phoenix. URL: http://cpgeosystems.com

Bush, A.B., George, S., Philander, H., 1997. The late Cretaceous: simulation with a coupled atmosphere-ocean general circulation model. Paleoceanogr. 12, 495–516.

Gibbons, A.D., Zahirovic, S., Müller, R.D., Whittaker, J.M., Yatheesh, V., 2015. A tectonic model reconciling evidence for the collisions between India, Eurasia and intra-oceanic arcs of the central-eastern Tethys. Gondwana Res. 28, 451–492.

Sha, J., 2003. Plankton and pseudoplankton of the marine Mesozoic bivalves. Acta Palaeontol. Sin. 42, 408–416 (in Chinese with English abstract).

Sha, J., Cestari, R., 2016. Late Aptian–Albian Yasin-type rudist assemblage in the Himalayas: palaeobiogeographic implications. Cretaceous Res. 65, 34–47.

Sha, J.G., Rao, X., Cai, H.W., Pan, Y.H., Wang, Y.Q., 2014. Pan-tropical distribution of the Jurassic ostreid bivalves. Palaeoworld 23, 155–161.

Skelton, P.W., Gili, E., Bover-Arnal, T., Salas, R., Moreno-Bedmar, J.A., 2010. A new species of *Polyconites* from the lower Aptian of Iberia and the early evolution of polyconitid rudists. Turkish J. Earth Sci. 19, 557–572.

Session 3
Cretaceous climate and environmental changes

Cretaceous paleoenvironments of the Russian Southeast

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Attention to the study of the Cretaceous System does not become weaker both on global and regional scales, since the most important geological events in the Earth's history as well as valuable mineral resources are associated with this system. International and All-Russian meetings are held regularly (Baraboshkin et al., 2014). New data on the southeastern Russia and adjacent territories of China, where Cretaceous rocks of different types are widespread (Fig. 1) are being published systematically (Decisions…, 1994; Likht, 1997; Liu et al., 1997; Markevich et al., 1997; Yarmolyuk et al., 2000; Zhang et al., 2008; Cao et al., 2013; Didenko et al., 2014; Kirillova et al., 2015; Khanchuk et al., 2015).

The development of the Far Eastern region during the Early Cretaceous closely follows that of the Late Jurassic (Kirillova et al., 2000). Three types of basins existed there in the Early Cretaceous. The Lower Amur and Sikhote-Alin basins, located eastward, are considered the first type and appear to be rather deep seas, in which mostly Berrisasin–Valanginian turbidites, about 6000 m thick, with a subordinate amount of cherty-volcanic rocks and limestones accumulated in the conditions of stable downwarping environment. Horizons with olistostromes containing diversified Paleozoic and Mesozoic clastics are often observed near the continental boundary. Some researchers suggest the existence of an early Cretaceous oceanic basin, the deposits of which (jasper, cherts, mudstones) are associated with alkaline basalts described in the Kiselevka–Manoma terrane.

Basins located along the margin of the pre-Jurassic continental structures (Torom, Uda, Bureya, Okrainy and South Primorye) belong to the second type (Kirillova et al., 2015). They are represented by epicontinental seas with rich benthos where diversified terrigenous material, generally containing products of terrestrial volcanism, accumulated during the Berriasian to Early Hauterivian. Here epochs of intensive downwarping repeatedly alternated with uplifting and erosion and continental sedimentation with coal formation. The thickness of the deposits varies from 2000 to 4000 m.

Intracontinental rift and postcollisional basins, in which continental coal-bearing 1000-m-thick sediments were deposited during the Berriasian–Hauterivian interval (Cao et al., 2013), are related to the third basin type. They are separated by low mountains (Amur-Zeya and Pre-Dzhugdzhur basins).

According to geodynamic reconstructions, the Khingan-Okhotsk active continental margin, bounded by the Amur suture from the east, existed in the Early Cretaceous. This margin comprised a magmatic arc marked by a chain of volcanic areas extending from the Lesser Khingan as far as the Sea of Okhotsk, along with an accretionary complex made up mainly of turbidites. Olistostrome horizons discovered at different Early Cretaceous stratigraphic levels are confined to zones of the largest bed-by-bed disintegration. As a result of the oblique subduction of the Izanagi Plate, the sinistral margin-slip movements have been initiated in the Valanginian on the East Asian margin and the transform continental margin started its formation. These movements accompanied by local collision events became more intensive in the Hauterivian, causing elevation of large tectonic blocks, hiatuses in sedimentation and considerable changes in the coastline.

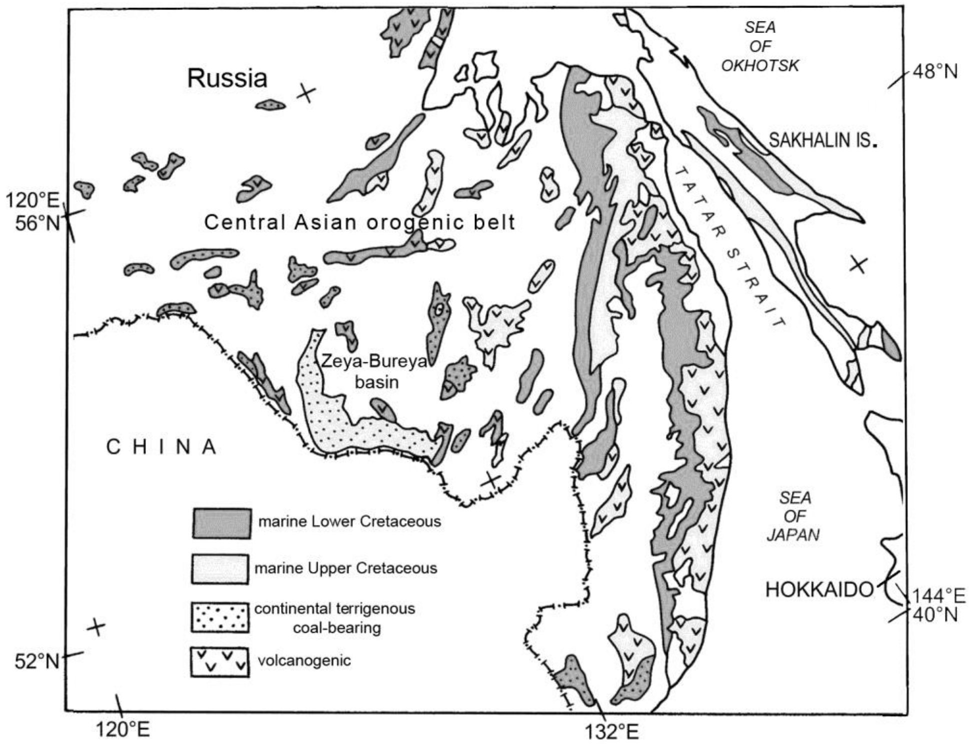

Fig. 1. The types of Cretaceous rocks in the southeastern Russia.

Marine Hauterivian deposits are reported only from the southeastern Primorye, where a continuous Berriasian–Albian section has been described, and no marine deposits of this age are observed in the rest of the area.

For the time interval from the Barremian to the mid-Albian, four sedimentation areas can be distinguished: West Sikhote-Alin basin area, East Sikhote-Alin basin area, marginal-continental basin area, and intracontinental basin area.

The West Sikhote-Alin basin is viewed as a pull-apart sea basin filled with Late Hauterivian and Barremian turbidites. In the Aptian–Early Albian the Samarga and Udyl island arcs were generated in the eastern part of the basin; and the basin assumed the features of a back-arc basin. Volcanogenic sandstones, tuffs and tuffaceous siltstones are among the terrigenous material predominant. The rate of sedimentation sharply increased after the Aptian time, when island arcs were becoming larger. The thickness of the Late Hauterivian–Middle Albian deposits reaches 5500 m.

The East Sikhote-Alin basin is also interpreted as a pull-apart basin being filled with terrigenous turbidites during the Hauterivian and Barremian. Since the beginning of the Aptian, a volcanic material is observed in the turbidites, and the rate of sedimentation increased sharply. Since that time, it was a forearc basin where sedimentation continued until the mid-Albian. The thickness of the deposits is about 9000 m.

The marginal-continental basin area covered the Uda, Torom, Bureya, Razdolny and Partizansk basins. Terrigenous continental deposits about 1500 m thick are among the deposits predominant. The deposits of the first two basins are represented mostly by conglomerates and diversified sandstones (about 600 m) which contain volcanic material, evidencing about the proximity to the volcanic arcs. In the Late Aptian to mid-Albian, the Okhotsk-Chukchi volcanic belt and its fragments began to form along the basin margins. Rhyolites and dacites were the first volcanics to appear. The Bureya, Razdolny and Partizansk basins were coastal-marine marsh plains during the Hauterivian to mid-Albian. A cyclic terrigenous coal formation about 1500 m thick accumulated there. The Razdolny and Partizansk basins can be considered as pull-apart basins because their formation during the Hauterivian was associated with the intensive left-lateral strike-slip faults. During the

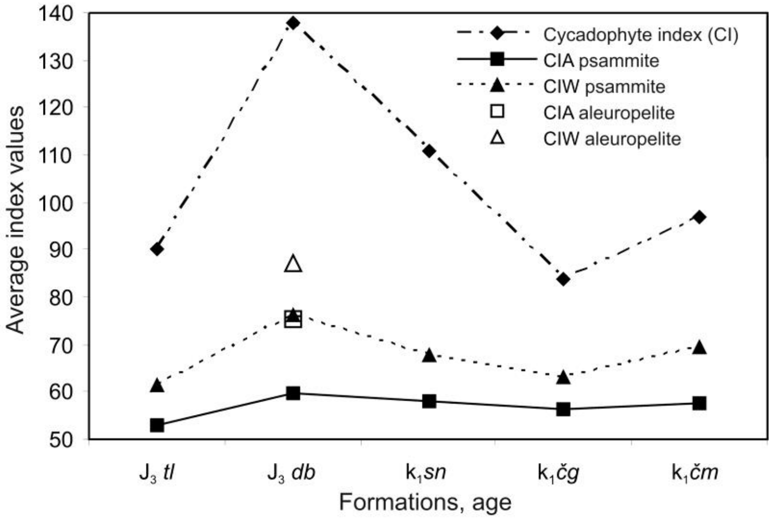

Fig. 2. Diagram showing CI, CIA and CIW values obtained for the Upper Jurassic–Lower Cretaceous of southeastern Russia. Formations: J_3*tl* – Talyndzhan, J_3*db* – Dublican, K_1*sn* – Soloni, K_1*čg* – Chagdamyn, K_1*čm* – Chemchuki.

mid-Albian transgression, the sea penetrated briefly the Bureya and Partizansk basins, as confirmed by the beds with marine *Trigonia* and foraminifers. Since the Late Albian, however, the type of sedimentation in the Partizansk and Razdolny basins sharply changed: after short pause the continental coarse clastic, variegated volcanogenic-terrigenous sediments about 3500 m thick were deposited.

The Amur-Zeya basin is related to the intracontinental basin areas that expanded substantially during the Hauterivian to early Albian, thus marking a post-rift subsidence stage of the development. During this time 1200 m of terrigenous deposits accumulated and acid volcanics erupted.

Early Cretaceous paleoclimates can be inferred from lithological, paleobotanic and lithochemical data obtained in the most studied Bureya Basin. The formation of the Late Jurassic–Early Cretaceous coal beds occurred in a warm humid climate.

From K. Raunkier cycadophyte index ($CI = \frac{b_1}{a_1} \div \frac{b}{a} \times 100$) of the floral remains V.A. Krassilov established that a warming event occurred in the Tithonian (Dublican Formation). This warm period was followed by a cooling in the Berriasian–Early Hauterivian (Urgal and Chagdamyn formations) and then by some warming in the Late Hauterivian–Aptian (Chemchuki Formation) (Krassilov, 1973).

We have determined standard lithochemical indices:

$$CIA = Al_2O_3 / (Al_2O_3+CaO^*+Na_2O+K_2O) \times 100$$

(*chemical index of alteration*)

$$CIW = Al_2O_3 / (Al_2O_3+CaO+Na_2O) \times 100$$

(*a new chemical index of weathering*)

The boundary between cold and warm climates is defined by CIA value of 70 or CIW value of 80 in the clay shales (aleuropelites) and by the lower values in the psammites. The average CIA and CIW values of the studied Late Jurassic psammites are 58.3 and 73.3, respectively, and those of the Early Cretaceous psammites are lower (57 and 67). The average CIA and CIW values of the Late Jurassic aleuropelites are 75.2 and 87.2. Based on these parameters, it should be concluded that climate in the Tithonian was warm while during the other studied time intervals the climate was warm-temperate (Fig. 2). An increase in CI values indicates a warming process.

The formation of the extended Okhotsk-Chukchi magmatic arc (or volcanic belt) was commenced in the mid-Albian and was the most remarkable event at the Early–Late Cretaceous transition. The East Sikhote-Alin belt, which also began to form at the same time, was a southern continuation of the Okhotsk-Chukchi belt.

In the Late Cretaceous the Far Eastern region included eastern and western depositional areas. The western continental area was characterized by the eruption of acid to intermediate volcanics during the Cenomanian–Turonian; however, a hiatus in sedimentation is observed in the Amur-Zeya basin. During the Turonian to Senonian, extensive 300 m thick lacustrine sandstones and clays with rich fauna were deposited. Along the basin margins, conglomerates occur with deposits reaching 800 m in thickness. Maastrichtian–Danian cyclic sandstones, gravels and claystones up to 450 m thick are widespread. Dinosaur remains were found in the mid-Maastrichtian beds.

In the eastern area, the Late Cretaceous East Sikhote-Alin volcanic belt was formed in the coastal part of the continent. An alternating series of lavas and intermediate to acid tuff of about 1500 m in total thickness have been formed. During the Late Cretaceous, the West Sikhote-Alin belt continued to form, generating 1800 m thick series of alternating lavas and intermediate to acid tuff. Volcanic arcs represented topographic highs that probably had an impact on local climatic conditions and thus sedimentary regimes. Within the back arcs, Cenomanian–Turonian continental variegated volcanogenic-sedimentary deposits (about 3000 m) were generated suggesting an initial high rate of volcanic arc denudation while troughs were being formed.

During the Late Cretaceous, most of the Far Eastern region was a land. A marine embayment persisted only in the northeastern part, along the present-day Amur River valley. It represented a back-arc basin, in which about 4000 m of coarse sandstones, siltstones and mudstones mixed with tuffaceous material were deposited during the Cenomanian–Turonian. Basal conglomerates mark the base of the sequence. At the end of the Turonian, the sea retreated from the region completely, and since that time until the latest Cretaceous, andesite and rhyolite volcanic rocks up to 1000 m thick were formed. The sea retreated to the eastern margin of the East Sikhote-Alin belt.

References

Baraboshkin, E.Yu., Markevich, V.S., Bugdaeva, E.V., Afonin, M.A., Cherepanova, M.V. (Eds.), 2014. Cretaceous System of Russia and the near abroad: problems of stratigraphy and paleogeography. Proceedings of the 7th Russian Scientific Conference with international participation. Dalnauka, Vladivostok.

Cao, C.R., Kirillova, G.L., Sorokin, A.P., Kaplun, V.B., Cao, Y.Qu., Zhang, Y.J., 2013. Structural framework and evolution of the Sunwu-Jiayin Basin in NE China and its relation to the structures of the Zeya-Bureya Basin, the Far East of Russia. Tikhookean. Geol. 32(6), 68–78.

Decisions of IV Interdepartment Regional Stratigraphic Meeting on Precambrian and Phanerozoic of the southern Far East and Eastern Transbaikalia. A set of stratigraphic charts. Khabarovsk, 1994.

Didenko, A.N., Khanchuk, A.I., Tikhomirova, A.I., Voinova, I.P., 2014. Eastern segment of the Kiselevka-Manoma terrane (northern Sikhote-Alin): Paleomagnetism and geodynamic consequences. Tikhookean. Geol. 33(1), 20–40.

Khanchuk, A.I., Didenko, A.N., Popeko, L.I., Sorokin, A.A., Shevchenko, B.F., 2015. Structure and evolution of the Central Asian orogenic belt, in: Kroner, A. (Ed.), The Central Asian orogenic belt: Geology, evolution, tectonics and models. Borntraeger Sci. Publ., Stuttgart, pp. 211–234.

Kirillova, G.L., Markevich, V.S., Bely, V.F., 2000. Cretaceous environmental changes of East Russia, in: Okada, H., Mateer, N. (Eds.), Cretaceous environments of Asia. Elsevier, pp. 1–47.

Kirillova, G.L., Krapiventseva, V.V., Gresov, A.I., 2015. Cretaceous evolution stage of the Jiamusi–Bureya fragment of the continental margin as exemplified from the Bureya and Hegang basins. Rus. J. Pac. Geol. 9(2), 96–108.

Krassilov, V.A., 1973. Palaeoecological correlation method for continental rocks. Bull. Moscow Soc. Nat., Geol. Ser. 48(4), 37–50.

Likht, F.R., 1997. Sedimentological features of the Cretaceous basins of the Western Sikhote-Alin. Tikhookean. Geol. 16(6), 92–101.

Liu, Zh., Kirillova, G.L., Zhang, X., Wang, S., 1997. Mesozoic–Cenozoic tectono-stratigraphic complexes along the Manchzhuria–Suifenhe transect zone and adjoining area as a reflection of geodynamic evolution of the region. Tikhookean. Geol. 16(6), 36–45.

Markevich, P.V., Konovalov, V.P., 1997. Early Cretaceous deposits of Sikhote-Alin: certain results of sedimentological investigations. Tikhookean. Geol. 16(6), 80–91.

Yarmolyuk, V.V., Kovalenko, V.I., Kuzmin, M.I., 2000. North Asian superplume in the Phanerozoic: Magmatism and deep geodynamics. Geotectonics 5, 3–29.

Zhang, X., Zhang, M., Chi, X., Liu, Zh., 2008.The division and evolution of Mesozoic basin groups in Northeastern China, in: Workshop on petroleum geology and mineral resources in Northeastern Asia: Abstract volume. Changchun, pp. 38–39.

Palynomorphs and biofacies in the Upper Cretaceous sediments of northern Siberia

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The significance of microphytofossils for paleogeographic and paleoecological reconstructions is one of the most complex and debatable questions. The distribution of different palynomorph groups, including dinoflagellate cysts, acritarchs, and unicellular green algae, through bionomic zones of sea depends on many interrelated factors, the influence of which on the biota structure frequently cannot be discriminated when reconstructing different parameters of paleobasin (depth, salinity, hydrodynamics, isolation degree of the basin, water chemistry and others). This work continues the series of papers dedicated to paleoecological properties of marine microphytofossils and their significance for reconstructing habitat conditions (Lebedeva and Zverev, 2003; Lebedeva, 2008). Altogether they present the results of the biofacies analysis of palynomorphs from natural outcrops of Upper Cretaceous sediments in the Ust'-Yenisei area. This section was selected to serve as a standard for development of methodical approaches, since it is composed of different-facies sediments with abundant and diverse assemblages of plant microfossils and is well studied both in the paleontological and sedimentological aspects (Zakharov et al., 1991, 2003; Sahagian et al., 1996; Lebedeva and Zverev, 2003; Lebedeva, 2006). The analysis of quantitative characteristics of individual palynomorph groups, morphotypes and taxa of dinocysts, as well as changes in their taxonomical structures revealed seven palynomorph assemblages that characterize terrestrial, coastal marine, shallow-, and deep-water settings (Lebedeva, 2008). It should be noted that the terms "shallow-water" and "deep-water" are conditional, since microphytoplankton is linked more to distance from the shore than to depth of the basin.

Terrestrial

Assemblage 1 is dominated by spores and pollen (90–100%) accompanied by common aqueous ferns and microphytofossils represented by freshwater *Schizoporis*, *Schizocysta*, and *Tetraporina* forms.

Coastal-marine (sublittoral settings with high-energy hydrodynamics and a varying degree of desalination)

Assemblage 2a is dominated by spores and pollen (40–90%). Phytoplankton includes freshwater algae (0–10%), acritarchs (8%: *Micrhystridium*, *Veryhachium*, *Leiofusa*), and prasinophytes (0–12%: *Pterospermella*, *Cymatiosphaera*). *Paralecaniella*: 5–45%. Dinocysts are largely represented by the gonyaulacoid group accompanied by chorate (0–40%), diverse cavate (*Chatangiella*, *Trithyrodinium*, *Alterbidinium*, *Palaeohystrichophora*), and rare (up to 6%) holocavate (*Chlamydophorella*, *Chlonoviella*) forms. The remarkable feature of the assemblage is the occurrence of proximochorate cysts of the *Cyclonephelium*–*Circulodinium* group, *Fromea*, and *Microdinium* species (locally >5%).

Assemblage 2b is also dominated by spores and pollen (40–90%). The composition of microphytofossils is highly impoverished. All the groups occur in insignificant quantities except for freshwater algae, which constitute 5–20%, and *Paralecaniella* (up to 50%). Dinocysts are of extremely low diversity with *Fromea* playing the most notable role.

Assemblage 3 is characterized by the dominant role of the genus *Paralecaniella* (80–100%) and a highly impoverished dinocyst composition, which are either missing or uniform lacking chorate forms such as *Pterospermella* and *Schizoporis* representatives.

Shallow-water (sublittoral settings with normal marine salinity, subjected to substantial influence of land: dominant role of terrestrial plants and others)

Assemblage 4 is largely composed of spores and pollen (40–60%) accompanied by freshwater algae (0–10%), acritarchs (0–20%), prasinophytes (0–12%), and *Paralecaniella* (0–20%). Dinocysts are dominated by the peridinioid group mainly represented by cavate, proximate (*Microdinium*, *Rhyptocorys*, *Glyphanodinium*), and chorate forms; the last group is relatively abundant (0–24%), although of uniform composition.

Assemblage 5 dominated by spores and pollen (40–60%) also includes freshwater algae (0–5%), acritarchs (0–15%), prasinophytes (1–25%), and *Paralecaniella* (0–40%) forms. Dinocysts are dominated by the peridinioid group with diverse cavate and proximate forms being represented in approximately equal proportions; chorate and holocavate forms are rare.

Deepwater (sublittoral zone with normal marine salinity, most remote from the shoreline)

Assemblage 6 is dominated by marine microphytoplankton (up to 70%) with freshwater algae, acritarchs, prasinophytes, and *Paralecaniella* present in small quantities. Dinocysts are alternatively dominated by either gonyaulacoid and peridinioid forms; diverse cavate and proximate forms occur in approximately equal proportions, and abundance of chorate cysts amounts to 40%.

Assemblage 7 is dominated by marine microphytoplankton (up to 100%) accompanied by rare freshwater algae, acritarchs, prasinophytes, and *Paralecaniella* species, which constitute a few percent. Diverse dinocysts represented by all morphotypes are dominated by the peridinioid group (mostly cavate forms).

The analysis of proportions between different taxa and morphotypes of dinocysts, acritarchs and prasinophytes in defined assemblages revealed certain patterns in their distribution.

Cavate cysts (*Eurydinium*, *Trithyrodinium*, *Palaeohystrichophora*, *Alterbidinium*, *Odontochitina*, *Spinidinium*, *Isabelidinium*, *Chatangiella*). This tolerant cosmopolitan group occurs in practically all the facies types of assemblages, except for assemblages 1 and 3, although is most abundant and diverse in assemblages 4–7 (shallow-water and deep-water facies). The genera *Chatangiella* and *Trithyodinium* are registered in all assemblages, being most abundant in assemblages 4–6 and prevailing in sandy sediments (Lebedeva, 2001). The genus *Palaeohystrichophora* occurs as single specimens in most sections, but is abundant only in the Seida and Leningradskaya-1 Well sections. It is conceivable that representatives of this genus may tolerate desalination, which is evident from its mass occurrence in assemblages 2a and 3. May (1980) noted the confinement of *Palaeohystrichophora* forms to estuarine or coastal bay settings. The genus *Odontochitina* is probably eurybiontic, since it occurs in all the defined assemblages, except for assemblages dominated by *Paralecaniella*. Many authors (e.g., Brideaux and McIntyre, 1975; Tocher and Jarvis, 1987) also emphasized the tolerance of this genus to changeable environments. The genera *Spinidinium* and *Isabelidinium* prefer shallow-water and deep-water facies (assemblages 4 and 7). The maximal *Spinidinium* content is recorded in the Seida River section.

Proximate, proximochorate cysts (*Rhyptocorys*, *Microdinium*, *Cribroperidinium*, *Apteodinium*, *Kallosphaeridium*, *Circulodinium*, *Laciniadinium*, *Dorocysta* and others) include taxa with a wide habitat range, being most abundant in assemblages 2a and 6. The genera *Cyclonephelium* and *Circulodinium* occur universally. They tolerate brackish-water settings, as is evident from their abundance in Assemblage 2a. The genera *Cribroperidinium*, *Apteodinium*, *Kallosphaeridium* and *Canningia* are similarly tolerant to different environments, which is also confirmed by published data (Harris and Tocher, 2003). Development of the genera *Apteodinium*, *Kallosphaeridium* and *Batiacasphaera* is closely connected with prograding transgression: their content increases seaward. The genus *Microdinium* is most abundant in coastal-marine and shallow-water settings (assemblages 2a, 4, 5). The genus *Rhyptocorys* is usually confined to shallow- and deep-water sediments (assemblages 4, 6).

Holocavate cysts (*Chlonoviella*, *Chlamydophorella*, *Membranisphaera*) occur in all the defined assemblages. They represent one of a few groups, which occur in Assemblage 3. In the Ust'-Yenisei section, the genera *Chlonoviella* and *Chlamydophorella* are abundant in Assemblage 6. In sections of West Siberia, Kara Sea shelf and Polar Cis-Urals, the content of holocavate cysts is substantially higher and they are abundant in shallow- and deep-water assemblages 5–7 as well as in coastal-marine Assemblage 2a. This group probably occupied remote biotopes regardless of their depths. This assumption is confirmed by data on other regions and stratigraphic intervals (e.g., Lebedeva and Nikitenko, 1999; Harris and Tocher, 2003; Nikitenko et al., 2008).

Chorate cysts (*Spiniferites*, *Achomosphaera*, *Coronifera*, *Oligosphaeridium*, *Hystrichosphaeridium*, *Heterosphaeridium*, *Exochosphaeridium*, *Florentinia*, *Pervosphaeridium*, *Membranilarnacia* and others) occur in all the assemblages (except for assemblages 1 and 3), although they prefer environments with low-energy hydrodynamics (assemblages 2a, 4, 6, 7). The genera and their species constituting this group exhibit different ecological preferences. As previously mentioned, the data on facies confinement of the genus *Spiniferites* are ambiguous. Our materials contribute little to the solution of this problem. The substantial increase in abundance and diversity of this genus is observable both in deep-water assemblages 6 and 7 and in coastal-marine Assemblage 2a. At the same time, there are no grounds to speak about wide-range tolerance of the genus *Spiniferites*, since in all other settings it is either absent or occurs as single specimens. The genus *Oligosphaeridium* occurs in all the settings, although the species *Oligosphaeridium complex* is usually confined to deep-water facies (Assemblage 7). *Oligosphaeridium pulcherrimum* is considered to be a euryhaline species (probably, preferring lowered salinity) (Harris and Tocher, 2003). The genera *Pterodinium* and *Dapsilidinium* are confined to deep-water remote settings. In contrast, the genera *Exochosphaeridium* and *Cleistosphaeridium* are abundant in coastal-marine and shallow-water facies.

Prasinophytes (*Pterospermella*, *Cymatiosphaera*, *Leiosphaeridia*) occur in facies of two types. They are usually confined to shallow-water and deep-water sediments (assemblages 5 and 6) in the Ust'-Yenisei section and coastal-marine facies (Assemblage 2a) in sections of West Siberia and Polar Cis-Urals region. The dual distribution patterns were also noted elsewhere (Lebedeva, 2008). It should, however, be noted that no representatives of the genus *Pterospermella* are found in brackish-water environments. The genus *Leiosphaeridia* occurs universally in small quantities being usually confined to sediments reflecting the onset of transgression or regressive phase.

Acritarchs occur in small abundance in Assemblage 2a, where they are represented by the genera *Micrhystridium* and *Leiofusa*. Such a distribution of acritarchs is consistent with the data indicating their confinement to sediments reflecting either the initial stage of a transgression or regression. Moreover, they are more abundant in clayey and silty sediments as compared with coarse-grained varieties. Acritarchs (largely *Veryhachium* representatives) are also abundant in deep-water environments with slightly stagnant waters.

Paralecaniella representatives occur in all the assemblages in variable proportions. The largest proportion of this genus is recorded in assemblages 2a and 3 with its dominant role in the last one. The genus is generally characteristic of rapidly changeable settings (Chaika River section). The coastal-marine settings with normal salinity, high-energy hydrodynamics and sufficient aeration were probably most favorable for the genus *Paralecaniella*. The data obtained are consistent with the results of other studies (Brinkhuis and Schiøler, 1996; Schiøler et al., 1997).

The comparative analysis of palynomorph assemblages from the Cenomanian–Coniacian sections of the Ust'-Yenisei area and other West Siberian areas (Berezovskaya-23k, Yuzhno-Russkaya-113, and Leningradskaya-1 wells) as well as from the Santonian–Campanian sediments of the Ust'-Yenisei, Khatanga and Polar Cis-Urals regions demonstrates that transgressive–regressive cycles reflected in the taxonomic structure of assemblages are most distinct in coastal sections (particularly at the transition between terrestrial and marine sediments) and less distinct in the marine section. The biofacies and palynomorph compositions exhibit regular succession from the periphery toward central parts of the West Siberian basin. It is established that facies successions in sections of the eastern and western areas of West Siberia during the Santonian–Campanian differ from each other, which is probably explained by the influence of both the West Siberian and Russian seas on sedimentation in the last domain at that time. Some defined patterns in the facies affinity of individual palynomorph groups, morphotypes and taxa of dinocysts may be used for paleogeographic interpretations. The established distribution patterns of dinocyst and other microphytofossil morphotypes determined by transgressive–regressive cycles make them a useful tool for reconstruction of sedimentation paleosettings.

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References

Brideaux, W.W., McIntyre, D.J., 1975. Miospores and microplankton from Aptian-Albian rocks along Horton River, district of Mackenzie. Geol. Surv. Can. 252, 1–81.

Brinkhuis, H., Schiøler, P., 1996. Palynology of the Geuihemmerberg Cretaceous/Tertiary boundary section (Limburg, SE Netherlands), in: Brinkhuis, H., Smith, J. (Eds.), The Geulhemmerberg Cretaceous/Tertiary boundary section (Maastrichtian type area, SE Netherlands). Kluwer Academic Publishers, Dordrecht, pp. 193–213 (Geol. Mijnb. 75, Spec. Iss.).

Harris, A.J., Tocher, B.A., 2003. Palaeoenvironmental analysis of Late Cretaceous dinoflagellate cyst assemblage using high-resolution sample correlation from the Western Interior Basin, USA. Mar. Micropaleontol. 48, 127–148.

Lebedeva, N.K., 2001. Genus *Chatangiella* (dinoflagellate cysts): stratigraphic significance and geographic distribution. News of Paleontology and Stratigraphy 4, 125–133; Suppl. to journal Geol. Geofiz. 42 (in Russian).

Lebedeva, N.K., 2006. Dinocyst biostratigraphy of the Upper Cretaceous of Northern Siberia. Paleontol. J. 40, 604–621.

Lebedeva, N.K., 2008. Biofacies analysis of Upper Cretaceous deposits in the Ust-Yenisei region: implications of palynomorphs. Stratigr. Geol. Correl. 16 (2), 182–197.

Lebedeva, N.K., Nikitenko, B.L., 1999. Dinoflagellate cysts and microforaminifera of the Lower Cretaceous Yatria River section, Subarctic Ural, NW Siberia (Russia). Palaeogeographic and paleoenvironmental discussion. Grana 38, 134–143.

Lebedeva, N.K., Zverev, K.V., 2003. Sedimentological and palynological analysis of the Cenomanian–Turonian event in Northern Siberia. Rus. Geol. Geophys. 44 (8), 769–780.

May, F.E., 1980. Dinoflagellate cysts of the Gymnodiniaceae, Peridiniaceae and Gonyaulacaceae from the Upper Cretaceous Monmouth Group, Atlantic Highland, New Jersey. Palaeontographica B 172, 10–116.

Nikitenko, B.L., Pestchevitskaya, E.B., Lebedeva, N.K., Ilyina, V.I., 2008. Micropaleontological and palynological analyses across the Jurassic–Cretaceous boundary on Nordvik Peninsula, Northeast Siberia. Newslett. Stratigr. 42, 181–222.

Sahagian, D., Pinous, O.V., Olferiev, A.G., Zakharov, V.A., 1996. Eustatic curve for the Middle Jurassic–Cretaceous based on Russian Platform and Siberian stratigraphy: zonal resolution. AAPG Bull. 80, 1433–1458.

Schiøler, P., Brinkhuis, H., Roncaglia, L., Wilson, G.J., 1997. Dinoflagellate biostratigraphy and sequence stratigraphy of the type Maastrichtian (Upper Cretaceous), ENCI Quarry, the Netherlands. Mar. Micropaleontol. 31, 65–95.

Tocher, B.A., Jarvis, I., 1987. Dinoflagellate cysts and stratigraphy of the Turonian (Upper Cretaceous) Chalk near Beer, Southeast Devon, England, in: Hart, M.B. (Ed.), Micropaleontology of Carbonate Environments. Ellis Horwood Ltd, pp. 138–175.

Zakharov, V.A., Beizel, A.L., Lebedeva, N.K., Khomentovsky, O.V., 1991. Evidence for eustatic fluctuations of the ocean in Northern Siberia during the Late Cretaceous. Geol. Geofiz. 8, 9–14.

Zakharov, V.A., Lebedeva, N.K., Marinov, V.A., 2003. Biotic and abiotic events in the Arctic biogeographic region during the Late Cretaceous. Rus. Geol. Geophys. 44, 1093–1103.

Pakistan paleoclimate under greenhouse conditions; Closure of Tethys from Pakistan; Geobiological evolution of South Asia (Indo-Pak subcontinent)

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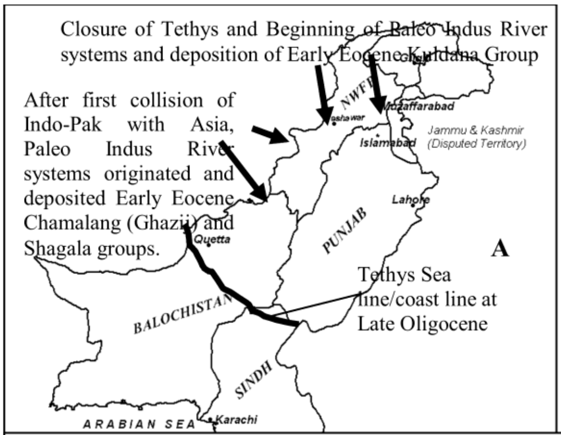
Pakistan paleoclimate under greenhouse conditions

Warm (greenhouse) climatic conditions prevailed in Pakistan. Warm climates were dominant here during the Paleozoic except the Early Permian, when Tobra/Talchir beds were deposited. These beds show cold (icehouse) climate/glaciations (tillites-cemented angular to sub angular pebbles, cobbles and boulders with faceted, smoothed, polished, striated and pitted rock fragments) in the Eastern Salt Range and Potwar (upper Indus) Basin. In the Mesozoic and Paleogene deposits of Pakistan, there are no evidences for icehouse climate, while the Pleistocene and Holocene in Kohistan-Ladakh, Hindukush-Karakoram and northern extremity of Azad Kashmir show glacial deposits, like tillites and moraines (cemented and stratified), and tills (nonsorted and non stratified), and fluvioglacial deposits. So far only two icehouse records have been found in Pakistan: Early Permian glaciations in eastern Salt Range, and Quaternary glaciations in northern areas of Pakistan.

Closure of Tethys from Pakistan

The Indo-Pak subcontinental plate first collided with Afghan block (close to Zhob-Waziristan) of Asia at the latest Cretaceous (70–67 Ma) and also docked with Kohistan-Ladakh Tethyan belt. The latest Cretaceous collision is responsible for the birth of Kohistan-Ladakh magmatic arc. The magmatism ended in Kohistan-Ladakh arc but it is continuing in Chagai magmatic arc. Curves of sea-level fluctuations in the Tethyan Sulaiman (Middle Indus) and Kohat-Potwar basins show considerable drop at the latest Cretaceous. During the Early Paleocene, the sea transgressed these areas. During the Late Paleocene, the sea regressed from the western Sulaiman, northern Balochistan, upper and uppermost Indus basins due to further uplift and continued collision of subcontinent. This first collision is responsible for the birth of Paleo Indus River systems which generally flow from north to south and from northwest to southeast, as well as for the birth of Paleo Ganges and Paleo Brahmaputra rivers systems which generally flow from west to east. As a result of the collision, the northwestern margin of Indo-Pak became elevated in the latest Cretaceous, creating terrestrial environments for the deposition of the Vitakri and Indus formations. The Vitakri Formation (red overbank muds and meandering sandstones) accumulated in the lower and middle Indus basins while the Indus Formation (bauxites and laterites) accumulated in the upper and uppermost Indus basins. During the Early Eocene, the suture and surrounding areas were uplifted enough to originate the Paleo Indus River systems supplying detritials/clasts from northwest and north. Major streams generally flow from northwest to southeast in Sulaiman (middle Indus) and from north to south in the Khyber-Hazara-Kashmir (uppermost Indus) and Kohat-Potwar (upper Indus) basins. During the Late Eocene, the sea further regressed from the uppermost, upper and middle Indus basins of Pakistan and was permanently closed.

The Early Eocene deposits of Paleo Indus River system are represented by Shaheed Ghat/Murgha Faqirzai shale (distal delta, mainly shale with some sand lenses), Toi/Mina (green shale and sandstone) and Kingri/Shagala (red shale and sandstone) formations of Chamalang (Ghazij)/Shagala groups in the Sulaiman/Balochistan basins, and by Chorgali (green shale, limestone and dolomite) and Kuldana (red and green muds, limestone and dolomite, and sandstone) formations of Kuldana Group in the upper and uppermost Indus basins. Further in the east (in India) the vertebrate-bearing Subathu Formation (Sahni et al., 1983) was deposited under the Paleo Indus River systems. The Kingri Formation (sandstone alternated with red and maroon muds) in Sulaiman, the Shagala Formation (sandstone alternated with red and



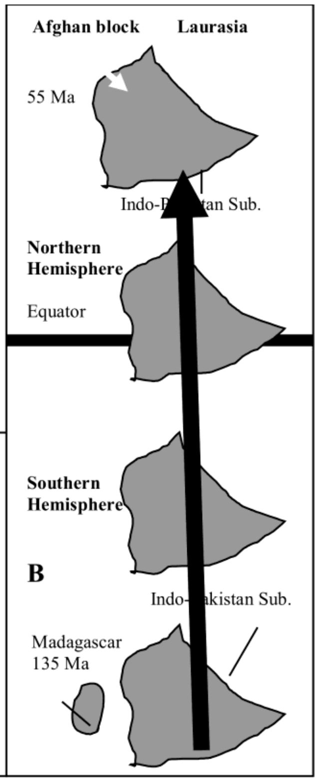


Fig. 1. (**A**) Early Eocene closure of Tethys, origin of Paleo Indus River systems and deposition of Shagala molase in Balochistan basin, Chamalang (Ghazij) group molase in Sulaiman and Waziristan-Parachinar regions, and Kuldana Group molase in Upper and uppermost Indus basins; start of Neotethys closure from Pakistan and adjoining Afghanistan. (**B**) Paleo-Vitakri River systems flow from southeast to northwest and east to west (Indo-Pak shield to Tethys); and Paleo-Indus River systems flow from northwest to southeast and north to south. White arrow shows direction of continental clastic movements and river systems. Large black arrow shows migration of Indo-Pak subcontinent.

maroon muds; fossils of land baluchithere *Pakitherium*) in the northern Balochistan Basin, and the Kuldana Formation in the upper and uppermost Indus basins are the result of terrestrial deposition. After their deposition a sea transgression occurred, and some other strata were deposited: the marine Drug and evaporitic Baska, marine Middle Eocene Kahan Group (Habib Rahi marl and limestone, Domanda shale, Pirkoh marl and limestone, and Drazinda shale) in Sulaiman; the upper Kuldana in the Kohat-Potwar and Khyber-Hazara-Kashmir basins; and the Mina/Panjgur Formation in southern Balochistan basin.

However, after the early Middle Eocene the Potwar and Khyber-Hazara-Kashmir basins uplifted, showing permanent closure of Tethys from the Potwar and uppermost Indus basins. This was the start of closure of Tethys from Pakistan.

At the Late Eocene, a major and hard collision of Indo-Pak subcontinent with Asia occurred. As a result, the Tethys retreated further to the south, just close to the northern margin of Kirthar/lower Indus Basin (Fig. 1).

The Oligocene shows no depositions in the Khyber-Hazara-Kashmir while the terrestrial Chitarwata Formation was deposited in the middle Indus, and the marine Nari and Gaj formations were deposited in the lower Indus Basin. The Tethys regressed permanently from the lower Indus Basin at the Oligocene–Miocene boundary. The Tethys further retreated backward to the south at the beginning of the Miocene, and consequently the Manchar Group (lower Indus Basin), the Vihowa, Litra and Chaudhwan formations of the Vihowa Group (northern Balochistan and middle Indus basins), the Murree Formation and Potwar Group (upper and uppermost Indus basins) and the Siwalik Group in India were deposited.

During the Pleistocene–Holocene, the sea further retreated to the south. In Balochistan, the Oligocene–Pliocene Talar (=Vihowa) Group (Parkini mudstone, Talar sandstone, and Chatti mudstone) were deposited in southern Makran Basin. The Sakhi Sarwar Group (conglomerate of the Dada Formation, and sandstone, mudstone and conglomerate of the Sakhi Sarwar Formation) in northern Balochistan, and lower and middle Indus basins as well as the Soan Group in the upper Indus Basin and the Kech/Kamerod/Bostan in Balochistan Basin were deposited by high energy fluvial processes. Fluvial systems represent much folding, faulting and uplifting of Himalayas, Karakoram, Hindukush and advancing part of Indo-Pak plate.

Geobiological evolution of South Asia (Indo-Pak subcontinent)

The geobiological evolution of Indo-Pak is significant due to its present regional contact with Asia but with Gondwana in the past. India was the only source of information on dinosaurs until 2000. In 2000 Pakistan appeared for the first time in the world dinosaur map. A few fossils of the Late Jurassic titanosaurian sauropod (*Brohisaurus kirthari*) and Late Cretaceous mesoeucrocodile/mesocrocodile (*Khuzdarcroco zahri*) were found in the lower Indus (Kirthar) Basin. In upper Indus (Kohat and Potwar) basins, trackways of a herd of wide-gauge titanosaurian sauropods (*Malakhelisaurus mianwali*) confronted by a running narrow-gauge theropod (*Samanadrinda surghari*) were recorded in the Middle Jurassic Samanasuk Limestone. In the middle Indus (Sulaiman) Basin, about 3000 fossils were collected from more than 30 localities in the latest Cretaceous Vitakri Formation (fluvial succession; two red mud horizons alternated with two sandstone horizons). These fossils include titanosaurian sauropods, abelisaurian and noasaurian theropods, mesoeucrocodiles, and pterosaurs (see Malkani in the present book of short papers). The trackways of titanosaurian sauropod dinosaurs are found on the thick sandstone bed of the Vitakri Formation in Sor Muzghai locality, Qila Saif Ullah District, Balochistan, and this discovery is the first in Asia.

The Mesozoic vertebrates show relatively close affinity to those of Gondwana than Laurasia while the Cenozoic vertebrates show Eurasian affinity and migrated from Indo-Pak to Eurasia or vice versa via Paleo Indus River systems along western and northern Indus Suture, after the terminal Cretaceous collision of Indo-Pak subcontinent with Asia.

Indo-Pakistan separated from Madagascar at the Jurassic–Cretaceous boundary time and started northward journey at the earliest Cretaceous (135 Ma). It migrated rapidly, covering more than 5000 km in about 60 Ma. Its northwestern corner for the first time collided with Afghan block of Tethys and Asia at the latest Cretaceous (about 70–67 Ma). This corner acted as a pivot point for counterclockwise rotation. Just after this collision the northern extremity of Indo-Pak docked with Kohistan-Ladakh Tethyan belt. The main geoevents occurred at the Pliocene–Pleistocene boundary time and resulted in further retreat of sea from the Kirthar (lower/southern Indus) basin as the terrestrial Vihowa/Manchar Group was deposited. The last major episode occurred at the terminal Pleistocene resulting in further retreat of sea in the south, folding and faulting. The northward movements of Indo-Pak plate are continuing so far. This orogeny is responsible for creating highest peaks and present morphology. Neotethys is remained in the east, south and mostly in the west and is named now as Indian Ocean, and the subcontinent is named as South Asia (Indo-Pak peninsula).

Reference

Sahni, A., Bhatia, S.B. Kumar, K., 1983. Faunal evidence for the withdrawal of the Tethys in the Lesser Himalaya, Northwestern India. B. Soc. Paleontol. Ital. 22 (1–2), 77–86.

Assessing effects of Deccan volcanism on biota and environments of non-marine Maastrichtian–Palaeogene sediments of Central India

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Link between Deccan Large Igneous Province (DLIP) and mass extinction at the Cretaceous–Palaeogene (K–Pg) boundary is still an ongoing debate in spite that it is a best studied LIP in the world. It is expected that effects of hostilities of Deccan volcanism by gas emissions (Renne et al., 2015) and by lava flows were more pronounced on the environment and biota of India during the Maastrichtian–Palaeogene transition. Chenet et al. (2007, 2008) considered that Deccan flood basalts (DCFB) erupted in three phases: the first phase in C30n at 67.4 Ma, the second/main phase in C29r (200–100 ky before the K–Pg boundary), and the third phase in C29r in the Danian. However, recent studies (Schöbel et al., 2014; Schoene et al., 2014; Renne et al., 2015) show that the second phase lasted much beyond the K–Pg boundary and outpoured over 80% of the total Deccan lava eruptions.

Our investigation focuses on sedimentary beds at different stratigraphic levels in the Deccan volcanic sequence (DVS) of Central Deccan Volcanic Province (CDVP) and Eastern Deccan Volcanic Province (EDVP). The multiple sedimentary layers studied have an adequate stratigraphic constraints provided by a flow-wise mapping on 1:50K scale and volcano-stratigraphy established by Geological Survey of India. The DVS in the geographically separated areas have different sites and centres of magmatic eruptions. In the CDVP and EDVP, few flows are indicated to be chemical analogues of the flows of Western Deccan Volcanic Province (WDVP) but such flows outpoured at different magnetochrons. The sediments associated with the DCFB are deposited in CDVP and EDVP as infratrappean/Lameta Formation before the arrival of the first lava flows that terminated sedimentation or as intertrappean sediments deposited at different stratigraphic levels during pauses in the volcanic eruptions. Sedimentary record of environmental and biotic changes is mainly influenced by the Deccan volcanism. We studied volcano-, palyno-, and magnetostratigraphy in the selected field transects in the EDVP and CDVP. These transects include (i) Chandrapur-Wardha-Amravati-Yavatmal-Nanded in the Sahyadri Group of Deccan Traps targeting sediments at 13 stratigraphic levels within the sequence of 28 basaltic flows between 200 and 498 m RL covering 30 localities, (ii) Chhindwara-Seoni in the Amarkantak Group at 10 stratigraphic levels in the sequence of 31 flows between 530 and 870 m RL in 19 localities, and (iii) Dhar-Bagh in the Malwa Group at 8 stratigraphic levels in the lower 18 flow sequence between 216 and 333 m RL in 14 localities. We also studied the intertrappean beds at different stratigraphic levels in Saurashtra and Kutch.

The Lameta outcrops are found scattered in central and western India as thin narrow discontinuous bands round the borders of the trap country and are covered by earliest lava-flows in the basins. The sediments are not of any great vertical extent in comparison to its wide horizontality. They are deposited (Mohabey, 1996) in different inland basins: (1) Nand-Dongargaon (N-D), (2) Jabalpur, (3) Sagar, (4) Ambikapur-Amarkantak, (5) Balasinor-Jhabua-Bagh (B-J-B), (6) Salburdi, and (7) Adilabad and Ranga Reddy. The timing of the arrival of the first lava flows that terminated the sedimentation and arrival of the last flow is observed to be different in these basins. Litho- and biofacies analysis shows that sediments are pedogenically modified and are deposited in alluvial-limnic environments under semiarid climate.

The sediments in different basins are time transgressive, they were deposited during the magnetochrons C30n to C29r of the Maastrichtian (Hansen et al., 2005; Mohabey and Samant, 2013). The B-J-B Basin sediments were deposited during C30n, whereas the sediments of N-D and Jabalpur basins were deposited during C30n–C29r. The sediments are rich in fossils of vertebrates, including non-avian titanosaurid-abelisaurid dinosaurs, bothremydid turtles, *Simosuchus* crocodiles, madtsoid snakes, frogs, and fishes; invertebrates, like molluscs and ostracods; pteridophyte-angiosperm dominated flora (Huene and Matley, 1933; Mohabey, 1984; Wilson et al., 2010; Samant and Mohabey, 2014). The intertrapean sedimentary beds between the lava flows are mainly deposits of ponds and lakes that developed over the fresh lava surface. Reports of marine or near-marine sediments are rare. The intertrappean sediments also yield diversified fauna comprising titanosaurs, turtles, lizards, crocodiles, frogs, fishes, micromammals, ostrocods, and molluscs; megaflora is dominated by gymnosperms and angiosperms.

The study shows that the appearance of angiosperms and non-avian dinosaurs in India was coeval and took place in the Maastrichtian chron C30n. Dinosaurs appeared about 550 ky before the K–Pg boundary and disappeared completely about 350 ky before the K–Pg boundary. The decline in the diversity and abundance of dinosaurs is commensurate with beginning of volcanic eruptions in the province. It is also observed that eruption of the first Deccan volcanic flows markedly changed the existing floral composition, from a flora dominated by pteridophytes and angiosperms to a flora dominated by gymnosperms and angiosperms; this event appears to be close to the chrons C30n–C29r in the Maastrichtian. Presence of Palaeocene palynoflora in sediments associated with flows, with normal magnetic polarity interpreted as C30n is recorded in the Sahyadri Group of Yavatmal and Amarkantak Group of Chhindwara area. We conclude that the Deccan volcanism in the CDVP and EDVP was initiated in C30n of the Maastrichtian and lasted with an extended duration at least till C28n in the Palaeocene.

References

Chenet, A.L., Quidelleur, X., Fluteau, F., Courtillot, V., Bajpai, S., 2007. ^{40}K–^{40}Ar dating of the main Deccan large igneous province: further evidence of KTB age and short duration. Earth Planet. Sci. Lett. 263, 1–15.

Chenet, A.L., Fluteau, F., Courtillot, V., Gerard, M., Subbarao, K.V., 2008. Determination of rapid Deccan eruptions across the KTB using paleomagnetic secular variation: results from a 1200-m-thick section in the Mahabaleshwar escarpment. J. Geophys. Res. 113, B04101.

Hansen, H.J., Mohabey, D.M., Lojen, S., Toft, P., Sarkar, A., 2005. Orbital cycles and stable carbon isotopes of sediments associated with Deccan volcanic suite, India: Implications for the stratigraphic correlation and Cretaceous/Tertiary boundary. Gondwana Geol. Mag. Spec. Vol. 8, 5–28.

Huene, F.B. von, Matley, C.A., 1933. The Cretaceous Saurischia and Ornithischia of the central provinces of India. Mem. Geol. Surv. India: Palaeontol. Indica 21, 1–24.

Mohabey, D.M., 1984. Study of dinosaurian eggs from Infratrappean Limestone in Kheda District, Gujarat. J. Geol. Soc. India 25(6), 329–337.

Mohabey, D.M., 1996. Depositional environment of Lameta Formation (Late Cretaceous) of Nand-Dongargaon inland basin, Maharashtra: the fossil and lithological evidences. Mem. Geol. Soc. India 37, 363–386.

Mohabey, D.M., Samant, B., 2013. Deccan continental flood basalt eruption terminated Indian dinosaurs before the Cretaceous–Paleogene boundary. Geol. Soc. India Spec. Publ. 1, 260–267.

Renne, P.R., Sprain, C.J., Richards, M.A., Self, S., Vanderkluysen, L., Pande, K., 2015. State shift in Deccan volcanism at the Cretaceous–Paleogene boundary, possibly induced by impact. Science 350(6256), 76–78.

Samant, B., Mohabey, D.M., 2014. Deccan volcanic eruptions and their impact on flora: palynological evidence. Geol. Soc. Am., Spec. Pap. 505, 171–191.

Schöbel, S., de Wall, H., Ganerød, M., Pandit, M.K., Rolf, Ch., 2014. Magnetostratigraphy and ^{40}Ar–^{39}Ar geochronology of the Malwa Plateau region (Northern Deccan Traps), central western India: Significance and correlation with the main Deccan Large Igneous Province sequences. J. Asian Earth Sci. 89, 28–45.

Schoene, B., Samperton, K.M., Eddy, M.P., Keller G., Adatte, T., Bowring, S.A., Khadri, S.F.R., Gertsch, B., 2014. U-Pb geochronology of the Deccan Traps and relation to the end-Cretaceous mass extinction. Science 347(6218), 182–184.

Wilson, J.A., Mohabey, D.M., Peters, S.E., Head, J.J., 2010. Predation upon hatchling dinosaurs by a new snake from the Late Cretaceous of India. PLoS Bio. 8(3), 1–10.

Environmental changes in Early Cretaceous palaeobasin of Western Siberia based on marine and terrestrial palynomorphs

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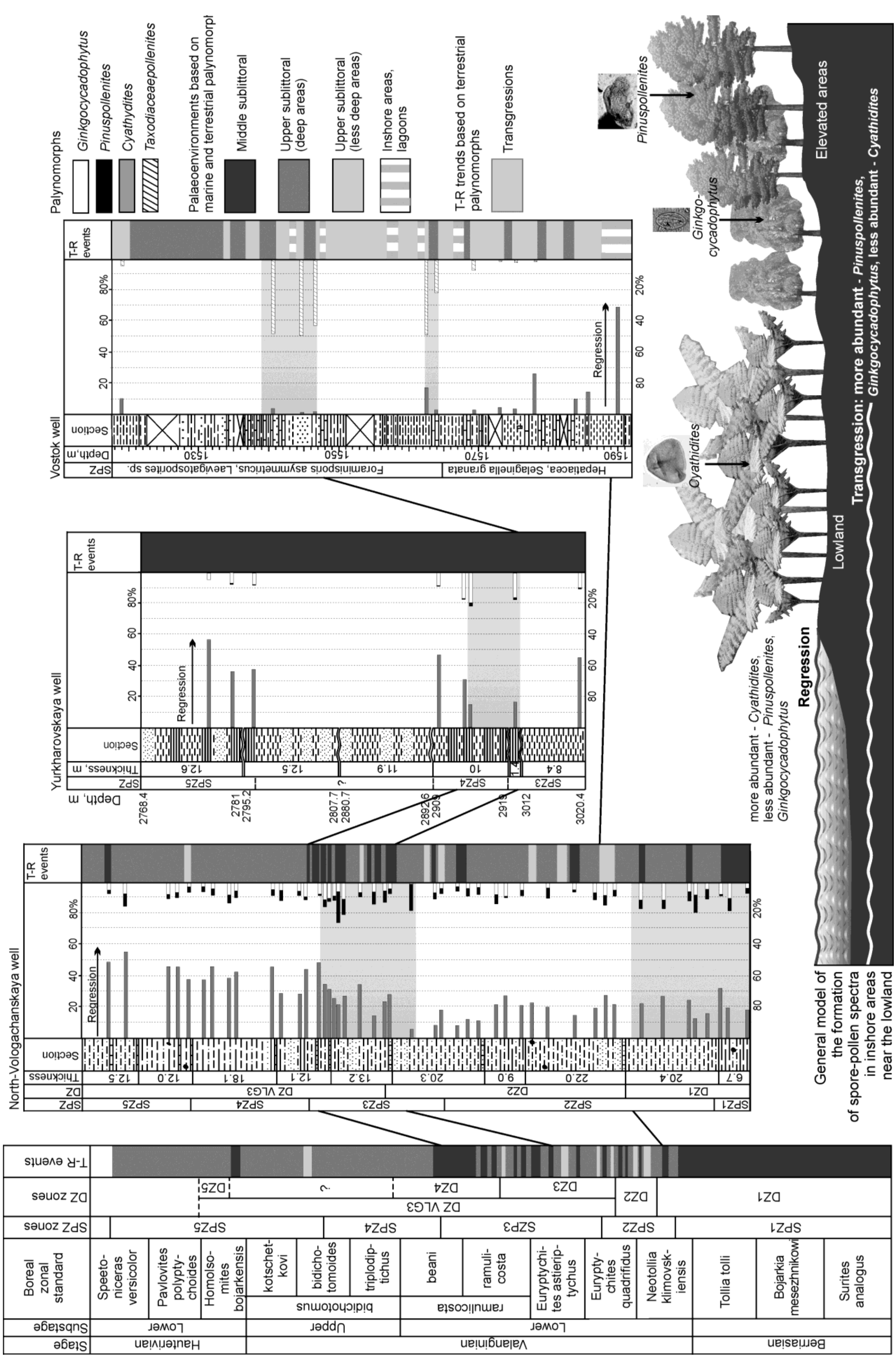
Detailed biostratigraphic scales on dinoflagellates, spores and pollen of terrestrial plants are developed for the Lower Cretaceous of Western Siberia based on the investigations of well materials and stratotype sections of Khatanga depression (Fig. 1). Palynological successions are calibrated against the Boreal zonal standard. Key taxa allow the interregional correlations on several stratigraphic levels (Pestchevitskaya 2007a, 2007b, 2010).

These palynological stratigraphic scales serve as a basis for a detailed study of facial changes and dynamics of the West Siberian palaeobasin. Taking into account the results of quantitative analysis of microphytoplankton distribution in different sections, transgressive-regressive (T-R) trends of low-level are revealed (Fig. 1). It should be note, that a complete coincidence of T–R sequences in different sections is impossible, as it is impossible to take samples exactly at the same stratigraphic levels. Nevertheless, some general regularities can be discussed. Against the background of general regression trend from the Berriasian to the Hauterivian, several minor T–R events can be determined including more pronounced regression in the middle part of the dinocyst zone DZ 2 in the lower part of the Lower Valanginian and more pronounced transgression in the upper part of the dinocyst zone DZ 3 in the middle part of the Lower Valanginian. In some cases, this sequence of T–R event allows more accurate and reliable correlation of Siberian sections. It is especially important for the southern regions of Western Siberia, where palynological assemblages often lack main key taxa, which are significant correlative markers in north Siberian biostratigraphic successions (Pestchevitskaya et al., 2012).

The T–R sequences in several sections are supported by data on micro- and macrofauna (Nikitenko et al., 2008; Pestcheviskaya et al., 2009). There are two patterns: 1) palynological successions from the sections located relatively close to the palaeo coastline are characterised by increasing microphytoplankton percentage during the transgressions (Fig. 1); 2) palynological successions of offshore marine areas follow the reverse trend, when microphytoplankton percentage increases during the regressions. It can be related to the distribution of nutrients and some other factors influencing microphytoplankton development. In recent marine basins, microphytoplankton concentrates in stable marine environments with intensive mixing of water and a high content of biogenic components. These are often quite deep areas of neritic zone. Apparently, in the Early Cretaceous, such conditions occurred in coastal areas during the transgressions of West Siberian palaeobasin, and in inland areas during the regressions. Note, that T–R events are more evident in in-shore areas, and less clear in central ones, sometimes showing no indications. In this case, additional information can be obtained from quantitative analysis of the distribution of palaeoecological groups of terrestrial palynomorphs (Fig. 1).

Spores and pollen of terrestrial plants arrived within the palaeobasin mainly from coastal areas, so the composition of spore-pollen associations is not directly related to the T–R events. However, the composition of spore-pollen associations indirectly reflects the changes in sedimentation features depending on the composition of coastal vegetation and palaeolandscapes, which are largely changed due to palaeobasin dynamics. It allows the definition of

Fig. 1. Distribution of some terrestrial palynomorphs reflecting T–R trends of Western Siberian palaeobasin (areas with sediment supply from the lowland).


Palynomorphs
Ginkgocycadophytus
Pinuspollenites
Cyathydites
Taxodiaceaepollenites
Palaeoenvironments based on marine and terrestrial palynomorphs
Middle sublittoral
Upper sublittoral (deep areas)
Upper sublittoral (less deep areas)
Inshore areas, lagoons
T-R trends based on terrestrial palynomorphs
Transgressions
Vostok well
Yurkharovskaya well
North-Vologachanskaya well
Regression
Lowland
Elevated areas
Transgression: more abundant - Pinuspollenites, Ginkgocycadophytus, less abundant - Cyathidites
more abundant - Cyathidites, less abundant - Pinuspollenites, Ginkgocycadophytus
General model of the formation of spore-pollen spectra in inshore areas near the lowland
Stage
Substage
Boreal zonal standard
SPZ zones
DZ zones
T-R events
Berriasian
Valanginian
Hauterivian
Lower
Upper
Depth, m
Thickness, m
Section

T–R trends based on quantitative ratio of spores and pollen of hydrophilous and drought-tolerant plants. In the Early Cretaceous of Siberia, hydrophilous plants included various ferns, mosses, lycopsids and some gymnosperms producing the pollen of *Alisporites* and *Piceapollenites* types and some other morphotypes. Drought-tolerant plants in northern regions were mostly represented by ginkgophytes and ancient conifers producing the pollen of *Pinuspollenites* type, while in southern regions, this group of plants was mainly represented by *taxodialeans*. Two trends are revealed: 1) for palaeobasin areas, where spores and pollen of terrestrial plants arrived from the lowland; 2) for areas with a supply of terrestrial palynomorphs from the elevated areas. The first trend is characterised by a decreasing percentage of spores and pollen of hydrophilous plants and increasing quantity of drought-tolerant plants during the transgression. The second trend is characterised by a reverse pattern. Interestingly, T–R trends determined on terrestrial palynomorphs can be identify not only in coastal areas, but also in the central regions of West Siberian palaeobasin, where microphytoplankton data are sometimes uninformative for the reconstruction of detailed T–R sequences.

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References

Nikitenko, B.L., Pestchevitskaya, E.B., Lebedeva, N.K., Ilyina, V.I., 2008. Micropalaeontological and palynological analyses across the Jurassic–Cretaceous boundary on Nordvik Peninsula, Northeast Siberia. Newslett. Stratigr. 42(3), 181–222.

Pestchevitskaya, E.B., 2007a. Lower Cretaceous biostratigraphy of Northern Siberia: Palynological units and their correlation significance. Russ. Geol. Geophys. 48, 941–959.

Pestchevitskaya, E.B., 2007b. Dinocyst biostratigraphy of the Lower Cretaceous in North Siberia. Stratigr. Geol. Correl. 15(6), 577–609.

Pestchevitskaya, E.B., 2010. Dinocysts and palynostratigraphy of the Siberian Lower Cretaceous. Geo, Novosibirsk (in Russian).

Pestchevitskaya, E.B., Urman, O.S., Shurygin, B.N., 2009. Early Valanginian associations of fauna and palynomorphs from eastern margin of Western Siberian basin: Biostratigraphic and palaeoecological aspects, in: Paleontology and improvement of stratigraphic basis of geological mapping: Proceedings of LV session of the Paleontological Society of RAS. St. Petersburg, pp. 105–107 (in Russian).

Pestchevitskaya, E.B., Smokotina, I.V., Baykalova, G.E., 2012. Lower Valanginian palynostratigraphy of southeastern regions of Siberia, palaeoenvironment and vegetation reconstructions. J. Stratigr. 36(2), 179–193.

Palaeoenvironmental changes in the Early Cretaceous of Gydan region (NW Siberia)

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The paper presents the results of a comprehensive study of the Lower Cretaceous section in several boreholes from the west of Gydan Peninsula, which is an area the least explored by drilling within Western Siberia. The study is based on sedimentological and palynological analyses and interpretation of well-log data. Some lithofacies corresponding to certain sedimentation environments as well as typical trends in the changes of lithofacies sequences, fixing sedimentation cycles of different scales, are determined.

The lower part of the Cretaceous section consists of the Akhskaya Formation built on flat-lying clinoforms. Thin pack (20–40 m) of Berriasian–Valanginian condensed deposits and mostly clayer Hauterivian sediments (up to 250 m) lies at its base. Taking into consideration the lateral position of these sediments in clinoform structure, we can conclude that they were formed at the foot or in the slope of "sedimentary" shelf. The base of the Hauterivian is studied in the core material from one of the boreholes. It is represented by black and brownish mudstone interbedded with rare clayey siltstone. The rock is massive, with thin vague horizontal lamination and rare pyrite impregnations. There is a level with trace fossils *Phycosiphon*. According to lithological data, the formation of these deposits mainly occurred in the calm hydrodynamic environments, and silt only occasionally supplied from shallow water areas. Palynological data evidence the middle part of neritic zone: palynological assemblages are dominated by marine palynomorphs with abundant dinocysts, mostly represented by the families Gonyaulacaceae and Areoligeraceae.

The upper part of the Akhskaya Formation is composed of alternating silty claystone and silty sandstone (beds BG12, BG19, few meters up to 40 m) of mostly progradation structure. Core material is represented by light gray fine-grained sandstone and siltstone, often irregular interbedded with mudstone characterising by undulating and lenticular textures sometimes disturbed by deformation. The typical feature is the frequent active bioturbation. Carbonised plant detritus rare occurs in core material. The formation of these deposits occurred in the facies of periodic offshore progradation of coastal sedimentary systems resulted in continuous change from low-energy environments of moderately deep shelf to shallow shelf.

Palynological data show shallow water neritic zone. Palynological assemblages are constantly dominated by spores and pollen of terrestrial plants. Microphytoplankton is not abundant (5–20%) and mainly represented by prasinophytes Leiosphaeridia. There is a regressive trend upward in the section resulting in an overall reduction of microphytoplankton, especially dinocysts represented here by taxa capable of surviving in coastal environment. These are mainly gonyaulacoid simple morphotypes of the group *Escharisphaeridia–Sentusidinium* and areoligerceous dinocysts (*Circulodinium*). Slight increases in the percentage and diversity of dinocysts indicate periodic short-term transgressions.

The composition of terrestrial palynomorphs shows that terrigenous material derived from continental areas mainly occupied by coniferous forests with an admixture of ginkgoaleans growing in rather wet and warm-temperate climate. Spore-pollen assemblages contain considerable percentages of poorly preserved saccate pollen of ancient coniferous plants (5–24%) and *Alisporites–Pseudopicea* group (2–20%), as well as *Piceapollenites* (1–8%) and *Ginkgocycadophytus* (2–7%). The pollen of Taxodiaceae is also revealed (2–5%). Spore-pollen assemblages include many species widespread in Siberia and other Boreal regions: *Protopinus subluteus*, *Pseudopicea magnifica*, *Piceapollenites mesophyticus* and others. Pollen of heirolepidiaceous conifers (*Classopollis*) regarded as an indicator of hot and arid climate, are not permanent component (0–4%) of palynological assemblages. Wet areas near the sea coast and river shores apparently were mostly occupied by cyatheaceous and dipteridaceuos ferns: smooth trilete spores of *Cyathidites–Biretisporites* group are most abundant (12–41%). Its percentage increases in northern and northeastern boreholes, whereas coniferous pollen is more typical for western regions. Heterogeneous composition of the main components of spore-pollen assemblages throughout studied area can be explained by terrigenous material supply from the areas with different vegetation. Probable terrigenous supply from northern or northwestern regions is evidenced by insufficient quantity of gleicheniaceous ferns (2–7%). Its percentage in palynological assemblages of the Hauterivian and Barremian in northeastern regions of Western Siberia is very low, while western regions are characterised by its increased amount.

The Lower Tanopcha Subformation (Upper Hauterivian–lowermost Aptian) is of 433–460 m thick in the studied area. Its base is composed of light grey fine-grained sandstone, silty to varying degrees, formed the beds BG10 (10–18 m) and BG11 (18–29 m) of Late Hauterivian age. Uneven low-angle and cross-undulating lamination is caused by disposal of clayey and carbonaceous material with frequent siderite inclusions. Sandy layers in this part of section were mainly formed in the environments of migrating delta distributaries, and to a less extent in estuarine bars. Silty claystone is characterised by contorted texture and fine bioturbation, it contains small detritus particles and siderite inclusions. The formation of these sediments occurred in the environments of delta plains and prodeltas.

The overlying layers of the Lower Barremian (56–91 m, beds TP24–TP23) are represented by continental sediments mostly formed as the filling of large alluvial channels. Core material mainly consists of light grey fine- and medium-grained sandstone with massive texture and rare low-angle cross lamination due to disposal of plant detritus. The beds of silty claystone are less common, and they were apparently formed within alluvial floodplains.

The upper part of the Lower Tanopcha Subformation (beds TP15–TP22, the Upper Barremian–Lower Aptian) is composed of fine-grained and sometimes silty sandstone. Predominant textures are massive and cross-bedded with rare current ripples, flaser and horizontal lamination. The typical feature is plant detritus with frequent siderite inclusions. There are some levels with clayey and rarer carbonaceous intraclasts as well as contorted texture and trace fossils *Skolithos* and *Ophiomorpha*. The layers of silty claystone separated sandy beds are often carbonaceous, they contain rather abundant root plants and plant imprints of medium and well preservation. The areas of thin intercalation of siltstone and claystone exhibit contortion and rarer local erosion, and deformation under gravity loading. Siderite inclusions are common here. The formation of the sediments from this part of the section mainly occurred in the environments of delta complex. Sandstone was accumulated in fluvial deltaic arms, and siltstone and claystone were deposited in delta plains often undergone waterlogging.

The Upper Tanopcha Subformation (509–556 m, Aptian) is represented by irregular alternation of sandstone and siltstone (beds TP1–TP14, up to 102 m thick) with silty claystone and rare thin layers and lenses of coal. Core material mainly consists of fine- and medium-grained sandstones and rarer siltstone. Textures are massive and cross-bedded due to accumulation of small and large particles of plant detritus sometimes containing siderite inclusions. Well-preserved plant fossils and several layers with clayey and carbonaceous intraclasts are revealed. The layers separated sandy beds are mostly composed of intercalation of clayey siltstone, claystone and clay. The typical features are plant detritus, siderite concretions, root plants and carbon-bearing inclusions. These sediments were formed within large alluvial plain with meandering rivers. The upper part of the Upper Tanopcha Subformation (beds TA1–TP2-3 and separating layers) was accumulated in deltas and coastal marine environments. Their typical features are progradation character of sedimentary sequences, undulating lamination of silty and clayey layers including glauconite, fragments of bivalve shells, and rare root plants.

Brackish or continental environments in the Barremian and Aptian are confirmed by palynological data. Palynological assemblages contain low percentage of microphytoplankton mostly represented by prasinophytes (Leiosphaeridia). Small-scale transgressive events in the middle of the Barremian and in some levels of the Aptian are indicated by dinocysts. The spore-pollen data evidence gradual change of land vegetation on the areas of sediment source, that was caused by both evolutionary processes and changes in palaeoenvironments. The quantity of taxodiaceous pollen increases from the Barremian to the Aptian characterised by appearance of first angiosperms. Later, these palynomorphs gradually become the main components in the Late Cretaceous plant communities. At the same time, increased abundance and diversity of schizaeaceous ferns in the Barremian could have been related to the development of the river network and occurrences of wet, but drained areas with sufficient light input along river shores. Gradually increased abundance of sphagnaceous mosses in the uppermost Barremian and Aptian may have been due to expansion of wetlands.

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Palynological study of intertrappean sediments in the central and eastern parts of Deccan volcanic province of India to understand age and depositional environment

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The Deccan volcanic eruptions covering an area of about 500.000 km^2 with eruptive volume of 1.3x10^6 km^3 in western, central and southern part of India in the Late Cretaceous–Early Paleocene are one of the largest volcanic eruptions in the Earth's history. Whether volcanism or Chicxulub impact caused global mass extinction at the Cretaceous–Paleogene (K–Pg) boundary is still a matter of debate. However, recent studies suggest that both volcanism and impact played important role in global environmental deterioration (Schoene et al., 2014; Renne et al., 2015) in the Late Cretaceous–Early Paleocene. If volcanism can cause global environmental changes, then its impact on Indian subcontinent is expected to be pronounced due to its proximity to source of eruption. We conducted palynological study of the intertrappean sediments in the adjoining eastern and southern parts of Deccan volcanic province in the Yavatmal and Chandrapur districts of Maharashtra and the Rangareddy District of Telangana. The findings are significant as the palynological information on the intertrappean sediments from the present study area is either absent or meager in comparison to the information on mega- and microflora bearing intertrappean localities to the northeastern part of the Deccan volcanic province (DVP).

Flows in the Deccan volcanic province are divided into four groups, namely Mandla and Malwa groups to the north of Narmada River, Satpura Group to the south of Narmada River up to Tapti River, and Sahyadri Group to the south of Tapti River in the central and southern part of DVP. The volcanic flows in the northwestern part are still unclassified (Nair and Bhusari, 1991). The intertrappean sediments are mostly found in the fringe areas of the Deccan volcanic sequence. The study of biota associated with intertrappean sediments is important to know age, correlation and assessing impact of volcanism in space and time.

Intertrappean deposits of the Chandrapur and Yavatmal districts occur in the lowermost Ajanta Formation of Sahyadri Group, and intertrappean sediments of Naskal and Rangpur in Rangareddy District occur between the lower flows of the Deccan volcanic sequence (DVS) in the area. Eight intertrappean beds including six beds in Yavatmal and Chandrapur districts (Shibla, Shankar lodi, Bari, Mauda, Maria patnam and Lendi gauda beds) and two beds in Rangareddy District (Naskal and Rangpur beds) were palynologically investigated. Out of these, six intertrappean localities yielded palynoassemblage.

Palynoflora of Chandrapur–Yavatmal localities show presence of pollen grains of pteridophytes, gymnosperms, angiosperms, and fungal spores. Pollen grains of *Proxapertites operculatus*, *Gabonisporis vigourouxii* and *Sparaganiaceaepollenites* sp. are the dominating taxa. *Incrotonipollis neyvelii* and *Lygodiumsporites* also form significant member of these intertrappeans. The presence of palynotaxa such as *Aquilapollenites bengalensis*, *Gabonisporis vigourouxii*, *Sparganiaceaepollenites*, *Jiangsupollis* and *Azolla cretacea* suggests Maastrichtian age for these intertrappean. One intertrappean near village Shibla is rich in megaflora, especially fossil woods of palms. Megaflora such as roots of the family Cyperaceae, woods *Ailanthoxylon indicum* of the family Simaroubaceae and seeds *Indovitis chitaleyae* of the family Vitaceae have been recorded from this intertrappean. The palynoassemblage of Rangpur intertrappean shows dominance of *Sparganiaceaepollenite*s sp. and *Mulleripollis bolpurensis*. Significantly, *Proxapertites operculatus* form dominant taxa of Chandrapur–Yavatmal intertrappean beds. Zetter et al. (2001) consider that pollen grains of *Proxapertites* shows possible affinity with Araceae and it could be an herb living in coastal environment along the shores of river channels and lagoons. Singh et al. (2007) recorded pollen grains of *Proxapertites*, *Spinizonocolpites* (*Nypa*) and *Lithopyrophysis* from Naskal intertrappean. Hence, data suggest possibility of existence of estuarine or distant estuarine conditions in this part of DVS.

References

Nair, K.K.K., Bhusari, B., 2001. Stratigraphy of Deccan Traps: A review. Geol. Surv. India Spec. Publ. 64, 477–491.

Renne, P.R., Sprain, C.J., Richards, M.A., Self, S., Vanderkluysen, L., Pande, K., 2015. State shift in Deccan volcanism at the Cretaceous–Paleogene boundary, possibly induced by impact. Science 350(6256), 76–78.

Schoene, B., Samperton, K.M., Eddy, M.P., Keller G., Adatte, T., Bowring, S.A., Khadri, S.F.R., Gertsch, B., 2014. U-Pb geochronology of the Deccan Traps and relation to the end-Cretaceous mass extinction. Science 347(6218), 182–184.

Singh, R.S., Kar, R., Prasad, G.V.R., 2006. Deccan intertrappean beds of Naskal, Rangareddi District, Andhra Pradesh. Curr. Sci. 90, 1281–1285.

Zetter, R., Hesse, M., Frosch-Radivo, A., 2001. Early Eocene zona-aperturate pollen grains of the Proxapertites type with affinity to Araceae. Rev. Palaeobot. Palynol. 117(4), 267–279.

The Cretaceous flora of Mongolia and its paleoenvironment

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Introduction

In Central Asia, Mongolia is one of the countries extremely rich in fossil flora. There are widespread sediments that accumulated here during the most geological stages and are determined by unique combinations of the stages' own plants. The sediments containing Cretaceous plants are mainly restricted to Central and Eastern Mongolia. Non-sufficient number of findings from the lower and middle parts of the Upper Cretaceous has been observed. In summary, more than 30 localities yielding remains of Cretaceous plants were identified in the country. This abstract highlights the key results and brief summary of the research works that focused on flora composition and paleoenvironment in the Cretaceous in Mongolia.

Cretaceous flora

By the Early Cretaceous, paleogeographic landscapes in regions of Mongolian Altai, Khangai, Huvsgul and Khentii were changed, and accumulation of sediments was generally directed from west to east, from southwest to northeast, and to latitudinal direction as it had been predominating in earlier periods. The most important event in the flora is that plants flourished and, moreover, ferns, some of gymnosperms, lycopods were spreading; conifers reached their maximum development. First information about Early Cretaceous plants of Mongolia was originally created as result of Third Expedition into Central Asia by American Museum of Natural History (Cockerell, 1924). Later, the studies have been carried out by Neuburg (1932), Krassilov and Martinson (1982), Jahnichen and Kahlert (1972), Vakhrameev (1988; Vakhrameev et al., 1970), Krassilov and Makulbekov (2003, 2004). Most significant work summarizing Lower Cretaceous paleobotanical studies of Mongolia has been performed by Krassilov (1979, 1985, 2003, 1982). Mongolian paleobotanist Sodov (1980, 1981) and palynologist Ichinnorov (1995, 1999, 2002, 2003, 2004, 2012) were carrying out studies on leafy plants and spore-pollens of Early Cretaceous flora of Mongolia, respectively; and they have participated in the classification of stratigraphic conclusions based on paleoflora of the certain period. Their research works were mainly carried out to place labeled Gurvan-Ereen, Baruun-Erdene Mt., Böön-tsagaan Lake, Kholboot-Gol River, Tsagaantsav, Shine-khudag, and Manlai. According to Vakhrameev (1990), the Lower Cretaceous floras of Mongolia are represented by the following plants: maidenhair trees such as ginkgoaleans *Ginkgoites*, *Baiera*, *Sphenobaiera*, and *Karkenia* (seeds), bennettitaleans such as *Otozamites*, *Neozamites*, *Pterophyllum*, *Nilssoniopteria*, and *Cycadolepis*, conifers such as *Araucaria mongolica*, heyrolepids such as *Brachyphyllum*, and *Podozamits*, and ancient pine trees such as *Pseudolarix*, *Pityophyllum*, *Pityospermum*, and *Schizolepis*.

Cretaceous flora of Mongolia contains the following plants: *Muscites ostracodiferus*, *Lycopodites falcatus*, *Equisetites lateralis*, *Limnothetis gobiensis*, *Limnoniobe insignis*, *Onychopsis psilotoides*, *Karkenia mongolica*, *Cladophlebis denticulate*, *Pterophyllum burjense*, *P. sutchanense*, *P. angulatum*, *Nilssoniopteris denticulata*, *Cycadolepis* sp., *Otozamites lacustris*, *Ginkgoites mongoliensis*, *Ginkgo* sp., *Sphenobaiera ikorfatensis*, *S. altaica*, *Baierella hastate*, *Baiera manchurica*, *Leptostrobis* sp., *Hartzia multifolia*, *Pheonicopsis angustifolia*, *Swedenborgia junior*, *S. longilobia*, *Darneya angusta*, *Araucarites mongolicus*, *Brachyphyllum densiramosum*, *B. sulcatum*, *Pseudolarix erensis*, *P. asiatica*, *Samaropsis aurita*, *S. sagittata*, *Schizolepis drepanoides*, *Willsiostrobus latisaccus*, *Pityanthus microsaccus*, *Gurvanella dictyopers*, *Erenia stenoptera*, *Tuphaera fusiformis*, *Williamsonia whitbiensis*, *Arctopteris* sp., *Naozamites vachrameevii*, *Adiantites kochibeanus*, *Sephalotaxopsis* sp., *Lobifolia ajakensis*, *Araucaria gobiensis*, *Sequoia microlepis*, and *Cedrus* sp. Since the previous studies, the main results of the studies that are conducted with participation of Mongolian scientists nowadays are briefly below.

Mongolian–Russian–Swedish joint research works are carried out on the Baganuur coal mine, Lake Böön-tsagaan, Bakhar Area, Tsagaan-chikh, Zuunbayan and Baruunbayan areas in Central and Southeastern Mongolia (Kodrul et al., 2012), achieving new results. During this study, regional distribution and some issues of stratigraphic boundaries and Cretaceous paleogeography were clarified on the base of newly discovered complex of Lower Cretaceous plants in Central Mongolia (Vakhrameev, 1988, 1991; Vakhrameev et al., 1970). Within frame of the study, the plants which were found in markered sites of Central Mongolia are close to Cretaceous flora that has been found in Siberia; therefore, in terms of paleogeography, the Central Mongolia rather belongs to Siberian-Canadian Belt than to Euro-Sinian Belt. As a result of the studies of spore-pollen assemblages of the Zuunbayan and Baruunbayan formations, it was concluded that studied areas belonged to Amur Province, Siberia-Canadian Belt. It was also stated that warm and dry climate predominated there (Kodrul et al., 2012).

Mongolian–American joint research works. The Shine-khudag markered flora site is located in Southern Mongolia. The paleofloras found at the site were studied by famous Russian scientist V.A. Krassilov for many years, and his data are being the markered studies for Cretaceous plants of Mongolia. However, Mongolian–American cooperating studies started only two years ago. During these studies, most of plant species that had been found and determined by V.A. Krassilov, have been identified. Nonetheless, there is stated number of issues, which need further classification. Now the main part of the expedition's activity focuses on those flora remnants which are contained in coal and studying them in details; this kind of research way is very familiar worldwide, in last time. Also, Mongolian–American joint research team pays attention to investigation of seeds; research works are continuing in the sector.

Mongolian research team. One of the major areas of the expedition's study is brown coal mine site labeled Shivee-Ovoo in Central Mongolia. According to results of spore-pollen study (Ichinnnorov, 1995, 1996, 1999), the coal-bearing sediments are belonged to the Aptian–Albian (Lower Cretaceous). Further studies should include research of megaflora and repeating of spore-pollen studies and should elaborate on the age classification of the coal-bearing sediments. At the moment, a number of remnants of fossil plants, such as *Sphenopteris*, *Onychopsis*, *Phoenicopsis*, *Pityophyllum* and *Ginkgoites*, as well as many kinds of seeds have been found at Shivee-Ovoo, and the plants are considered to be Early Cretaceous. The site has high potential for discovery of a number of interesting fossils in future. In the next stage, the repeating studies will determine classification (based on compounds of the participating plants) of the complexes of coexisted flora that will be recovered from the coal-bearing sediments.

Paleoenvironments

The climate was dry and warm during the earliest Early Cretaceous while the wet climate predominated during the latest Early Cretaceous, causing formation of large caustobiolithic deposits of brown coal and peats. Therefore, the paleobotanic studies have importance to reveal the spatial distribution and timing of Cretaceous coal deposits in Mongolia. In the latest Early Cretaceous, coal-bearing sediments were accumulated in the areas located at Dundgovi, Nyalga, Dornogovi, Tamtsagbulag, Bayantumen, in the Onon-Balj Basin and Central Khalkha uplifted regions.

In general, during the Cretaceous Period, cooler and wet climate was predominating (not too hot); although territory of low mountains and plateaus were enlarged, in same time, valleys, hollows and intermontane troughs filled large territories, too.

Conclusion

It is significantly important to find out new places prospective for studies and to carry out comparative studies of Cretaceous paleoenvironments and plant assemblages composed of similar flora on certain coal-bearing basins or mine sites.

Discontinuous euxinia during the early Aptian oceanic anoxic event (OAE 1a): A case study from the Russian Platform

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The Cretaceous is marked by several episodes of widespread anoxia in the oceans, resulted in black shale deposits known as Oceanic Anoxic Events (OAE) (Schlanger and Jenkyns, 1976). Extremely warm paleotemperatures connected to a global sea-level highstand such as in the early Aptian support the idea of glacio-eustasy even during hot greenhouse phases of Earth climate (e.g., Sames et al., 2016).

Bituminous shales interbedded by concretionary limestones ("Aptian Slab") which accumulated in the shallow epicontinental sea on the Russian Platform are widely interpreted as being a regional manifestation of the global anoxic episode OAE la (Gavrilov et al., 2002; Zorina, 2016; Zakharov et al., 2013).

The studied "Tatar-Shatrashany" borehole section is located on the Russian Platform. During the Early Aptian, this site belonged to the northern-eastern part of the Peri-Tethys, being situated within a sea-strait connecting the Tethys Ocean with the Boreal-Arctic Sea. The Lower Aptian strata reported to correlate with OAE 1a (Gavrilov et al., 2002; Zorina, 2016) include bituminous shales ("Aptian Slab"), 4.2 m in thickness consist of dark brown thin-laminated siltstones and clays (1–5 mm thick) cemented by pyrite. The value of TOC in the bituminous shales from the "Tatar-Shatrashany" section is 7.55%.

Importantly, BF have not been found in the bituminous shales. The bedding surfaces are covered by numerous ammonites from the *Deshayesites volgensis* Zone and embrional ammonite conchs. Upward the section, a level of the light concretionary massive limestone, 0.8 m thick is traced at a distance of more than hundred kilometers (Gavrilov et al., 2002; Zorina, 2016).

The SEM study and microprobe analyzes undertaken at the Institute of Geology and Petroleum Technologies of Kazan Federal University (the Research Analyst B. Galiullin) revealed that the strata corresponding to the OAE1a are represented by two lithological types – bituminous micaceous clayey siltstone and concretionary limestone. The first one includes homogeneous dense flaky aggregate of chlorite and montmorillonite (Fig. 1A) with rare plant debris and pyrite framboids. The energy-dispersive spectrum of the pyrite framboid in the bituminous siltstone shows a high value of carbon (50%). The size of framboid is about 8 μm.

First appearance of foraminifera from the Lower Aptian *Mjatliukaena aptiensis*–*Haplophragmoides aptiensis* Zone is about 10 m below the base of the bituminous shales. The whole complex of this zone is fully restored directly above the bituminous shale and it becomes even more numerous.

Noteworthy, lamination caused by quiet depositional conditions and the lack of bioturbation (Oschmann, 2011) means the termination of the sea currents, sudden appearance of euxinic conditions leading to stratiphying water column and preventing organic matter from dissolution.

Pyrite framboids are raspberry-shaped, spherical aggregates (2–50 μm in diameter) that consist of cubo-octahedron to octahedron, equimorphic microcrystals (0.5–2 μm) (Cavalazzi et al., 2014; Park et al., 2003). Pyrite framboids are very common component for black shales being formed in weakly reducing euxinic conditions as synsedimentary precipitates due to bacterially driven iron- and sulfate-reduction (Cavalazzi et al., 2014; Wignall et al., 2005).

There is no agreement on the origin of pyrite framboids, probably because they could be formed under different environmental conditions. We adhere to the hypothesis suggested the possibility of magnetotactic bacteria containing ferromagnetic sulphides (Sawlowicz, 1993). Farina et al. (1990) showed that a colony of magnetotactic bacteria is similar to framboids in appearance and size (5–10 μm).

As homogenization of framboids usually spreads from the centre to the surface of the spherules, organic matter and clayey particles may be captured as inclusions (Sawlowicz, 1993).

This probably explains a high value of C (50%), the presence of Si, Al, Na and Ca in the energy dispersive spectra taken from the pyrite framboid of the studied bituminous shale (Fig. 1A).

Pyrite framboids evidently indicate the euxinic (sulfidic) condition (Meyer and Kump, 2008) with increased organic matter preservation. So, it is more correct to speak not about anoxia in the basin, but about euxinia, a state with toxic levels of hydrogen sulfide concentrations.

The intercalations of concretionary limestones underlying and overlying by the bituminous shales are of great interest. They are composed of assemblage of well-preserved skeletons of coccoliths from the Lower Aptian *Rhagodiscus angustus* NC7 nannofossil Zone (Fig. 1B, C) (Bralower et al., 1995).

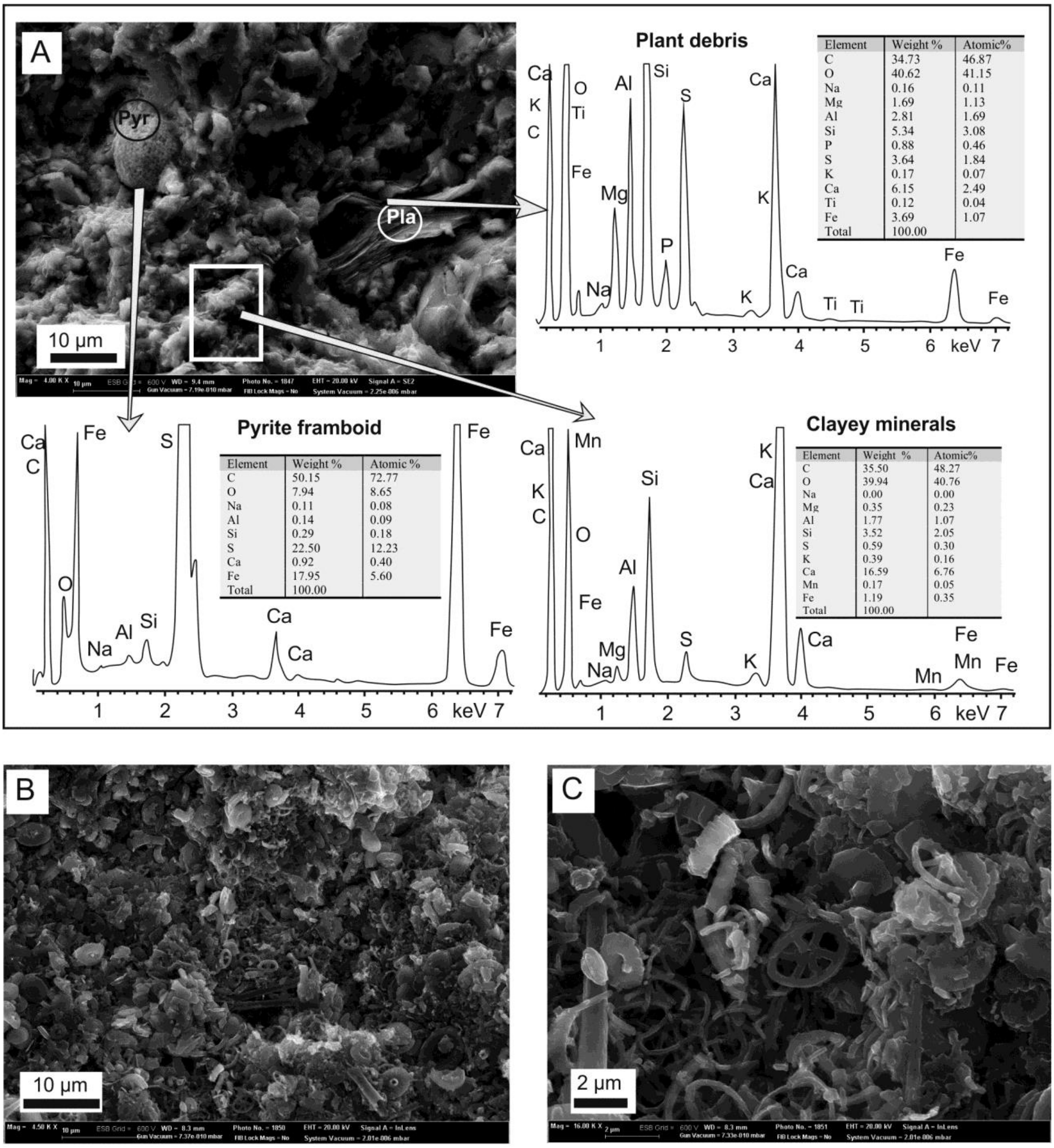

Fig. 1. (A) SEM images and energy-dispersive spectra of the Lower Aptian rocks from the "Tatar-Shatrashany" section. Plant particle (Pla) and pyrite framboid (Pyr) in the carbonate clayey matrix of the bituminous shale. (B, C) SEM images of the limestone with well preserved coccolith skeletons.

These limestones indicate that the OAE 1a on the Russian Platform was heterogeneous. The total euxinia had been interrupted by a short episode of rapid oxidization, and restoration of normal marine conditions. At that time there had been a sharp increase in bioefficiency of nanoplankton. But stagnation and euxinity have been recovered as quickly as they stopped. This is evidenced by the renewed accumulation of bituminous shales overlying limestones.

References

Bralower, T.J., Leckie, R.M., Sliter, W.V., Thierstein, H.R., 1995. An integrated Cretaceous microfossil biostratigraphy. SEPM Spec. Publ. 54, 65–79.

Cavalazzi, B., Agangi, A., Barbieri, R., Franchi, F., Gasparotto, G., 2014. The formation of low-temperature sedimentary pyrite and its relationship with biologically-induced processes. Geology of oil deposits 56, 395–408.

Farina, F., Esquivel, D.M.S., Lins de Barros, H.G.P., 1990. Magnetic iron-sulphur crystals from a magnetotactic microorganism. Nature 343, 256–258.

Gavrilov, Yu.O., Shchepetova, E.V., Baraboshkin, E.Yu., Shcherbinina, E.A., 2002. The Early Cretaceous anoxic basin of the Russian Plate: Sedimentology and geochemistry. Lithol. Miner. Resour. 37(4), 310–329.

Meyer, K.M., Kump, L.R., 2008. Oceanic euxinia in Earth history: Causes and consequences. Ann. Rev. Earth Planet. Sci. 36, 251–88.

Oschmann, W., 2011. Black shales, in: Reitner, J., Thiel, V. (Eds.), Encyclopedia of Geobiology. Springer Science+Business Media B.V., Dordrecht, pp. 201–210.

Park, M.-H., Kim, I.-S., Ryu, B.-J., 2003. Framboidal pyrites in late Quaternary core sediments of the East Sea and their paleoenvironmental implications. Geosci. J. 7(3), 209–215.

Sames, B., Wagreich, M., Wendler, J.E., Haq, B.U., Conrad, C.P., Melinte-Dobrinescu, M.C., Hu, X., Wendler, I., Wolfgring, E., Yilmaz, I.Ö., Zorina, S.O., 2016. Review: Short-term sea-level changes in a greenhouse world – A view from the Cretaceous. Palaeogeogr. Palaeoclimatol. Palaeoecol. 441(3), 393–411.

Sawlowicz, Z., 1993. Pyrite framboids and their development: a new conceptual mechanism. Geol. Rundschau 82, 148–156.

Schlanger, S.O., Jenkyns, H.C., 1976. Cretaceous oceanic anoxic events: Causes and consequences. Geol. Mijnbouw 55, 179–184.

Wignall, P.B., Newton, R., Brookfield, M.E., 2005. Pyrite framboid evidence for oxygen poor deposition during the Permian–Triassic crisis in Kashmir. Palaeogeogr. Palaeoclimatol. Palaeoecol. 216, 183–88.

Zakharov, Yu.D., Baraboshkin, E.Yu., Weissert, H., Michailova, I.A., Smyshlyaeva, O.P., Safronov, P.P., 2013. Late Barremian–early Aptian climate of the northern middle latitudes: Stable isotope evidence from bivalve and cephalopod molluscs of the Russian Platform. Cretaceous Res. 44, 183–201.

Zorina, S.O., 2016. Sea-level and climatic controls on Aptian depositional environments of the Eastern Russian Platform. Palaeogeogr. Palaeoclimatol. Palaeoecol. 441(3), 599–609.

Session 4
Cretaceous stratigraphy and sedimentology

Chronostratigraphy of the Jurassic–Cretaceous lacustrine deposits in southeast Mongolia: Brief results of Japan–Mongolia Joint research project

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Lower Cretaceous lacustrine oil shale deposits (Shinekhudag Formation) are widely distributed in southeastern Mongolia. Their high organic carbon content has motivated many geochemical and petroleum exploratory studies. Most of the lacustrine oil shales are considered to be of Early Cretaceous age, but our recent studies revealed that some of them are of Middle Jurassic age (Li et al., 2014). Thus, the present study aims are to explore the spatial and temporal distribution of the Mongolian oil shales, establishing the chronostratigraphy of the Jurassic–Cretaceous lacustrine deposits in Mongolia. This study has been conducted as the Japan–Mongolia–China joint researches since 2009 (Ando et al., 2011; Hasegawa et al., in press).

The Shinekhudag Formation (250 m thick) exposed in the Shine Khudag (type) area of Shaazangiin Gobi region below the fluvio-lacustrine Tsagantsav Formation and above the coal-bearing fluvial Khuhuteg Formation is studied to cover the majority of terrestrial sequences for constructing a composite section (Jerzykiewicz and Russell, 1991; Hasegawa et al., 2012).

The Middle Jurassic lacustrine deposits of the Eedemt Formation encompass alternating shale, dolomitic marl, siltstone and sandstone beds. In the type locality of the Khootin Khotogor area, the 150 m thick Eedemt Formation overlies the coal-bearing fluvial deposits of the Khootin Khotogor Formation.

To establish the chronostratigraphy of these lacustrine deposits, fission-track and U–Pb age dating of zircon in intercalated tuff and K–Ar age dating of intercalated basalt were conducted. Based on that radiometric age dating, the Shinekhudag Formation is considered to be deposited between ca. 123–119 Ma (Early Aptian), while the Eedemt Formation straddles 165 Ma or the late Middle Jurassic.

The Shinekhudag Formation is composed mainly of alternating beds of dark greyish paper shale (oil shale), greyish calcareous shale, light greyish dolomitic marl, and yellowish to brownish dolomite. The shale and dolomite successions are rhythmically alternated (decimeter-, meter-, tens of meter-scale), possibly controlled by orbitally driven changes in lake level and lake productivity changes reflecting precipitation changes. Paper shale contains micrometer-scale laminations (ca. 60–100 μm thick), which are most likely of varve origin. Fluorescent microscopic inspection reveals that they are composed of repetitive couplets of algal organic matter-rich and detrital mineral-rich lamina. The estimated sedimentation rate is ca. 6.3–12.5

cm/k.y. by the varve-counting methods on thin sections. Thus, the Shinekhudag Formation has a potential to record the annual-scale climatic change and seasonal changes in mid-latitude Asia during the Aptian time. To obtain the continuous paleoclimatic record of this unique lacustrine deposit, we have drilled two scientific research cores (CSH01, 02) in Shine Khudag area in 2013 and 2014 summer seasons. CSH01 core is 150 m long and covers the lower to middle part of the formation. CSH02 core is 192 m long and covers the middle to upper part of the formation.

In order to clarify the depositional environments and the controlling factors for the rhythmically alternating lithofacies changes, we conducted XRD analysis, elemental analysis (C, N, S), Rock-Eval pyrolysis, and a quantitative study of palynofacies to evaluate the organic matter (OM) composition. The mineral composition results confirmed the cyclic alternations (ca. 1.5 m cycle) of dolomite abundant layers and detritus minerals and calcite rich layers. C/N values are significantly low (<10) in the dolomite samples and higher (>15) in shale samples. Rock-Eval analysis shows significantly high hydrogen index (>650 mg/g) with relatively high T_{max} values (430–440°C), and all the samples are composed of Type I–II OM. Palynofacies analysis further indicated the dominance of *Botryococcus* colonies in dolomite layers, whereas shale layers are abundant in amorphous OM, algal cysts, and terrestrial palynomorphs.

Therefore, the dolomite layers are inferred to be formed during low lake levels by microbially mediated precipitation in highly alkaline lake waters. *Botryococcus* colonies were abundant under such oligotrophic and euryhaline conditions. On the other hand, the shale layers were deposited during high lake levels, which were characterized by higher algal productivity and increased inputs of detrital minerals.

Both of the Jurassic–Cretaceous lacustrine oil shale deposits took place in intra-continental rift basins at middle latitude of the paleo-Asian continent. Although basin evolution tectonics may have been involved in the deposition of these lacustrine oil shale, it is enhanced precipitation under a humid climatic setting during the Early Aptian and the late Middle Jurassic times that is more likely to be a key factor in the widespread occurrence of lacustrine environments in southeast Mongolia.

References

Ando, H., Hasegawa, H., Hasegawa, T., Ohta, T., Yamamoto, M., Hasebe, N., Li, G., Ichinnorov, N., 2011. Jurassic–Cretaceous lacustrine deposits in the East Gobi Basin, southeast Mongolia. J. Geol. Soc. Japan. 117, XI–XII.

Hasegawa, H., Ando, H., Hasebe, N., Ichinnorov, N., Ohta, T., Hasegawa, T., Yamamoto, M., Li, G., Erdenetsogt, B., Murata, T., Shinya, H., Enerel, G., Oyunjargal, G., Munkhtsetseg, O., Buyantegsh, B., Enkhbat, D., Suzuki, N., Irino, T., Yamamoto, K., Kouchi, Y., Orihashi, Y., Heimhofer, U., in press. Island Arc.

Hasegawa, H., Tada, R., Jiang, X., Suganuma, Y., Imsamut, S., Charusiri, P., Ichinnorov, N., Khand, Y., 2012. Drastic shrinking of the Hadley circulation during the mid-Cretaceous Supergreenhouse. Clim. Past 8, 1323–1337.

Jerzykiewicz, T., Russell, D.A., 1991. Late Mesozoic stratigraphy and vertebrates of the Gobi Basin. Cretaceous Res. 12, 345–377.

Li, G., Ando, H., Hasegawa, H., Yamamoto, M., Hasegawa, T., Ohata, T., Hasebe, N., Ichinnorov, N., 2014. Confirmation of a Middle Jurassic age for the Eedemt Formation in Dundgobi Province, southeast Mongolia: Constraints from the discovery of new spinicaudatans (clam shrimps). Alcheringa 38, 305–316.

Supersequenses in the Upper Jurassic and Lower Cretaceous of Western Siberia

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There are very different stereotypes in the development of stratigraphic schemes of the Jurassic and Lower Cretaceous of Western Siberia due to both objective and subjective reasons. However, these categories are difficult in some cases. The West Siberian stratigraphic scheme of the Jurassic reflects the structure of the incisions, but the Cretaceous scheme is built largely on biostratigraphic basis.

It should be noted that during the comparative analysis of the structure of the sections, we need to adhere to a unified perspective on a key mechanism of formation of the sedimentary cycles, as they can be different in the Jurassic and Lower Cretaceous. According to the author, that mechanism is the geographical conversion cycles of relief – rejuvenation due to tectonic activity and subsequent smoothing by exogenous processes. Regarding the sedimentary basins, it is expressed in periodic subsidence of the seabed and the subsequent filling of the formed containers by the sediments. Thus, the sedimentary cycles have the tectono-sedimentary nature. This mechanism is characteristic of the entire sedimentary cover, including the Lower Cretaceous part of the section.

The formation of regular tectonic–sedimentary cycles in the pool occurred in the Jurassic. The lower part of these cycles is represented by clayey rocks, and the upper part consists of sandy sediments substantially composed of cyclites of a lower order. Alternating clayey and sandy strata are the basis for the allocation of regional lithostratigraphic units, the horizons.

In the transitional Jurassic–Cretaceous interval, there is a continuous succession of three clayey horizons: Georgievka, Bazhenovo horizons, and unnamed Lower Cretaceous clayey strata located between the Bazhenovo Horizon and so-called ‘offshore’ Neocomian sandstones. The Cretaceous Kulomzino, Tara, etc. horizons allocated here have a completely different meaning in comparison to the preceding horizons and do not reflect the structure of the section.

Notable ‘violations’ in the work of the mechanism of cyclogenesis are obviously associated with widespread boreal transgression begun in the end of the Bathonian and in the Callovian. This marine transgression has evolved in several stages, reaching a maximum at the Kimmeridgian–Volgian boundary. It was followed by general regression, which was slow in the Volgian and became more rapid in the Early Cretaceous, reaching its maximum in the Valanginian–Early Hauterivian. In this case, the Bazhenovo Horizon composed of oil shales occurs in the initial step of the regression. The Volgian is overall regressive, as it is evidenced by the study of the outcrops and well sections in different regions of Western Siberia.

Clinoform complex of the Lower Cretaceous of Western Siberia is traditionally displayed as an expressive series of clinoforms, which are limited by the top of the Bazhenovo Horizon in the lower part, while the upper part of clinoform complex is less certain. In western regions, westerly-dipping clinoforms meet the opposite branch of easterly-dipping clinoforms, and eastern regions are characterized by uncertain structure. Clinoform stratum of transitional zone is characterized by different structure, which is poorly studied.

By analyzing the Lower Cretaceous clinoforms of the Yenisei-Khatanga trough, V.A. Kontorovich et al. (2014) identify the southern boundary of the area with clinoform structure and define the area, where the clinoforms are absent. The width of this region is of hundreds of kilometers. Structure of the sections in the margins of the trough is shown by the author (Beisel, 2014) on the example of the reference Lower Cretaceous section situated on the Boyarka River (south margin of the Khatanga depression). In general, the section is represented by parasequences that become more clear in the upper part of the section. Their hierarchical order corresponds to the West Siberian clinoforms that is proved by the coincidence of their number (about 15 in the Valanginian–Lower Hauterivian).

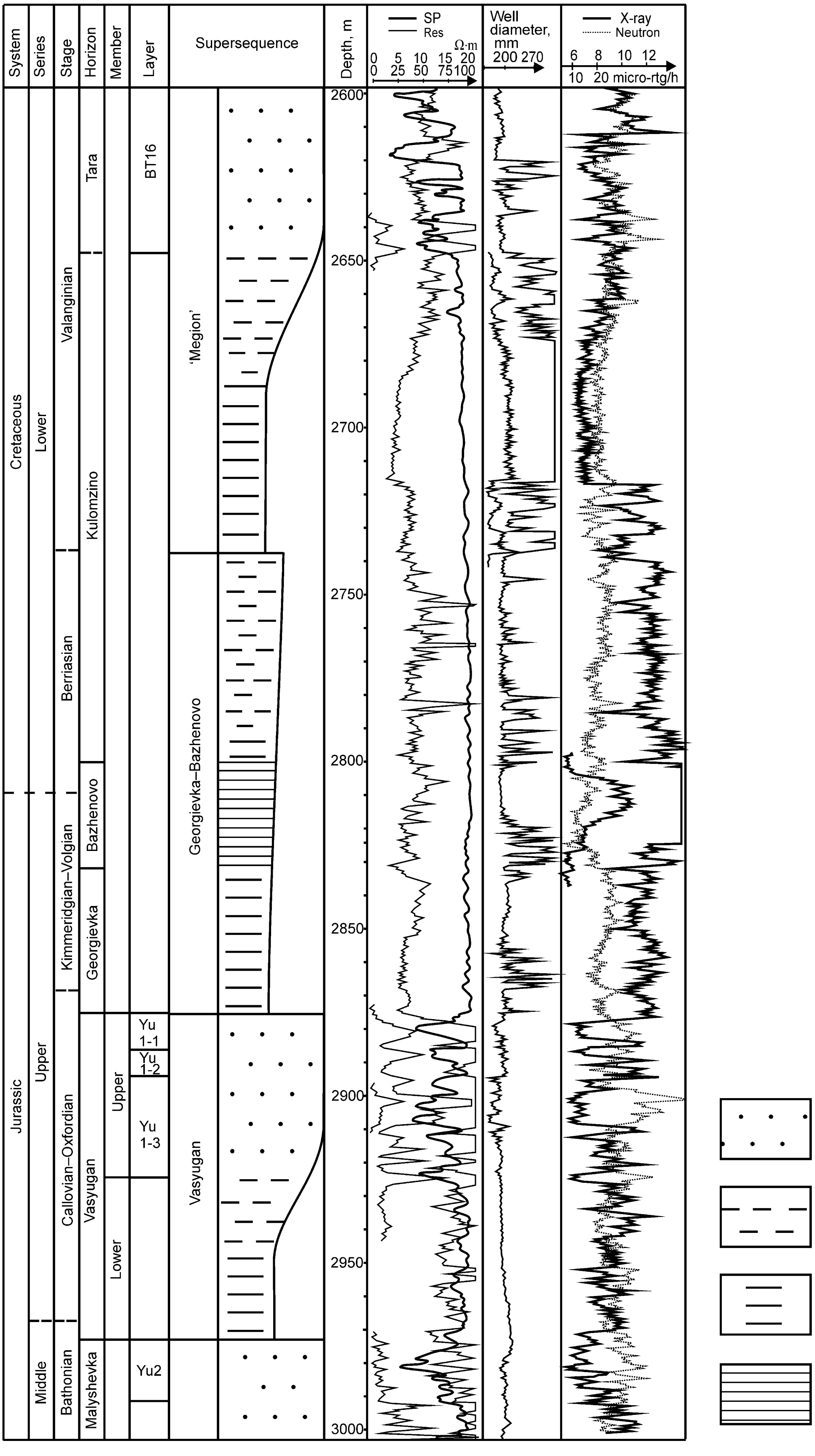

Fig. 1. Suresequenses in the Kharampurskaya-314 Well section (NE Western Siberia), based on well log data. 1 – predominantly sand, 2 – silt, 3 – clay, 4 – oil shale.

Thus, clinoforms were formed in relatively deep-water part of the basin, and ordinary parasequences occur in the coastal zone. Another important feature of the reference section on the Boyarka River is the absence of the progradation of coastal facies. This section was formed in 15 km from the paleocoast characterizing by permanent location during the Neocomian.

In Western Siberia, there are three supersequences in the Upper Jurassic and lower part of the Lower Cretaceous: the Vasyugan, Georgievka–Bazhenovo and Megion supersequences (Fig. 1). The last two supersequences are proposed for the first time. The boundary between the second and third supersequences presumably corresponds to the Berriasian–Valanginian boundary. In northern Siberia, this boundary is characterized by some features evidencing on a major geological event, which was accompanied by erosion of the Upper Jurassic rocks, changing of sedimentation conditions, etc.

Thus, the analysis of section structure shows that there is no fundamental difference between the Lower Cretaceous and Jurassic in Western Siberia. Here, the formation of sequences and parasequences is related to the cycles of rejuvenation and smoothing of the relief. A prominent episode of rejuvenation of the relief occurred in the Neocomian, near the Berriasian–Valanginian boundary, and was followed by the formation of a new transgressive-regressive cycle with the layers of clay at the bottom and at the top of progradational sandstone. The Georgievka–Bazhenovo and Megion supersequences have not been previously defined, because their boundaries are regarded as changing in time. However, it is not confirmed by reliable biostratigraphic data.

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References

Beisel, A.L., 2014. The value of the reference sections of the Lower Cretaceous of Siberia in the knowledge of the clinoform structure of the Neocomian of Western Siberia, in: Baraboshkin, E.Yu., et al. (Eds.), Cretaceous System of Russia and the near abroad: problems of stratigraphy and paleogeography. Proceedings of the 7th Russian Scientific Conference with international participation (September 10–15, 2014, Vladivostok). Dalnauka, Vladivostok, pp. 52–54 (in Russian).

Kontorovich, V.A., Lapkovski, V.V., Lunev, B.V., 2014. Model of formation of the Neocomian clinoform complex, West Siberian oil and gas province, taking into account isostasy. Oil Gas Geol. 1, 65–72 (in Russian).

The Jurassic–Cretaceous boundary in the Asian part of Russia

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The Global Stratotype Section and Point (GSSP) for the Berriasian, the basal stage of the Cretaceous, is currently under examination by the International Subcommission on Cretaceous Stratigraphy (ISCS) and the ISCS Berriasian Working Group. Marine sections in Tethys are only considered for the definition of the Jurassic–Cretaceous (J–K) boundary. These sections, especially in western Tethys, are easily accessible and highly fossiliferous, and they were intensively studied during the last decades. However, a small number of continuous, non-condensed J–K sections, which are also to be characterised by palaeontological and non-palaeontological key markers, is still a problem for formal Berriasian GSSP proposal.

The traditional J–K boundary, which was defined by the first appearance of ammonite *Berriasella jacobi* in the West Mediterranean region (Flandrin et al., 1975), gradually loses its defining value owing to widespread endemism in ammonites and their scarcity in the J–K transition beds at many sites. Therefore, other events (not only biological, but also physical and chemical) have been analysed as potential primary and supporting markers of the J–K boundary.

Many efforts were made by Russian stratigraphers to search for the most preferable level or, at least, interval for determination of the Berriasian GSSP (for references see Zakharov, 2011; Guzhikov, 2013; Arkadiev et al., 2014; Shurygin and Dzyuba, 2015). Recently it was concluded that the least interval of the uncertainty of the position of the J–K boundary in Siberian and some other sections will be ensured by the selection of one of two markers: biostratigraphic (base of the Grandis Subzone) or magnetostratigraphic (base of the M18r). Both these markers are located within the upper part of the Upper Volgian, close to several other important markers: the Brodno (M19n.r1) Subzone, the widely traceable positive $\delta^{13}C$ excursion, and the boundary between the *Craspedites taimyrensis* and *Chetaites chetae* ammonite zones. In Siberia, the uncertainty interval is quite narrow, corresponding to the upper part of the *C. taimyrensis* Zone – a cointerval of this zone with the *Arctoteuthis tehamaensis* belemnite Zone (Shurygin and Dzyuba, 2015). However, the separation of the Jacobi and Grandis subzones is still difficult in practice, and neither the base of the Grandis Subzone nor the base of M18r is supported by majority of members of the Berriasian WG as a primary marker (Wimbledon, 2016).

Despite controversies, the position of the J–K boundary at the base of the *Calpionella alpina* Subzone (i.e., at the base of the *Calpionella* Zone) is currently largely accepted. The boundary falls in the pre-Brodno part of M19n, commonly in the middle part of M19n.2n, and is constrained by the FADs of some nannofossil species. In Boreal regions, this level falls within the middle part of the Upper Volgian (see Shurygin and Dzyuba, 2015). *C. alpina*, mostly large forms of this species is a common element of the Tithonian *Crassicollaria* Zone, while the boundary between the *Crassicollaria* and *Calpionella* zones is defined by an 'explosion' event in abundance of small globular *C. alpina*. According to Michalík and Reháková (2011), this event was soon followed by the onset of the monospecific *C. alpina* association that is the reflection of environmental instability related to eustatic lowering of the sea level.

The Boreal–Tethyan correlation of the J–K boundary interval is a stratigraphic problem that cannot be solved solely by using the biostratigraphic method. This problem is rooted in the fact that the latest Jurassic and earliest Cretaceous was a time of extreme differences between the Boreal and Tethyan marine biota. As a result, the Tithonian and Berriasian stages, which are between the Kimmeridgian and Valanginian stages, are assigned to the Tethyan scale, while the Volgian and Ryazanian stages are assigned to the Boreal scale. Unlike the Tithonian–

Berriasian boundary, only the Volgian–Ryazanian boundary in Boreal sections has reliable bioevent markers. In Siberia, it was assigned to the base of the *Chetaites sibiricus* or *Praetollia maynci* ammonite zones.

The J–K boundary deposits are observed in a huge territory of the Asian part of Russia, mainly in its northern and eastern regions. These deposits are dominated by terrigenous rocks of marine and continental geneses, which are of very different lithologic compositions; but in eastern areas of Russia, the siliceous-terrigenous and volcano-siliceous deposits are also developed. Typically 'Boreal' fossils characterise the J–K boundary beds in Siberia and major part of the Russian Far East; only a few 'Tethyan' fossils have been recorded from the Southern Primorye and Sikhote-Alin.

The best integrated stratigraphic study of the J–K boundary interval in the Asian part of Russia was performed for the Nordvik section located in northern East Siberia. Here, the J–K boundary beds contain ammonites, belemnites, bivalves, foraminifers and dinocysts, which provide a precise biostratigraphy for the section (Zakharov et al., 2014). Both $\delta^{13}C$ and $\delta^{18}O$ curves have been reconstructed for the J–K boundary interval of the Nordvik section (Dzyuba et al., 2013; Zakharov et al., 2014). Moreover, a continuous succession of magnetozones from M20n to M16r, including two important subzones (M20n.1r, the Kysuca Subzone, and M19n.1r, the Brodno Subzone), was established here (Houša et al., 2007; Bragin et al., 2013). Chrons M19n to M17r reveal apparently lower sedimentation rates (up to 0.5–2.0 m/m.y.) comparable to those from ammonitico rosso facies (Bragin et al., 2013; Wierzbowski and Grabowski, 2013).

Note that the most of magnetozone M19n in the Nordvik section belongs to an ammonite-free interval (Rogov et al., 2015; Schnabl et al., 2015). Only one biostratigraphic marker, the base of the *Arctoteuthis tehamaensis* belemnite Zone was undoubtedly recorded within M19n, close to the middle part of M19n.2n (see Shurygin and Dzyuba, 2015). However, it cannot be excluded that the base of the *Craspedites taimyrensis* ammonite Zone is also close to this level, but this issue needs further investigation. The middle part of M19n.2n does not show any isotopic events, while two significant positive $\delta^{13}C$ excursions have been established at Nordvik. The first excursion was defined in M20n1n, and the second positive event marks M19n–M18r transition (Dzyuba et al., 2013).

In Western Siberia, the most stratigraphically-complete section spanning the J–K boundary is located in the foothills of the Northern Urals on the Maurynya River. Ammonite-based and belemnite-based biostratigraphy, and high-resolution C- and O-isotope stratigraphy have been clarified for the Maurynya section. The $\delta^{13}C$ values in the section show two large positive excursions (Dzyuba et al., 2013). The first excursion found in the lowermost part of the section is well correlated with the positive excursion defined within M20n1n of northern East Siberia (Dzyuba et al., 2013; Zakharov et al., 2014) and Tethys (Weissert et al., 2008). The second excursion found within the *Craspedites taimyrensis* Zone corresponds to the positive excursion recognised near the boundary of M19n–M18r in northern East Siberia. Additionally, the first Sr isotope data were recently reported from the Maurynya section (Izokh et al., 2015).

The J–K boundary beds at Maurynya have not yet received the palaeomagnetic characteristics, and *Arctoteuthis tehamaensis* belemnite has not been found here. The position of the J–K boundary can be provisionally defined at the base of the *Simobelus compactus* belemnite beds (age analogue of the *A. tehamaensis* Zone), between two positive $\delta^{13}C$ excursions but closer to upper one.

In the northeastern Russia, there are a number of sites with continuous J–K transition successions (Burgakhchan, Bannaya, Tantyn, Ilguveem, and Perevalnaya rivers, etc.), where biostratigraphic frame is based mainly on *Buchia* (Paraketsov and Paraketsova, 1989). Among ammonites, only *Chetaites* sp. has been found here within the interval under consideration (Pezhenka River). All these sections were not restudied during a long time mainly because of their inaccessibility. Magneto- and chemostratigraphic works have not been conducted here at all. The J–K boundary is within the wide ranging *Buchia terebratuloides–B. tenuicollis* Zone (Upper Volgian–lowermost Ryazanian).

In the Russian Far East, the Komsomolsk section located in the Northern Sikhote-Alin is also mainly characterised by *Buchia*-based biostratigraphic succession (Urman et al., 2014). The J–K boundary is within the wide ranging *Buchia unschensis–B. terebratuloides* beds (uppermost Upper Volgian–lowermost Ryazanian), which also yield ammonite *Pseudosubplanites*? sp. of Tethyan affinity.

Integrated bio- and magnetostratigraphic study of the J–K boundary in the Russian Far East was recently performed for the Chigan section, Southern Primorye (Guzhikov et al., 2016). Several Tethyan ammonites, characteristic for the Jacobi Zone, are known from this section: *Dalmasiceras orientale*, *Berriasella* cf. *jacobi*, *B.* ex gr. *jacobi*, *Pseudosubplanites* cf. *combesi*, *P.* aff. *combesi*, and *P.* cf. *grandis*. Investigations show the possibility of obtaining of palaeomagnetic data, but the presence of magnetozone M19n was not established in this section with certainty. Boreal bivalves (*Buchia*) and foraminifers have been revealed here, and palynological objects (pollen and spores, dinocysts, etc.) were also studied. However, the real stratigraphic ranges of all these fossils in the section need further investigation.

Thus, the J–K boundary defined in Tethys by the morphological change of *Calpionella alpina* cannot be strictly recognised in the Asian part of Russia. The problem of identification of approximate position of this level can be solved only using a combination of data obtained by palaeontological and non-palaeontological methods of stratigraphy.

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References

Arkadiev, V.V., Baraboshkin, E.Yu., Guzhikov, A.Yu., 2014. About Jurassic–Cretaceous boundary, in: Baraboshkin, E.Yu., et al. (Eds.), Cretaceous System of Russia and the near abroad: problems of stratigraphy and paleogeography. Proceedings of the 7th Russian Scientific Conference with international participation. Dalnauka, Vladivostok, pp. 27–30 (in Russian).

Bragin, V.Yu., Dzyuba, O.S., Kazansky, A.Yu., Shurygin, B.N., 2013. New data on the magnetostratigraphy of the Jurassic–Cretaceous boundary interval, Nordvik Peninsula (northern East Siberia). Russ. Geol. Geophys. 54, 329–342.

Dzyuba, O.S., Izokh, O.P., Shurygin, B.N., 2013. Carbon isotope excursions in Boreal Jurassic–Cretaceous boundary sections and their correlation potential. Palaeogeogr. Palaeoclimatol. Palaeoecol. 381–382, 33–46.

Flandrin, J., Schaer, J.P., Enay, R., Remane, J., Rio, M., Kubler, B., Le Hégarat, G., Mouterde, R., Thieuloy, J.P., 1975. Discussion générale préliminaire au dépôt des motions. Colloque sur la limite Jurassique–Crétacé, Lyon–Neuchâtel, September 1973. Mém. B.R.G.M. 86, pp. 386–393.

Guzhikov, A.Yu., 2013. Solving unsolvable problems in stratigraphy. Russ. Geol. Geophys. 54, 349–354.

Guzhikov, A.Yu., Arkadiev, V.V., Baraboshkin, E.Yu., Feodorova, A.A., Shurekova, O.V., Baraboshkin, E.E., Manikin, A.G., Golozubov, V.V., Kasatkin, S.A., Nechaev, V.P., 2016. New bio- and magnetostratigraphic data at the Jurassic–Cretaceous boundary of the Chigan Cape (Vladivostok region, Russia), in: Michalík, J., Fekete, K. (Eds.), XIIth Jurassica, IGCP 632 and ICS Berriasian workshop: Field Trip Guide and Abstracts Book. ESI SAS, Bratislava, pp. 101–104.

Houša, V., Pruner, P., Zakharov, V.A., Kostak, M., Chadima, M., Rogov, M.A., Šlechta, S., Mazuch, M., 2007. Boreal–Tethyan correlation of the Jurassic–Cretaceous boundary interval by magneto- and biostratigraphy. Stratigr. Geol. Correl. 15, 297–309.

Izokh, O.P., Kuznetsov, A.B., Dzyuba, O.S., Kosenko, I.N., Shurygin, B.N., 2015. Short-term perturbations of marine $^{87}Sr/^{86}Sr$ near the Jurassic–Cretaceous boundary in the Maurynya Section, West Siberia: Potential causes and correlative value. Ber. Inst. Erdwiss. K.-F.-Univ. Graz 21, 181.

Michalík, J., Reháková, D., 2011. Possible markers of the Jurassic/Cretaceous boundary in the Mediterranean Tethys: A review and state of art. GSF 2(4), 475–490.

Paraketsov, K.V., Paraketsova, G.I., 1989. Stratigraphy and fauna of the Upper Jurassic and Lower Cretaceous deposits of Northeast USSR. Nedra, Moscow (in Russian).

Rogov, M.A., Alifirov, A.S., Igolnikov, A.E., 2015. Revised ammonite succession of the upper Volgian of Nordvik section: Zonal boundaries and uncertainties, in: Baraboshkin, E.Yu., Bykov, D.E. (Eds.), The International Scientific Conference on the Jurassic/Cretaceous boundary: Proceedings volume. Kassandra, Togliatti, pp. 70–76.

Schnabl, P., Pruner, P., Wimbledon, W.A.P., 2015. A review of magnetostratigraphic results from the Tithonian–Berriasian of Nordvik (Siberia) and possible biostratigraphic constraints. Geol. Carpathica 66(6), 489–498.

Shurygin, B.N., Dzyuba, O.S., 2015. The Jurassic/Cretaceous boundary in northern Siberia and Boreal–Tethyan correlation of the boundary beds. Russ. Geol. Geophys. 56, 652–662.

Urman, O.S., Dzyuba, O.S., Kirillova, G.L., Shurygin, B.N., 2014. Buchia faunas and biostratigraphy of the Jurassic–Cretaceous boundary deposits in the Komsomolsk section (Russian Far East). Russ. J. Pac. Geol. 8(5), 346–359.

Weissert, H., Joachimski, M., Sarnthein, M., 2008. Chemostratigraphy. Newsl. Stratigr. 42(3), 145–179.

Wierzbowski, A., Grabowski, J., 2013. The meteorite Mjølnir crater in the Barents Sea in stratigraphical interpretations. Prz. Geol. 61: 516–522.

Wimbledon, W.A.P., 2016. Resolving the positioning of the Tithonian/Berriasian stage boundary and the base of the Cretaceous System, in: Michalík, J., Fekete, K. (Eds.), XIIth Jurassica, IGCP 632 and ICS Berriasian workshop: Field Trip Guide and Abstracts Book. ESI SAS, Bratislava, pp. 128–130.

Zakharov, V.A., 2011. The Jurassic–Cretaceous boundary and Berriasian GSSP: is there light at the end of the tunnel? (Comments to proposals on the Jurassic–Cretaceous boundary by Berriasian Working Group). News Paleontol. Stratigr. 16–17 (Suppl. Russ. Geol. Geophys. 52), 69–86 (in Russian with English summary).

Zakharov, V.A., Rogov, M.A., Dzyuba, O.S., Žák, K., Košťák, M., Pruner, P., Skupien, P., Chadima, M., Mazuch, M., Nikitenko, B.L., 2014. Palaeoenvironments and palaeoceanography changes across the Jurassic/Cretaceous boundary in the Arctic realm: case study of the Nordvik section (north Siberia, Russia). Polar Res. 33, 19714.

Lower Cretaceous formations and palynology of the Matad area (Tamsag Basin), southeastern Mongolia

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Introduction

In Mongolia, Upper Jurassic to Cretaceous non-marine sedimentary rocks are widely distributed. The Lower Cretaceous rocks contain important mineral resources, such as coal, oil, bituminous shales, gypsum, quart, fluorite, zeolite, rare metals, and gold.

In Eastern Mongolia, the Lower Cretaceous sedimentary sequence is classified into several different formations in different basins.

The stratigraphy of Lower Cretaceous strata in the Tamsag Basin has been studied by Marinov et al. (1973), Khosbayar (1996), Tooruul and Makhbadar (1990), PAM report (1990), Tomortogoo (1998), Geerdts (2007) assigned these rocks to the Tsagaantsav and Zuunbayan (also spelled Dzunbayan and Dzun Bayan) formations (Shuvalov, 1975). The Zuunbayan Formation is the thickest unit in the Tamsag Basin. It is divided into the upper and lower formations, based on depositional environment dominance.

The Lower Zuunbayan Formation is called Shinekhudag Formation in Southeastern Gobi (Martinson and Shuvalov, 1973; Shuvalov, 1980, 2003; Jerzykiewicz and Russell, 1991; Badamgarav et al., 1995; Graham et al., 2001; Ichinnorov and Hofmann, 2012), in Eastern Mongolia (Bat–Erdene, 1992; Yamamoto et. al., 1993) and consists mainly of deep lacustrine shale rich in organic matter. The Upper Zuunbayan Formation is called Khukhteeg Formation in Southeastern Gobi (Martinson and Shuvalov, 1973; Shuvalov, 1980, 2003; Jerzykiewicz and Russell, 1991; Badamgarav et al., 1995; Graham et al., 2001; Ichinnorov and Hofmann, 2012), and in Eastern Mongolia (Bat–Erdene, 1992; Yamamoto et al., 1993). In this study, we use the Shinekhudag and Khukhteeg formations.

The Shinekhudag Formation is composed of paper shale (well-laminated shale), dolomitic marls, dolomite, siltstone and sandstone, which represent the characteristics of offshore lacustrine facies in large (extensive), perennial lakes. The formation is about 300 to 700 m thick and is widely distributed in the Khangai, Mongol Altai, Gobi Altai, Central Gobi, East Gobi, Nyalga, and Choibalsan basins (Shuvalov, 1975; Jerzykiewicz and Russell, 1991).

Paleontological age constraints of the Shinekhudag Formation had been controversial. Although abundant molluscan and ostracod fossils have been cited as evidence of the Barremian to Hauterivian age (Martinson and Shuvalov, 1975; Khand et al., 2000), the Aptian age of the formation was suggested by floral, concostracans, and palynological evidence (Krassilov, 1982; Jerzykiewicz and Russell, 1991; Ichinnorov, 1998; Graham et al., 2001; Ichinnorov, 2005; Yuan and Chan, 2005; Ichinnorov and Hofmann, 2012). Martinson and Shuvalov (1975) previously considered the Hauterivian–Barremian age for the formation, based on the conchostracan assemblage of *Bairdestheria sinensis* (Chi), *B. mattoxi* Kras., *Pseudograpta asanoi* (Kob. et Kus) from the lower part of the Zuunbayan Formation of East Gobi. Some of lacustrine shales within the Tsagantsav Formation may be mistakenly correlated to the Shinekhudag Formation, as it is also pointed out by Graham et al. (2001). On the other hand, Krassilov (1982) defined the age of the Shinekhudag Formation as Aptian on the basis of two floral assemblage zones of *Baierella hastata–Araucaria mongolica*, and *Limnothetis gobiensis–Limnoniobe insignis*, which also occurred in dated strata in eastern Siberia. Based on the conchostracan assemblage in the Shine Khudag locality, Yuan and Chen (2005) concluded that the Shinekhudag Formation is correlated to the Jiufotang Formation of Liaoaning Province due to the similar faunal occurrence, whose age was assigned to the Early Aptian (Sha, 2007). In addition, Ichinnorov (1998, 2005) and Ichinnorov and Hofmann (2012) demonstrated pollen and spore assemblages of the Shinekhudag Formation from Bayan Erkhet, Matad, and Shine Khudag localities, and concluded an Aptian age of the formation.

The Khukhteeg Formation is composed mainly of dark greyish coaly mudstone, light greyish sandstone, and conglomerate. It is widespread in the east and center of Mongolia with a characteristic feature of abundant coal seams (e.g., Shivee Ovoo, Tevshin Gobi, Bayan Erkhet, Khuren Dukh, Nalaikh, Baga Nuur localities). Basic volcanics of different thickness (up to 100 m), as well as oval sandstone concretions, partial tree trunks, and other water-borne organic materials are intercalated in this formation. The thickness of the Khukhteeg Formation is about 150–300 m. In the type section of the Khukh Teeg hill, near the Shine Khudag locality of East Gobi, there are abundant remains of stromatolites (Sochava, 1977). The Khukhteeg Formation yields aquatic champsosaurs (Shuvalov, 2000). Angiosperms and some species of ferns occurred in all areas, but ginkgo pollen were less abundant (Ichinnorov, 1998, 2005; Ichinnorov and Hofmann, 2012). The Khukhteeg Formation is dated as Albian or Aptian–Albian based on the occurrences of turtles and mammals (Dosh Uul, Khar Khutul, Khukh Teeg; Shuvalov, 1975), molluscs (Khamaryn, Khural), and pollen–spore (Nichols et al., 2006; Ichinnorov, 1998, 2005; Ichinnorov and Hofmann, 2012). In the Trans-Altai Gobi, the Khukhteeg deposits ascribed to the Doshuul Formation contain a horizon of basalts, whose radiometric age is 110–113 Ma (Shuvalov, 2000). Based on plant megafossils Krassilov (1982) suggested that the deposits are Late Aptian to Albian in age due to the floral similarity with the equivalent strata in the Amur Basin, Japan and northeastern China (Shuvalov, 1975; Martinson, 1982). The Khukhteeg Formation contains the remains of elasmobranchs, which also occur in the sediments of Aptian age in Soviet mid-Asia. The Khukhteeg Formation has yet to yield trionychid turtles, which first appeared in the Late Albian in Soviet mid-Asia, while it is known from the overlying Bayanshiree Formation (Nessov, 1985; Vitek and Danilov, 2014). This evidence indicates that the deposition of the Khukhteeg Formation ended before the Late Albian.

Palynological results

The encountered specimens are characterized by 26–33% spores, 67–74% gymnosperm pollen. We recovered 46 fossil species of spores and 31 species of gymnosperm in the Aptian–Albian sediments of the lower Khukhteeg Formation.

Spores of pteridophytes, most of them probably ferns, are common in the assemblage. A single monolete form is present. It is assigned to the species *Laevigatosporites ovatus*. Among the spores, the species of trilete spores are dominated: *Aequitriradites spinulosus*, *Cooksonites variabilis*, *Foraminsporis asymmetricus*, *Cicatricosisporites hallei*, *Cicatricosisporites australiensis*, *Cicatricosisporites dorogensis*, *Appendicisporites tricornitatus*, *Pilosisporites trichopapillosus*, *Pilosisporites notensis*, *Kuylisporites lunarius*, *Leptolepidites verrucatus*, *Biretisporites potoniaei*, *Glecheniidites senonicus*, *Sphagnumsporites spilatus*, and *Osmundacidites wellmannii*. About 15 spores of pteridophytes were identified to the generic level.

Non-saccate gymnosperm pollen are represented by *Araucaricidites*, *Inaperturapollenites*, *Ephedripites*, *Ginkgocycadophytus*, *Monosulcites*, and *Cycadopites*.

In our assemblage, the specimens of bisaccate coniferous pollen are mostly assigned to the genera *Piceapollenites*, *Pinuspollenites*, *Cedripidites* and *Podocarpidites*. The following taxa are common: *Alisporites* sp., *Keteleriapollenites* sp., *Pinuspollenites divulgatus*, *Pinuspollenites minimus*, *Pinuspollenites* cf. *concessus*, *Pinuspollenites* sp. 1, *Pinuspollenites* sp. 2, *Piceapollenites exiloides*, *Piceapollenites mesophyticus*, *Protopiceapollenites exiloides*, *Piceapollenites* sp., *Podocarpidites multiformis*, *Podocarpidites dettmannii*, *Podocarpidites decorus*, *Podocarpidites* sp., *Cedripites libaniformis*, *Cedripites cretaceous*, and *Cedripites* sp.

Discussion

This palynological assemblage is completely different from palynological assemblages discovered from (Ichinnorov, 2005) and (PAM, 1997), concluded that the age of these sediments is Hauterivian–Barremian. Our palynological assemblage includes many different species of pteridophyte spores. *Aequitriradites spinulosus*, *Appendicisporites tricornitatus*, *Cicatricosisporites hallei*, *Cicatricosisporites australiensis*, *Cicatricosisporites dorogensis*, *Pilosisporites trichopapillo-*

sus, *Pilosisporites notensis*, *Leptolepidites verrucatus*, *Biretisporites potoniaei*, and *Glecheniidites senonicus* are the typical Neocomian species, but most of them were found in the Aptian–Albian Khukhteeg Formation of Mongolia (Bratseva and Novodvorskaya, 1975; Ichinnorov, 2003, 2005; PAM, 1997). *Foraminsporis asymmetricus*, *Cooksonites variabilis*, *Laevigatosporites ovatus* have been found in the Aptian–Albian of Mongolia (Ichinnorov, 2003, 2005), Russia (Kotova, 1970), and western Canada (Pocock, 1962; Singh, 1964), in the Albian–Cenomanian of Central Alberta (Norris, 1967). *Appendicisporites tricornitatus* is a typical Lower Cretaceous species ranging from the top of the Berriasian to the Albian. It has been recorded from the Aptian–Albian of England (Kemp, 1970) and Mongolia (PAM, 1997), and from the Maastrichtian of Wyoming (Michael et al., 1986).

According to the occurrences of spores and pollen listed above and absence of angiosperms, the palynological assemblage is dated as Aptian–Albian (the lowest Khukhteeg Formation), and it is well correlated with the Aptian–Albian assemblage of the locality Shivee–Ovoo (Ichinnorov, 2003, 2005). The palynological evidence is consistent with a humid and warm paleoclimate.

Ryazanian (Boreal Berriasian) ammonite succession of the Nordvik section (Russian Arctic): Revision and new data

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The section on the Nordvik Peninsula (the Laptev Sea coast, Anabar Bay) is studied since the 50th of last century that provides a lot of material. Nevertheless, it requires new revision. This investigation is based on some samples collected by V.A. Zakharov, Yu.I. Bogomolov, V.A. Marinov, but major part of the material was collected by the authors during 2003, 2009, 2011, and 2014 field seasons. The published data were analyzed (Basov et al., 1970; Zakharov et al., 1983; Bogomolov, 1989), and the N.I. Shulgina's collection located in the CSRGS museum (Saint Petersburg) was investigated.

The entire Ryazanian stage is here exposed comprising five ammonite zones. The base of the first *Chetaites sibiricus* Zone (about 3.5 m thick) is commonly defined in the Nordvik section at the base of thin bed 18 (3–5 cm) of phosphatic chalk (Fig. 1) according to the first occurrence of *Praetollia*. It should be noted that there are some questions on *Chetaites* occurrences from *C. sibiricus* Zone in the Nordvik section. The specimens of *C.* cf. *sibiricus* previously represented by N.I. Shulgina (Zakharov et al., 1983) cannot be attributed to this genus, because they are characterized by Craspeditidae-like suture pattern and a moderately tight umbilicus that allows the reliable identification of these forms as *Praetollia*. *C.* cf. *sibiricus* shown by Zakharov and Rogov (2008; Table II, Fig. 8) is hardly belongs to this genus; *C.* aff. *sibiricus* mentioned in the same publication (Ibid, Table II, Fig. 9) is characterized by a Craspeditidae-like suture pattern. This form is close to *Craspedites* (*Taimyroceras*), but differs in its large size in comparison to other *Craspedites* (*Taimyroceras*). In the collection of the authors, there is an exclusive specimen with wide umbilicus, which is important diagnostic feature of the genus *Chetaites*. However, this specimen was found in the next higher ammonite zone, i.e. *Hectoroceras kochi* Zone.

The assemblage of the *Chetaites sibiricus* Zone generally consists of various *Praetollia* as well as rare *Craspedites* (*Taimyroceras*), *Boreophylloceras*, and *Borealites* (?). New data show that previous occurrences of *Borealites* at such low stratigraphic level (Igolnikov, 2010) cannot be considered as definitive, because some large shells of *Praetollia* can have rather clear rib differentiations, typical for *Borealites*.

The base of second Ryazanian zone, *Hectoroceras kochi* (about 8.9 m thick), is defined by first appearance of index species and confined to the base of massive concretion horizon in the bed 23 (Fig. 1). It confirms the initial point of view on the location of zone base (Basov et al., 1970) that is supported by new occurrences of *H. kochi* at this level. In the lower third of the zone, various *Praetollia* continue to prevail among ammonites, several specimens of *Borealites* (*Borealites*) and single *Chetaites*, *Bochianites*, and *Biasaloceras* are found. Well preserved ammonites are rare in the middle part of the section commonly containing rare concretions, but there are some imprints defined as *Borealites* (?) sp. ind. There are plenty of ammonites in the upper part of the zone: *Borealites* (*Borealites*) and *Borealites* (*Pseudocraspedites*) are the most abundant, and *Boreophylloceras* and *Anabaroceras* are rare here. As the last one concerned, we should note that these are not the first findings outside the type locality (Anabar River lower reaches), but they are most ancient (type collection contains Valanginian specimens) (Repin, 2012).

New data on the succession of *Surites* from the *analogus* group fully comply with previous results (Basov et al., 1970; Zakharov et al., 1983), and the base of the *Surites analogus* Zone (4.3 m) is defined at the base of the bed 31 (Fig. 1). Along with *Surites*, the assemblage also comprises *Borealites* (*Pseudocraspedites*) and *Borealites* (*Ronkinites*), but they are less frequent.

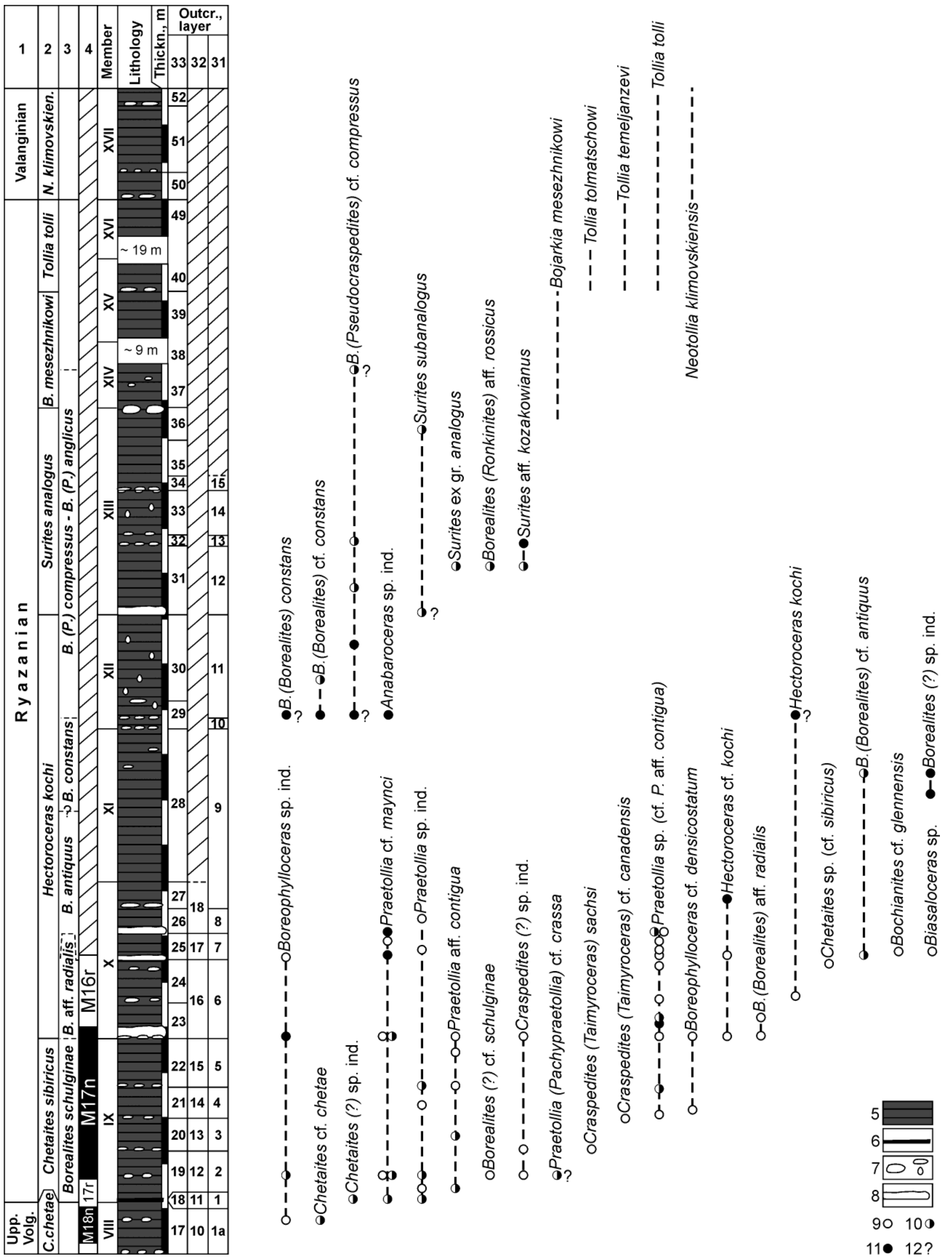

Fig. 1. Distribution of all known Ryazanian ammonite records in the Nordvik section (1967–2014). 1 – stage/substage, 2 – ammonite zones (Boreal standard), 3 – *Borealites* beds (A.E. Igolnikov), 4 – paleomagnetic zones; 5–8 – lithology: 5 – silty clays to claystones, 6 – phosphatic chalk, 7 – carbonate concretions, 8 – massive concretion horizon; 9–11 – localities: 9 – Outcrop 32, 10 – Outcrop 33, 11 – Outcrop 31; 12 – approximate position or loose occurrences from bed. Numbers of beds are after Zakharov et al. (1983) for the outcrops 32 and 33, and after A.E. Igolnikov (field data 2014) for the Outcrop 31. Thickness scale 1 m.

The *Bojarkia mesezhnikowi* and *Tollia tolli* zones, the uppermost two Ryazanian zones in the Nordvik section, are defined according to Yu.I. Bogomolov (1989). There are no fundamentally new data on these intervals, but the occurrence of *Boreophylloceras* sp. in the rock debris of *B. mesezhnikowi* Zone should be noted.

The continuous Ryazanian from the Nordvik outcrops with abundant ammonites and distinct zone boundaries can be regarded as a reference section for the north of Siberia. For instance, *Praetollia* confined only to the bottom of the *Chetaites sibiricus* Zone in the Kheta River section (Alekseev, 1984) remained unexplainable for a long time. *Praetollia* and *Hectoroceras* were previously reported from the Nordvik Peninsula and Greenland (Basov et al., 1970; Zakharov et al., 1983; Surlyk, 1973), and they are recently found in the *Hectoroceras kochi* Zone in the Lena River (Rogov et al., 2011) and in the North Sea regions (Abbink et al., 2001). Thus, the part of the Kheta River section previously assigned to the *C. sibiricus* Zone (Saks, 1972; Alekseev, 1984) can be now considered as the *H. kochi* Zone due to co-occurrence of *Chetaites* sp. and *Hectoroceras* sp. in the base of the section (Saks, 1972; Zakharov, 1990). The base of the *H. kochi* Zone must be identified by the first appearance of *Hectoroceras* (Casey et al., 1988). Nevertheless, *Hectoroceras* specimens from the Kheta River have never been described in the publications and they are absent in the collection (excluding the specimen from the rock debris apparently of the higher stratigraphic levels), so it is impossible to check the accuracy of their definitions. According to the field data of M.A. Rogov (2015 season), Outcrop 21 in the Kheta River completely consists of Quaternary rock debris, and the Lower Cretaceous with very rare ammonites can be only found in the pits. All specimens of *C. sibiricus* were found in the large bun-shaped concretions of calcareous siltstones from the rock debris of lower stratigraphic level that is evidenced by rock structure, as opposed to the visible section basement in the publications of predecessors (Saks, 1972; Alekseev, 1984; Zakharov, 1990). In this case, it is important either to select the neostratotype for the *C. sibiricus* Zone or use *Praetollia maynci* as index species for the lowermost zone of the Ryazanian stage in Siberia.

Chetaites and *Borealites* successions in the Nordvik section show that S.N. Alekseev's (1984) tripartite division of the *Hectoroceras kochi* Zone can be extended. Approximately 5 m of the section between the layers containing *Hectoroceras* and the last *Chetaites*, which can be compared with the *H. kochi* Subzone, and the level marked by the first appearance of *Borealites* (*Borealites*) *constans* do not contain any ammonites (Fig. 1). This lacuna corresponds to the layers with *B.* (*B.*) *antiquus*.

Using the data on ammonite succession in the Nordvik section, the boundaries of the *Hectoroceras kochi* Zone can be more accurately defined in the absence index species. The section in the Lena River lower reaches can be used as an example (Rogov et al., 2011). Here, there is the *Chetaites sibiricus* Zone with *Chetaites*, *Praetollia*, and *Borealites* in the bottom of the Ryazanian part of the section. This assemblage is typical for the lower third of the *H. kochi* Zone, so the *C. sibiricus* Zone may be absent in the region.

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References

Abbink, O.A., Callomon, J.H., Riding, J.B., Williams, P.D.B., Wolfard, A., 2001. Biostratigraphy of Jurassic–Cretaceous boundary strata in the Terschelling Basin, the Netherlands. Proc. Yorkshire Geol. Soc. 53, 275–302.

Alekseev, S.N., 1984. New data on a zonal subdivision of the Berriasian in the north of Siberia, in: Menner, V.V. (Ed.), The Jurassic and Cretaceous boundary stages. Nauka, Moscow, pp. 81–106 (in Russian).

Basov, V.A., Zakharov, V.A., Ivanova, E.P. et al., 1970. Zonal classification of the Upper Jurassic and Lower Cretaceous deposits on Urdyuk–Khaya Cape (Pakhsa Peninsula, Anabar Bay), in: Gerke, A.A. (Ed.), Science memoirs NIIGA. Palaeontology and biostratigraphy. NIIGA, Leningrad, pp. 14–31 (in Russian).

Bogomolov, Yu.I., 1989. *Polyptychites* (Ammonoids) and biostratigraphy of the Boreal Valanginian. Nauka, Novosibirsk (in Russian).

Casey, R., Mesezhnikow, M.S., Shulgina, N.I., 1988. Ammonite zones in Jurassic–Cretaceous boundary sediments of the Boreal realm. News AS USSR. Geol. Ser. 10, 71–84 (in Russian).

Igolnikov, A.E., 2010. New ammonite's finds from Berriasian of the Nordvik Peninsula, in: Proc. 5th All-Russia meeting "Cretaceous system of Russia and near Overseas: problems of stratigraphy and paleogeography". UlGU, Ulyanovsk, pp. 163–165 (in Russian).

Repin, Yu.S., 2012. The endemic branch of the Phylloceratida (Ammonoidea) of Arctic Mesozoic, in: Proc. conf. "Contributions to current cephalopod research: Morphology, systematics, evolution, ecology and biostratigraphy". PIN, Moscow, pp. 73–76 (in Russian).

Rogov, M.A., Zakharov, V.A., Ershova, V.B., 2011. Detailed stratigraphy of the Jurassic–Cretaceous boundary beds of the Lena River lower reached based on ammonites and Buchiids. Stratigr. Geol. Correl. 19, 641–662.

Saks, V.N. (Ed.), 1972. Jurassic–Cretaceous boundary and Berriasian stage in Boreal realm. Nauka, Novosibirsk (in Russian).

Surlyk, F., 1973. The Jurassic–Cretaceous boundary in Jameson Land, East Greenland. Geol. J., Spec. Iss. 5, 81–100.

Zakharov, V.A., 1990. Definition of Jurassic–Cretaceous boundary on buchias, in: A boundary of Jurassic–Cretaceous system. Nauka, Moscow, pp. 115–128 (in Russian).

Zakharov, V.A., Rogov, M.A., 2008. The Upper Volgian substage in northeast Siberia (Nordvik Peninsula) and its Panboreal correlation based on ammonites. Stratigr. Geol. Correl. 16, 423–436.

Zakharov, V.A., Nalnyaeva, T.I., Shulgina, N.I., 1983. New data on the biostratigraphy of the Upper Jurassic and Lower Cretaceous deposits on Paksa Peninsula, Anabar Embayment (north of the Middle Siberia), in: Jurassic and Cretaceous paleobiogeography and biostratigraphy of Siberia. Nauka, Moscow, pp. 56–99 (in Russian).

The closing age of Himalayan Tethys: New evidence from planktic foraminifera

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The Yadong area was located at the residual basin of the Neotethys during the Paleogene, which develops a set of youngest marine deposition of the Tethyan Himalayas, and therefore the biostratigraphic data from the Tingri-Gamba-Yadong area are essential to constrain the age of the India–Asia collision.

Planktic foraminifera study is usually considered to be one of the most important methods to determine the age of Meso-Cenozoic marine sediments and thus can be used to define the age of latest sediments in Tethyan Himalayas, which can provide well-constrained age of the India–Asia collision (Wan, 1990; Willems et al., 1996; Rowley, 1998; Wang et al., 2002; Li and Wan, 2003; Li et al., 2004, 2005, 2006; Najman et al., 2010).

A detailed investigation of planktic foraminfers was firstly provided for the newly discovered marine horizon (Zhepure Formation of Paleogene age) in the Gulupu section, Duina, Yadong, southern Tibet (Fig. 1). The Zhepure Formation was further divided into underlying Limestone Member and overlying Shale Member, which conformably contact each other. Abundant benthic and planktic foraminifera are respectively revealed in the Limestone and Shale members (Fig. 2). This paper focuses on the planktic foraminiferal biostratigraphy of the Shale Member.

Examination of foraminiferal tests and thin-section fossils of the Shale Member has yielded 135 species of 28 planktic foraminiferal genera, and ten planktic foraminiferal biozones were recognized, in ascending order: *M. formosa formosa*, *M. aragonensis*, *A. pentacamerata*, *H. nuttalli*, *G. subconglobata subconglobata*, *M. lehneri*, *O. beckmanni*, *T. rohri*, *G. semiinvoluta*, and *T. cerroazulensis* s.l. zones. The planktic foraminifera retrieved from the Shale Member give an Eocene age, spanning the interval from the middle Ypresian to the latest Priabonian (P7–P17, deposited ~52–34 Ma) and indicating that the final closure of the Tethys seaway in this region should occur later than ~34 Ma.

Keywords

Planktic foraminifera, Zhepure Formation, Tethyan Himalaya, Gulupu, Yadong, Priabonian, Eocene.

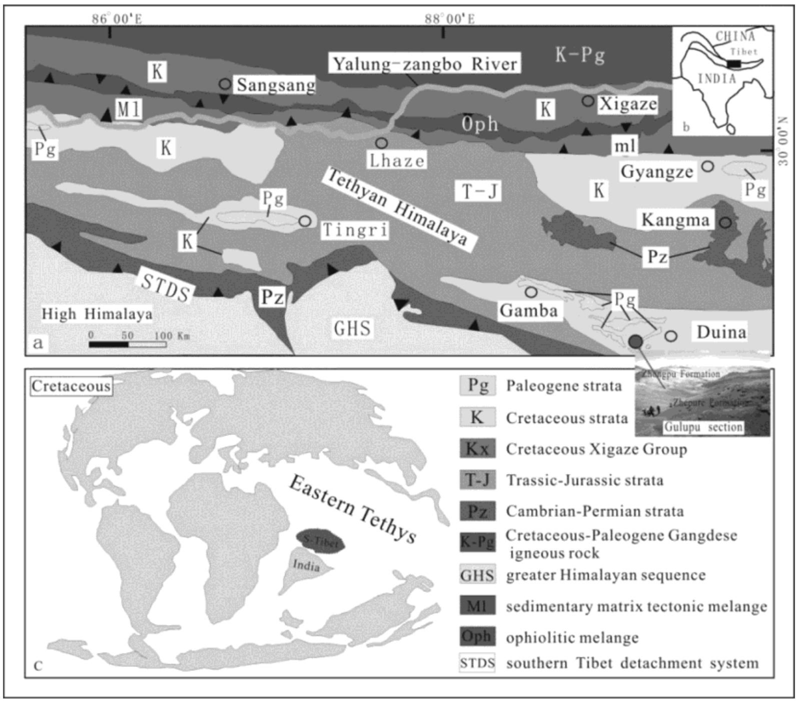

Fig. 1. Geological setting and locality of the studied section.

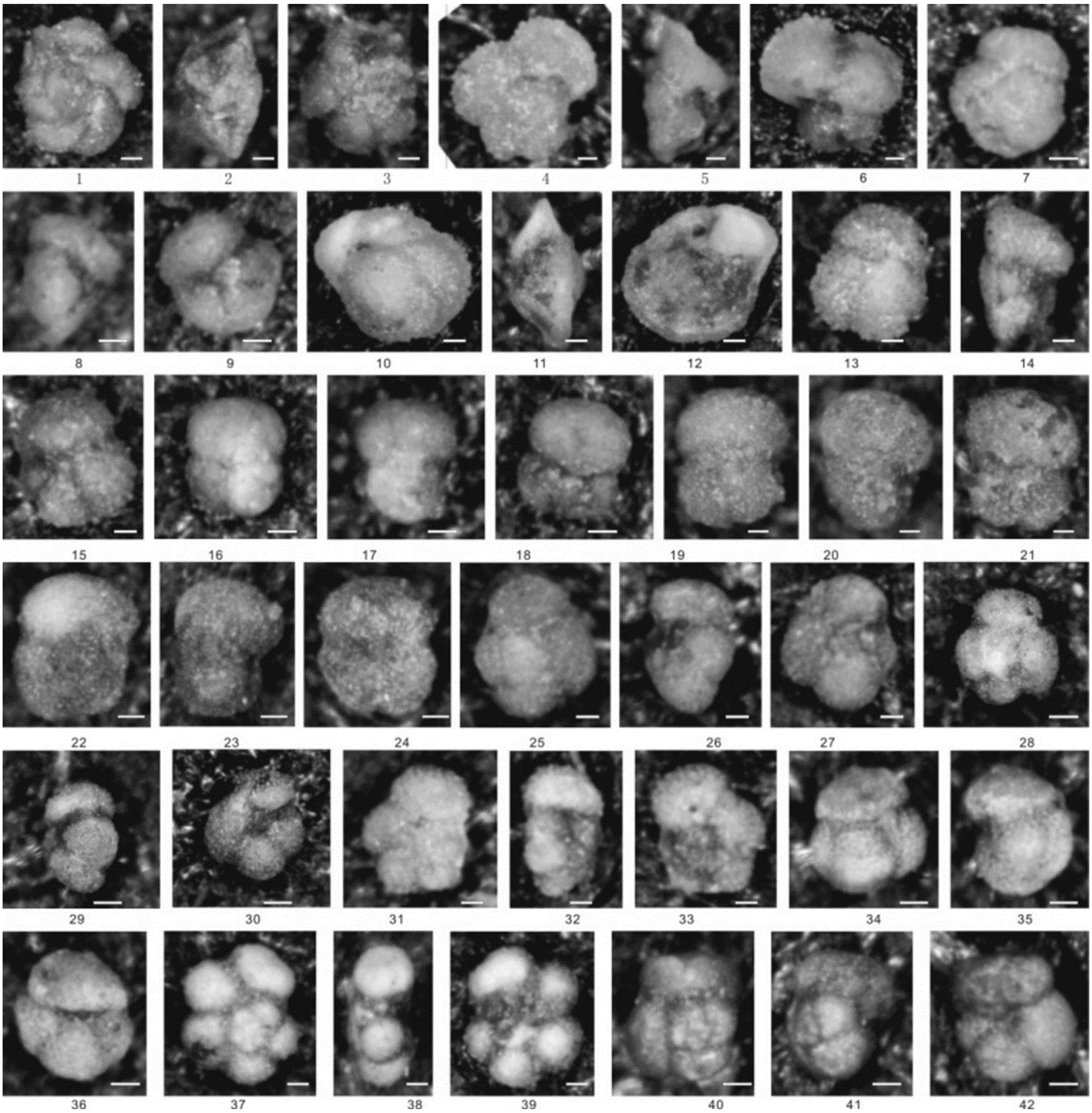

Fig. 2. The representative species of planktic foraminiferal assemblages from the Gulupu section. 1–5 – *Globigerina lozanol* Colom; 4–6 – *Morozovella spinulosa* (Cushman); 7–9, 13–15 – *Morozovella aequa* (Cushman et Renz); 10–12 – *Morozovella aragonensis* (Nuttall); 16–21 – *Turborotalia boweri* (Bolli); 22–24 – *Turborotalia cerroazulensis possagnoensis* (Toumarkine et Bolli); 25–30 – *Turborotalia cerroazulensis pomeroli* (Toumarkine et Bolli); 31–33 – *Globorotaloides eovariabilis* Huber et Pearson; 34–36 – *Globigerina senni* (Beckmann); 37–39 – *Morozovella conicotruncata* (Subbotina); 40–42 – *Acarinina primitiva* (Finlay). Scale bar equals 100 μm.

References

Li, G.B., Wan, X.Q., 2003. Eocence microfossils in southern Tibet and the final closing of the Tibet–Tethys. J. Stratigr. 27, 99–108.

Li, G.B., Wan, X.Q., Ding, L., Liu, W.C., Gao, L.F., 2004. The Paleogene foreland basin and sedimentary responses in the southern Tibet: Analysis on sequence stratigraphy. Acta Sedimentol. Sinica 22, 455–464.

Li, G.B., Wan, X.Q., Liu, W.C., 2005. Paleogene micropaleontology and basin evolution of southern Tibet. Geological Publishing House, Beijing.

Li, X.H., Wang, C.S., Luba, J., Hu, X.M., 2006. Age of initiation of the India–Asia collision in the east-central Himalaya: A discussion. J. Geol. 114, 637–640.

Najman, Y., Appel, E., Boudaghe-Fade, M.B., Bown, P., Carter, A., Garzanti, E., Godin, L., Han, J.T., Liebke, U. Oliver, G., Parrish, R., Vezzoli, G., 2010. The timing of India–Asia collision: Geological, biostratigraphic and palaeomagnetic constraints. J. Geophys. Res. 115, B12416.

Rowley, D.B., 1998. Minimum age of initiation of collision between India and Asia north of Everest based on the subsidence history of the Zhepure Mountain section. J. Geol. 106, 229–235.

Wan, X.Q., 1990. Cretaceous–Early Tertiary foraminifera of Xizang (Tibet) and evolution of the Tethys–Himalayan sea. Acta Micropalaeontol. Sinica 7, 169–186.

Wang, C.S., Li, X.H., Hu, X.M., Jansa, L., 2002. Latest marine horizon north of Qomolangma (Mt. Everest): Implications for closure of Tethys seaway and collision tectonics. Terra Nova 14, 114–120.

Willems, H., Zhou, Z.Y., Zhang, B.G., Gräfe, K.-U., 1996. Stratigraphy of the Upper Cretaceous and Lower Tertiary strata in the Tethyan Himalayas of Tibet (Tingri area, China). Geol. Rundschau 85, 723–754.

Revised stratigraphy of Indus Basin (Pakistan): Sea level changes

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The Indus Basin is located in the central and eastern part of Pakistan and further subdivided into the uppermost (Khyber–Hazara–Kashmir), upper (Kohat–Potwar), middle (Sulaiman) and lower (Kirthar) basins. The Indus Basin is situated in the west and north of Indo-Pak subcontinent, which belongs to Gondwana lands (southern earth). The sediments of Pakistan underwent significant tectonic deformation during the collision of Asian and Indo-Pak continental plates that started in the latest Cretaceous. As a result, strata were folded, faulted and elevated along with many variations of sea level (Fig. 1).

Revised stratigraphy of the Khyber-Hazara-Kashmir (uppermost Indus) Basin

The uppermost Indus Basin is the lateral extension of the upper Indus Basin in the downward slopes. In the upper Indus Basin, the alternating terrestrial and marine conditions were dominant, while the marine conditions were common in the uppermost Indus Basin. The example is the Datta Formation, which was deposited in terrestrial environments in the upper Indus Basin and marine environments in the uppermost Indus Basin.

The comprehensive and revised stratigraphic succession in the southern part of the Khyber-Hazara-Kashmir (uppermost Indus) Basin comprises the Hazara and Tanawal Quartzite formations (Precambrian), the Abbottabad and Hazira formations (Cambrian), the Chalk Jabbi Formation (Triassic), the Datta and Samanasuk formations (Jurassic), and the Chichali and Kawagarh formations (Cretaceous).

In the northern part, the succeccion includes the Panjal Formation with volcanic rocks, the Indus Formation with bauxite, chamosite and laterite of latest Cretaceous age, and the latest Cretaceous to Late Paleocene Hangu Formation. The Patala Formation is a lateral facies substitution of the Hangu Formation; its age is latest Cretaceous to Early Paleocene, because it is well correlated with the Vitakri coal of Kingri area in the Sulaiman Basin. The Hangu Formation is overlain by the Sakesar Formation (its lateral facies substitution is the Lockhart Formation). The Eocene Kuldana Group represents fine clastic Chorgali Formation and Kuldana Formation comprising red and varicoloured mudstone, sandstone, and dolomitic limestone. In this basin, first clastic material derived from the north showing first and feeble collision of Indo-Pak plate with Asia. The lower part of the Kuldana Formation is mostly continental; it is correlated with the Toi and Kingri formations of the middle Indus Basin. The upper part of the Kuldana Formation shows the transgression of the sea. It is correlated with the Habib Rahi, Domanda, Pirkoh and Drazinda formations of the Kahan Group of the middle Indus Basin. The next member of northern stratigraphic succeccion is the Miocene–Pliocene Murree Formation composed of fine to coarse clastic rocks, showing hard collision of Indo-Pak with Asia. The Soan Group is represented by the Pleistocene Lei Formation with mainly conglomerate and coarse clastic facies, and the Holocene Soan Formation comprising clay, sandstone and subordinate conglomerate and relatively fine clastic facies.

There are some problems in correlation of the Murree, Kamlial, Chinji, Nagri and Dhok Pathan formations, especially in Azad Kashmir and northern Potwar. So, the Murree Formation is the senior synonym of the Kamlial Formation. Thus, the revised succession in the Khyber-Hazara-Kashmir areas are the Murree and Soan formations, and in the Potwar area – the Murree, Chinji, Nagri and Dhok Pathan formations of the Potwar Group. In the Khyber area, the formation names are based on local names; it needs the revision and correlation to the Hazara-Kashmir area of the uppermost Indus Basin.

Revised stratigraphy of the Kohat-Potwar (upper Indus) Basin

Indo-Pakistan shield is represented by the Precambrian Nagar Parker granite in southern/lower Indus Basin and the Kirana Group composed of slate, quartzite and igneous rocks

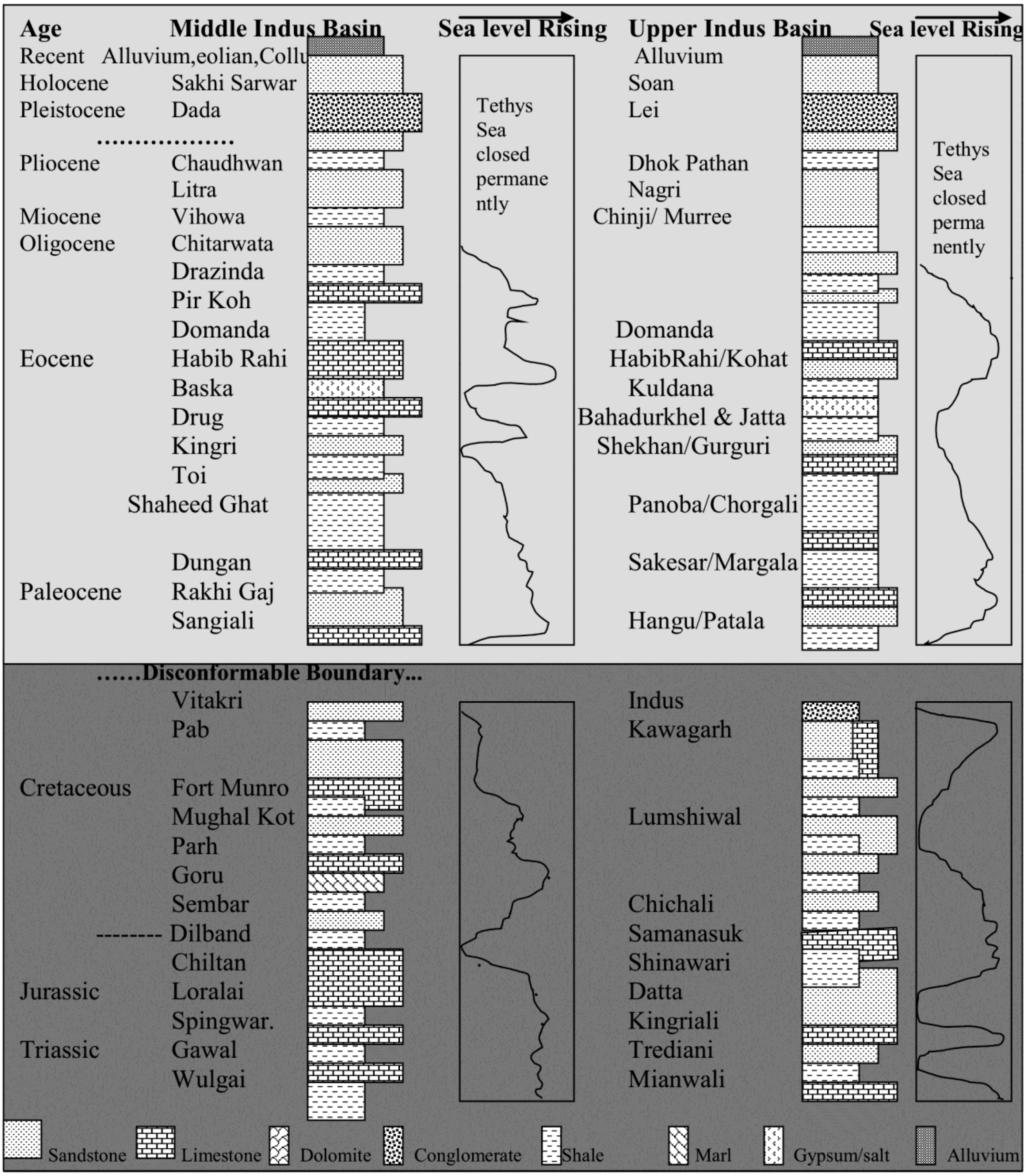

Fig. 1. Mesozoic and Cenozoic sea level curves for Sulaiman (middle Indus) and Kohat-Potwar (upper Indus) basins of Pakistan.

in the northern/upper Indus Basin. Stratigraphic succession in central and western Kohat sub-basin of the Kohat-Potwar Basin is following: the Precambrian Salt Range Formation composed of marl, gypsum, salt, and shale; the Cambrian Khewra (purple to brown sandstone), Kussak (greenish grey and glauconitic sandstone), Jutana (light green dolomite and shale), Baghanwala (red shale alternated with flaggy sandstone), and Khisor (gypsum with shale and dolomite) formations; the Permian Tobra (tillite conglomerate and sandstone), Dandot (sandstone and shale), Warcha (sandstone with some shale), Sardhi (shale with minor sandstone and siltstone), Amb (sandstone, limestone, and shale), Wargal (limestone and dolomite), and Chidru (shale and sandstone) formations; the Triassic Mianwali (shale, limestone, and sandstone), Tredian (sandstone), and Kingriali (dolomite and limestone with minor shale) formations; the Jurassic Datta (fluvial sandstone with minor shale), Shinawari (shale, limestone, and sandstone), and Samana Suk (limestone with subordinate shale) formations; the Cretaceous Chichali (glauconitic sandstone and shale), Lumshiwal (white sandstone and shale), and Kawagarh (limestone, marl, and shale) formations; the pre-Tertiary Indus Formation composed of bauxite, laterite, chamositic and glauconitic iron; the latest Cretaceous–Paleocene Hangu Formation with sandstone, shale, and coal (the synonym is the Patala Formation), the Sakesar Formation composed of nodular limestone with minor shale (synonyms are the Lockhart and Margala hill limestone), the Panoba Formation with shale, the Gurguri Formation (synonym is the Chashmai Formation, which is coeval with the Toi Formation of Sulaiman), the Shekhan Formation with limestone and shale, the Bahadurkhel Formation with halite salt, the Jatta Formation composed of gypsum with minor clay, the Habib Rahi Formation composed of limestone with marl and shale (coeval with the Kohat Formation), and the Domanda Formation (synonym is the Sirki Formation).

In Potwar, Hazara, Kashmir and eastern Kohat, the Kuldana Group includes the Chorgali Formation with shale and dolomitic limestone and Kuldana Formation composed of red and varicoloured shale, sandstone, and dolomitic limestone. The Miocene–Pliocene Murree Formation comprises sandstone, conglomerate, and shale (synonym is the Kamlial Formation), the Chinji Formation consists of red clays, sandstone and conglomerate, and the Nagri Formation is composed of sandstone with minor shale and conglomerate. The Pliocene Dhok Pathan Formation comprises clays with subordinate sandstone and conglomerate. The Pleistocene Lei Formation contains conglomerate. The Holocene Soan Formation is composed of clay, conglomerate, and sandstone; the subrecent and recent surface rocks are represented by alluvium, colluvium and eolian deposits (Fig. 1). The Waziristan–Kurram areas show the extension of Sulaiman Basin stratigraphy. The sedimentary section in Pezu to Parachinar area (Kurram Agency) is composed of interfingering strata of the middle and upper Indus basins.

Revised stratigraphy of the Sulaiman (middle Indus) and Kirthar (lower Indus) basins

The Sulaiman Basin shows the different updated succession of lithological units (Malkani 2010, 2012; Fig. 1). The Triassic Khanozai Group is represented by the Gwal Formation with shale and thin bedded limestone and the Wulgai Formation composed of shale with medium bedded limestone. The Jurassic Sulaiman Group is represented by the Spingwar Formation consisted of shale, marl and limestone with some igneous sills/dykes found close to the western Indus Suture, the Loralai Formation composed of limestone with minor shale, and the Chiltan Formation with limestone. The Cretaceous Parh Group is represented by the Sembar Formation with shale, the Goru Formation with shale and marl, and the Parh Formation composed of limestone with some volcanic sills/dykes found close to the western Indus Suture); the Fort Munro Group is represented by the Mughal Kot Formation consisted of shale/mudstone, sandstone, marl and limestone with some volcanics found close to western Indus Suture, the Fort Munro Formation with limestone, the Pab Formation composed of sandstone with subordinate shale with some evidences of Deccan volcanism, and the Vitakri Formation consisded of red muds which is the host of dinosaurs and grey to white sandstone. The Paleocene Sangiali Group is represented by the Sangiali Formation composed of limestone, glauconitic sandstone and shale, the Rakhi Gaj Formation with the Girdu Member composed of glauconitic and hematitic sandstone and the Bawata Member composed of alternation of shale and sandstone, and by the Dungan Formation with limestone and shale. The Eocene Chamalang (Ghazij) Group is represented by the Shaheed Ghat Formation with shale, the Toi Formation composed of sandstone, shale, rubbly limestone and coal, the Kingri Formation composed ofred shale/mud, grey and white sandstone, the Drug Formation composed of rubbly limestone, marl, and shale, and the Baska Formation with gypsum beds and shale; the Kahan Group is represented by the

Habib Rahi Formation with limestone, marl, and shale, the Domanda Formation composed of shale with one bed of gypsum, the Pir Koh Formation with limestone, marl, and shale, and the Drazinda Formation composed of shale with subordinate marl and *Sulaimanitherium dhanotri* (Basilosauridae) – the king of basal whale. The Oligocene–Pliocene Vihowa Group is represented by the Chitarwata Formation composed of grey ferruginous sandstone, conglomerate and mud with *Baluchitherium osborni*, the largest land mammal *Buzdartherium gulkirao*, and fresh water crocodile *Asifcroco retrai*, the Vihowa Formation composed of red ferruginous shale/mud, sandstone and conglomerate, the Litra Formation comprised of greenish grey sandstone with subordinate conglomerate and mud with host of large proboscidean *Gomphotherium buzdari*, and the Chaudhwan Formation composed of mud, conglomerate and sandstone. The Pleistocene Dada Formation is composed of conglomerate with subordinate mud and sandstone, subrecent and recent fluvial, eolian and colluvial deposits.

In general, the Kirthar Basin shows the same succession of lithological units like in the Sulaiman basin during the Mesozoic and Quaternary, but it varies in the Tertiary. The Paleocene Ranikot Group is represented by the Khadro Formation composed of sandstone, shale, limestone, and volcanics derived from Deccan volcanism, the Bara Formation composed of sandstone with minor limestone, coal and volcanics, and the Lakhra Formation with limestone and shale. The Early Eocene Chamalang/Ghazij Group (north source) has been recognized in northern Kirthar. In southern Kirthar, the Laki Group is represented by lateritic clay, ochre, coal and limestone of the Sohnari Formation and shale and limestone of the Laki Formation. The Kirthar Group is represented by the Kirthar Formation composed of shale and limestone, and the Gorag Formation mainly comprised resistant limestone. The Oligocene Gaj Group is represented by the Nari Formation composed of ferruginous sandstone, shale, limestone, and the Gaj Formation composed of shale with subordinate sandstone and limestone. The Miocene–Pliocene Manchar Group is represented by sandstone, conglomerate, and mud. Subrecent and recent surface sediments are represented by alluvium, colluvium, eolian, lacustrine, and evaporite deposits.

References

Malkani, M.S., 2010. Updated stratigraphy and mineral potential of Sulaiman (middle Indus) basin, Pakistan. Sindh Univ. Res. J., Sci. Ser. 42(2), 39–66.

Malkani, M.S., 2012. Revised lithostratigraphy of Sulaiman and Kirthar basins, Pakistan, in: Earth Sciences Pakistan 2012, Baragali Summer Campus, University of Peshawar, June 23–24, 2012, Pakistan: Abstract Volume and Program. J. Himalayan Earth Sci. 45(2), 72.

Stratigraphy of Jurassic–Cretaceous rocks of Thung Yai–Khlong Thom area, peninsular Thailand

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The Thung Yai–Khlong Thom area is located in the peninsular Thailand covering approximately 1.160 sq. km. The topography of the area is generally high mountainous and undulating landforms. The present investigation embraces defining the lithostratigraphy of non-marine Mesozoic rocks distributed in the Thung Yai–Khlong Thom area, southern Thailand. Additional attempt has been made to analyze the sedimentary sequences in terms of sedimentary facies and to reconstruct the depositional environment in the area. The oldest rocks of Thung Yai–Khlong Thom area is believed to be the Permian limestone and marine Triassic rocks. These rocks unconformably underlie the sedimentary sequences of non-marine Mesozoic rocks of the Trang Group.

The Jurassic–Cretaceous rocks (Trang Group) unconformably overlie the Permian to Triassic basement rocks. This group consists of four formations: the Khlong Min Formation, the Lam Thap Formation, the Sam Chom Formation, and the Phun Phin Formation (in ascending order). The total thickness varies from 65 to 1.145 m.

The Khlong Min Formation is represented by mudstone intercalated with fossiliferous limestone with abundant vertebrate and invertebrate fossils, and primary structures, i.e., hummocky and flaser bedding. The fossils assemblages in the lower part reflect lagoonal environment gradually changing over to lacustrine to the fluvial environment. The rocks of the Lam Thap Formation were believed to be deposited in meandering stream, floodplain, and alluvial fan environments. The paleo-currents are mainly characterized by east to west directions (285 directions). The conglomerate and conglomeratic sandstone of the Sam Chom Formation commonly exhibit sharp contacts, graded bedding, and finning upward the sequence in some areas, reflecting the braided stream and alluvial fan origins. The fine-grained sandstone is characterized by red to reddish brown color with commonly trough and planar cross-bedding of the Phun Phin Formation indicating braided stream with east direction of the paleocurrent in the lower part, and northeast direction in the upper part. The sharp contact, matrix-supported, and variety of clasts in the fanglomerate of the upper part of the Phun Phin Formation indicate debris flow origin. From stratigraphic and paleontological evidences, the age of the Trang Group should be determined as early Middle Jurassic–Late Cretaceous.

Keywords

Jurassic–Cretaceous rocks, Thung Yai–Khlong Thom, peninsular Thailand.

Palynology and magnetostratigraphy of Deccan volcanic associated sedimentary sequence of Amarkantak Group in Central India: Age and paleoenvironment

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The Deccan Continental Flood Basalt (DCFB) province covers an area of about 500.000 km² in central and western India. The study area falls in Chhindwara–Jabalpur–Seoni–Mandla (CJSM) sector of the eastern part of the Deccan Volcanic Province (EDVP) (Yedekar et al., 1996), which has ~431 m thick lava pile comprising of 34 flows and eight formations, namely the Mandla, Dhuma, Piperdehi, Linga, Multai, Amarwara, Khampa, and Kuleru formations (ascending stratigraphic order) (Geological Survey of India, 2000). Detailed palynological study of 23 intertrappean sections at nine stratigraphic levels was carried out to understand the flora, age and depositional environmental of the sediments. For better age constraint, paleomagnetic study of associated volcanic flows was also carried out.

The lowermost intertrappean, i.e. Mohgaon Kalan Well Section (MKWS), is mainly encountered in the dug wells, and the upper intertrappean, i.e. Mohgaon Kalan Fossil Forest (MKFF) rich in megaflora, is exposed in an area of about 100 km². Both these intertrappeans occur in between the Mandla and Dhuma formations.

Palynology

For palynological investigations, nine new dug well sections, namely the Government Well, Srivastava Well, Shriwas Well, Lodhi Well, Hakim-1 Well, Jamil Well, Idbi bano Well, Hakim Well, and Vishwakarma Well represented by various lithofacies (green shales, highly fossiliferous black lignitic shales, and carbonaceous clay), were studied. The samples from six dug wells (Government Well, Srivastava Well, Shriwas Well, Lodhi Well, Hakim Well, and Vishwakarma Well) yielded very good concentration of palynomorphs. The palynoflora is represented by pteridophytes, gymnosperms, angiosperms, fungal spores, fungal fruit bodies, and algal remains. The recovered palynomorphs are assigned to 35 genera and 63 species. Some of the important and newly recorded palynomorphs are *Ephedripites* spp., *Crenwellia* sp. A, *Dipterocarpuspollenites retipilatus*, *Farabeipollis minutes*, *Intratricolpites brevis*, *Incrotonipollis neyvelli*, *Jingsupollis* spp., *Paleosantalaceaepites miocenicus*, *Proteacidites spp.*, *Psilodiporites erdtmanii*, *Racemonocolpites maximus*, *Retibrevitricolporites* spp., *Retidiporites megadalensis*, *Scollardia conferta*, *Sparaganiaceaepollenites* spp., *Spinizonocolpites* spp., *Tribrevicolporites* sp., and *Tricolpites* spp. Overall, palynological assemblage of MKWS is dominated by *Ephedripites*, *Proxaperties* and *Spinizonocolpites*.

The overlying MKFF intertrappean dominated by chert yielded palynomorphs mainly from two sections, namely the Nala section and the section near Keriya village. The palynological taxa in MKFF are represented by 11 genera and 32 species. Some of the important taxa recorded from MKFF are *Aquilapollenites bengalensis*, *Azolla cretacea*, *Gabonisporis vigourouxii*, *Proxapertites operculatus*, *Spinizonocolpites echinatus*, *Jiagsupollis* spp., and the pollen of Normapolles group. Dominating forms are *Aquilapollenites bengalensis*, *Azolla cretacea* and *Gabonisporis vigourouxii*.

Overall, palynological assemblage from both intertrappean deposits shows close similarity, but palynoflora of MKWS is more diverse. The presence of *Aquilapollenites bengalensis*, *Azolla cretacea*, *Gabonisporis vigourouxii*, *Crenwellia* sp. A, *Scollardia conferta*, *Farabeipollis minutes* and *Jiagsupollis* spp. indicate Maastrichtian age for both intertrappean deposits. The presence of dominating *Spinizonocolpites* (*Nypa*) and *Proxapertites* (Arecaceae) suggests estuarine conditions at the time of deposition. High concentration of fungal remains and epiphyllous fungi (Microthyriaceae (*Phragmothyrites*), *Dicellaesporites fusiformis*, and *Frasnacritetrus indicus*) indicates the prevalence of humid conditions (Cookson, 1947; Dilcher, 1965; Selkirk, 1975; Samant and Mohabey, 2009).

The Jhilmili intertrappean occurs in between the Dhuma and Pipardehi formations. Paleocene intertrappean deposits comprise foraminifers of P1a Zone (Keller et al., 2009). They do not yield palynomorphs, but contain abundant diatoms and sponge spicules. The successively overlying Machagora, Bhutera and Lohara intertrappean deposits occur in between the Pipardehi and Linga formations, and the Umaria Isra, Imlikheda and Ghat Parasia intertrappean deposits occur in between the Linga and Multai formations. They yielded biodegraded organic material and *Glomus*-like mycorrhizal fungi only. The palynoflora is recorded from the successively overlying Pindrai, Surli and Tenadi intertrappen beds occur in between the Multai–Amarwara, Amarwara–Khampa and Khampa–Kuleru formations, respectively. The important palynotaxa recorded from these intertrappean deposits are *Cyathidites australis*, *Ericipites sahnii*, *Haloragacidites amolosus*, *Rhoipites* spp., *Psilodiporites erdtmanii*, *Retidiporites* spp., *Liliacidites* spp., *Incrotonipollis neyvelli*, *Longapertites vaneendenburgi*, *Mulleripollis bolpurensis*, *Palmaeopollenites* spp., *Proxapertites operculatus*, and *Sparganiaceaepollenites*. *Spinizonocolpites* and *Proxapertites*, which were dominant in the lowermost intertrappean, are not present in these intertrappean deposits. These intertrappeans are also characterized by high concentration of fungal fruit bodies of fungi microthyriaceae (*Phragmothyrites*) as well as *Pediastrum* and algae *Kalviwadithyrites saxenae*. The overlying Tenadi intertrappean in between the Khampa and Kuleru formations yielded mainly *Mulleripollis bolpurensis*. The stratigraphic position of the Pindrai, Surli and Tenadi intertrappean deposits is higher than the Jhilmili intertrappean, which has been dated as Paleocene on the basis of foraminifera of P0–P1 age (Keller et al., 2009). Palynology and stratigraphy suggest Paleocene age for the Pindrai, Surli and Tenadi intertrappean deposits.

Magnetostratigraphy

The study of magnetic polarity of 19 volcanic flows associated with intertrappean beds at nine stratigraphic levels between RL 525 to 850 m was carried out. The lowermost volcanic flow at the contact of Precambrian basement and successively overlying flow, i.e., upper flow of MKWS, and the lower flow of Jhilmili indicate normal polarity. The upper flow of MKFF shows mixed polarity. The basaltic flow overlying Jhilmili intertrappean, which contains foraminifers of P1a Zone of Early Paleocene age, indicates reverse polarity. The volcanic flow underlying the Ghat Parasia intertrappean indicates reverse polarity. After that, all the flows, i.e., flow overlying the Ghat Parasia, and upper and lower flows of Pindrai, Surli and Tenadi intertrappean deposits, indicate normal polarity. The magnetic polarity data indicate 30N–29R–29N sequence in the study area.

Summing up, palynology and magnetic polarity data in the study area indicate deposition of sediments in humid–semiarid–sub-humid climate under estuarine to increasingly fresh water depositional conditions during the chrons 30N–29R–29N of Late Maactrichtian to Early Paleocene.

References

Cookson, I.C., 1947. Plant microfosssils from the lignite of Kergulen Archipelago, in: BAN2ARE Report, Ser. A, II, pp.127–148.

Dilcher, D.L., 1965. Epiphyllous fungi from Eocene deposits in western Tennessee USA. Palaeontographica B 116, 1–156.

Geological Survey of India, 2000. District resource map, Chhindwara District, Madhya Pradesh.

Keller, G., Adatte, T., Bajpai, S., Mohabey, D.M., Widdowson, M., Khosla, A., Sharma, R., Khosla, S.C., Getsch, B., Fleitmann, D., Sahani, A., 2009. K–T transition in Deccan Traps of Central India marks major marine seaway across India. Earth Planet. Sci. Lett. 282, 10–23.

Samant, B, Mohabey, D.M., 2009. Palynoflora from Deccan volcano-sedimentary sequence (Cretaceous–Palaeocene transition) of central India; implications for spatio-temporal correlation. J. Biosci. 34, 811–823.

Selkirk, D.R., 1975. Tertiary fossil fungi from Kiandra, New South Wales. Proc. Linn. Soc. N.S.W. 100, 70–94.

Yedekar, D.B.S., Aramaki, T., Fujii, T., Sano, T., 1996. Geochemical signature and stratigraphy of Chhindwara–Jabalpur–Seoni–Mandla sector of the Eastern Deccan Volcanic province and problem of its correlation. Gondwana Geol. Magazine, Spec. Vol. 2, 49–58.

Bio- and lithostratigraphy of the Jurassic–Cretaceous boundary deposits in the Komsomolsk section (Russian Far East)

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The Komsomolsk section (also known as the Pivan section) crops out in a series of exposures at the right bank of the Amur River opposite to Komsomolsk-on-Amur and runs for over 18 km. In 1960s, the clastic strata of 6000 m thick were subdivided into six formations in the area near Komsomolsk-on-Amur, namely the Ulbin Formation, the Silinka Formation, the Padali Formation, the Gorin Formation, the Pioneer Formation, and the Pivan Formation. The latter three were usually joined into the Komsomolsk Group (e.g., Vereshchagin, 1977). The section's folded structure was considered as a limb of a large anticline with a dominant monoclinal southeast dip. The anticline hinge was suggested to be northwesterly off the Komsomolsk section.

Later, during the more detailed mapping and investigation of the folding character, a set of large isoclinal folds locally faulted was revealed. It was assumed that the sediments previously ascribed to the Ulbin, Padali and Pioneer formations, having similar rock compositions, are actually the same single unit. This conclusion was then confirmed by different fauna, which in all the earlier isolated formations are represented by the Volgian–Valanginian species (e.g., Kirillova, 2009). The Silinka and Pivan formations occurring in syncline hinges also turned out to be a single unit having a higher stratigraphic position. Finally, three nameless strata were recognised: (1) the stratum of rhythmic alternation of Volgian age, (2) the siliceous–siltstone stratum of Volgian–Valanginian age, and (3) the sandstone Valanginian stratum (e.g., Kirillova et al., 2002; Kirillova, 2009). The rhythmic alternation stratum is correlated with the former Gorin Formation.

The most complete section of the rhythmic alternation stratum was described at the right bank of the Amur River near the Pivan wharf; here, its thickness reaches 700 m. The rhythmic alternation of sand and siltstone and the subordinate layers and lenses of gravelite and conglomerate are characteristic for the stratum. During the 2001 Russian–Japanese expedition to the Komsomolsk section, this stratum was sampled for radiolarian. In the NE stratum's outcrop, the cherty siltstone with felsic tuff layers yielded, according to K. Isida (Kirillova et al., 2002), the Late Tithonian radiolarians. The same stratum contains an exotic block of tectonic melange (120 m); this block comprises chert, cherly mudstone slate, and limestone and produced the Early–earliest Late Jurassic radiolarians.

The middle siltstone stratum comprises siltstone, silty sandstone, and a subordinate amount of small-grained and fine-grained sandstone. The most complete section of the siltstone stratum (stratotype of the former Pioneer Formation) was described in the Komsomolsk section; here, its thickness reaches 1100 m. For this stratum, vast lists of bivalves (*Buchia*, *Anopaea*, *Inoceramus*, and *Lima*) were compiled by V.N. Vereschagin, T.D. Zonova, A.A. Kapitsa, L.D. Tretiakova, V.P. Pokhialainen, and K.V. Paraketsov along with sparse record of ammonite (*Thurmanniceras? thurmanni*) and occasional plant remnants (e.g., Vereshchagin, 1977; Kirillova, 2009). Only a few of them have been illustrated: *Buchia* aff. *jasikovi*, *Anopaea pivanensis*, *A. stempeli*, *A. savrasovi*, *A. gerasimovi*, *Inoceramus vereshagini*, *I.* cf. *vereshagini*, *I. glasunovi*, *I. koslovi*, *I. acuticostatus*, *I. subardonensis*, and *Lima* (*Lima*) aff. *consobrina* (e.g., Pokhialainen, 1969; Kapitsa, 1978; Sey et al., 2004).

The upper sandstone stratum conformably overlies the siltstone one. The former is dominated by medium-grained coarse-layered sandstone with sparse coarse-grained sandstone, gravelite, sedimentary breccia, siltstone, and beds of alternation of sandstone and siltstone.

The stratum sequence is most fully presented in the Komsomolsk section; however, it lacks there its upper horizons. The stratum's total thickness is about 800 m. The publications contain illustrations of bivalves *Anopaea amurensis* and *Inoceramus quasineocomiensis* (Kapitsa, 1978), and ammonite *Sarasinella* cf. *varians* (Sey et al., 2004). Apparently, the same strata (the formation was not mentioned) yielded *Buchia keyserlingi* and *B*. ex gr. *keyserlingi* (Sey et al., 2004).

An analysis of the stratigraphic distribution of the *Buchia* assemblages in the Komsomolsk section allowed us to establish four successive beds with *Buchia* (Urman et al., 2014).

Beds with *B*. *terebratuloides* were identified in the "rhythmic alternation stratum" in which *B*. *terebratuloides* has been found along with *Buchia* sp. ind., *Malletia* sp. ind., and an indefinable fragment of ammonite. The upper boundary of the beds is defined by the change of buchiid assemblages and the first appearance of *B*. *unschensis*. These beds are comparable with the *B*. *obliqua* Zone, which was recognised in the same volume as the lowermost Upper Volgian *Craspedites okensis* ammonite Zone in Siberia, in the Pechora River basin, and on Franz Josef Land (Rogov and Zakharov, 2009). At the base of the *B*. *obliqua* Zone, according to V.A. Zakharov (1981, 1987), there are representatives of the index species along with *B*. *terebratuloides*.

Beds with *B*. *unschensis* and *B*. *terebratuloides* were identified in the middle part of the "siltstone stratum," in which numerous *B*. *terebratuloides*, *B*. *fischeriana*, and *B*. *unschensis* typical of the Volgian–Ryazanian boundary layers have been found. These layers in the Komsomolsk section also provided sparse bivalves *Lima* sp. ind. and *Inoceramus* sp. ind., and a Tethyan ammonite provisionally determined as *Pseudosubplanites?* sp. The *B*. *unschensis* Zone has been recognised in many Boreal sections (e.g., Zakharov, 1981, 1987; Jeletzky, 1984); this zone corresponds to the beds with *B*. *unschensis* and *B*. *terebratuloides* of East Greenland (Surlyk, 1982), and these are the same beds as identified in the Komsomolsk section.

Beds with *B*. *volgensis* were recognised at the top part of the "siltstone stratum" by finds of typical Berriasian *B*. *volgensis* and *B*. *okensis*. The latter species is found only in the lower half of the beds. The beds also contain scattered rare shells of *B*. *terebratuloides*, *B*. *fischeriana* (close to the bottom), *B*. *unschensis*, and probably *B*. aff. *jasikovi* illustrated by Sey et al. (2004). Some of inoceramids, illustrated by A.A. Kapitsa (1978), were found in this part of the section (for discussion see Urman et al., 2014). Beds with *B*. *volgensis* correlate with the eponymous *Buchia* zone of Siberia, the Pechora River basin, and Svalbard (e.g., Zakharov, 1981, 1987).

Beds with *B*. *inflata* and *B*. *keyserlingi* were established in the "sandstone stratum". They are comparable to two buchiazones widespread in the Boreal sections: the *B*. *inflata* Zone (lower upper part of the Lower Valanginian; in some regions, it also includes the uppermost Berriasian) and the *B*. *keyserlingi* Zone (upper part of the Lower Valanginian). A more detailed subdivision of these beds in the Komsomolsk section did not succeed, because the *B*. *keyserlingi* was seen rarely and was not recorded separately from *B*. *inflata*. Therefore, it is possible that beds with *B*. *inflata* and *B*. *keyserlingi* embrace here only the *B*. *inflata* Zone.

Cephalopod remains in the Komsomolsk section are very rare. However, certain intervals of the section may be correlated with the Berriasian (based on the findings of *Pseudosubplanites?* sp.) and Valanginian (the findings of *Sarasinella* cf. *varians*). The complete absence of belemnites in the Komsomolsk section possibly may be explained by the relatively deep environment of its formation. In the modern palaeogeographic scheme of the East-Asian continental margin for the Jurassic–Cretaceous transition (Volgian–Valanginian), the Komsomolsk section territory fits the zone of a moderately deep-water continental slope (Kirillova, 2009). Notably, cylindroteuthid belemnites preferred to inhabit shallow depths of probably less than 200 m (e.g., Dzyuba, 2013).

Thus, the stratigraphic subdivision and correlation of the Komsomolsk section with sections in adjacent regions is based mainly on buchiids. An analysis of the stratigraphic distribution of the *Buchia* assemblages allowed us to establish here a sequence of beds with *Buchia* that is well comparable with the buchiid zonal scales of many Boreal regions. Ammonite findings permitted us to correlate some intervals of the section with the Berriasian and the Valanginian. On the basis of the revision of the palaeontological characteristics and biostratigraphic studies, the Komsomolsk section has gained significantly updated ages of strata recognised here. It was established that the "rhythmic alternation stratum" is an earliest Late Volgian in age, the "siltstone stratum" is a latest Late Volgian–Ryazanian, and the "sandstone stratum" is an Early Valanginian. Palaeontological data indicate the presence of the large synclinal fold in the studied outcrops: while approaching toward the alleged location of the large synclin's hinge, the layers gradually youthen from both the southwest and northeast.

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References

Dzyuba, O.S., 2013. Belemnites in the Jurassic–Cretaceous boundary interval of the Mauryn'ya and Yatriya River sections, Western Siberia: Biostratigraphic significance and dynamics of taxonomic diversity. Stratigr. Geol. Correl. 21(2), 189–214.

Jeletzky, J.A., 1984. Jurassic–Cretaceous boundary beds of Western and Arctic Canada and the problem of the Tithonian–Berriasian stages in the Boreal Realm. Geol. Assoc. Canada, Spec. Pap. 2, 175–255.

Kapitsa, A.A., 1978. New species of the Lower Cretaceous inoceramids of the Lower Amur region, in: Biostratigraphy of the Southern Far East (Phanerozoic). Vladivostok, pp. 65–77 (in Russian).

Kirillova, G. L., Natal'in, B.A., Zyabrev S.V., et al., 2002. Upper Jurassic–Cretaceous deposits of East Asian continental margin along the Amur River, in: Kirillova, G.L. (Ed.), Field excursion guidebook. Khabarovsk.

Kirillova, G.L. (Ed.), 2009. Middle Amur sedimentary basin: Geology, geodynamics, and fuel-energetic resources. DVO RAN, Vladivostok (in Russian).

Pokhialainen, V.P., 1969. Neocomian inoceramids of the Anadyr–Koryak fold area, in: Jurassic and Cretaceous inocerams of Northwest USSR. SVKNII, Magadan, pp. 124–162 (in Russian).

Rogov, M., Zakharov, V., 2009. Ammonite and bivalve based biostratigraphy and Panboreal correlation of the Volgian Stage. Sci. China Ser. D-Earth Sci. 52(12), 1890–1909.

Sey, I.I., Okuneva, T.M., Zonova, T.D., et al., 2004. Atlas of the Mesozoic marine fauna of the Russian Far East. VSEGEI, St. Petersburg (in Russian).

Surlyk, F., Zakharov, V.A., 1982. Buchiid bivalves from the Upper Jurassic and Lower Cretaceous of East Greenland. Palaeontol. 25, 727–753.

Urman, O.S., Dzyuba, O.S., Kirillova, G.L., Shurygin, B.N., 2014. Buchia faunas and biostratigraphy of the Jurassic–Cretaceous boundary deposits in the Komsomolsk section (Russian Far East). Russ. J. Pac. Geol. 8(5), 346–359.

Vereshchagin, V.N., 1977. Far East Cretaceous System. Nedra, Leningrad (in Russian).

Zakharov, V.A., 1981. Buchiids and biostratigraphy of the Boreal Upper Jurassic and Neocomian. Nauka, Moscow (in Russian).

Zakharov, V.A., 1987. The bivalve Buchia and the Jurassic–Cretaceous boundary in the Boreal Province. Cretaceous Res. 8, 141–153.

Environments of conservation of the dinosaurs in the Mesozoic deposits of south-eastern West Siberia (Shestakovskii Yar section)

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A skull and partial skeleton of a small *Psittacosaurus* named *Psittacosaurus sibiricus* were discovered in the coastal cliff of the Kiya River near Shestakovo village (Kemerovo Oblast) in 1953. The age of the deposits comprising skeletal remains of the dinosaur was dated as an Early Cretaceous. It is based on the widely spread opinion that the psittacosaurs reached their acme in Central Asia in the Early Cretaceous, so fossils of this fauna group serve as indicators of this epoch. Deposits built up the coastal cliff of the Kiya River were attributed to the continental Ilek Formation. According to the stratotype, its distinctive feature is the intercalation of calcareous clay or marl (reddish-brown or cherry-red in color, often with bluish-green or purple stains), brown and greenish siltstone, and green fine-grained sandstone (Khlonova et al., 1990). The Ilek Formation (100–760 m thick) formed in the Chulym-Yenisei facial area during the Berriasian and Valanginian was studied in natural outcrops and drill cores, and dated by the rare freshwater fauna, skeletal remains of the dinosaur, spores and pollen.

A major discovery was made in this outcrop in the end of 20th century. Monolithic blocks were sawed out at different levels and moved down to for preparation. Further layer-by-layer preparation (top down) of one block revealed well preserved skeletal remains, similarly oriented and arranged on one surface, one next to the other, and belonging at least to three psittacosaurs. In this connection, a hypothesis of their possible burial during the lifetime was suggested. Such occurrences are rare and unique. Moreover, a smaller animal was found in the other monolith block, probably belonging to a different species. The lithological study of the nearby deposits provided the evidence of undisturbed burial of the first group of dinosaurs confirmed by grain size distribution and mineralogical composition of the sediments, studied in different layers of the section.

The nearby rocks are visibly homogeneous. They are represented by light-greenish, weakly cemented silty sandstone or sandy silt, without any inclusions, and with massive texture. Rare thin fragments of charred plant detritus were only documented using microscopic study. Particle-size distribution in the sample taken from the surface on which psittacosaurs were standing or lying, demonstrates perfect symmetrical monomodal spectrum, where the moda is the size of the most commonly encountered grains (in this case up to 9.7%) corresponds to 74 microns (Fig. 1a). This type of distribution appears to be the most typical for the sublittoral sediments (underwater coastal slope), formed on the continental shelf below the level of the lowest tide. Deposits characterized by more complex and usually bimodal curves are formed in the environments of tideland zone (upper littoral by Sverdrup et al., 1942). Spectrum changes in the layer lying two centimeters above (Fig. 1b). Mode corresponds to the size of 176 microns, and the number of clasts with such diameter is 8.6%. The cumulative percentage at the level of mode (the total content of all particles with a diameter smaller than that of the most common grains) is 73.5. The distribution curve becomes asymmetrical. The rocks overlying the skeletal remains tend to be more poorly sorted (Fig. 1c). The number of grains with the dominant diameter (148 microns) constitutes only 7%, with the cumulative percentage at the level of mode being 69.3. At this, the content of pelitic fractions (particles with a diameter smaller than 0.01 mm) is almost unchanged in the sediments, ranging within 7.9–10.4% from the base to the top of the monolith block. The nature of the change of the curves indicates the input of coarser material into the sedimentation area from the deposits with distribution type close to symmetric. The breaking rocks probably also represented facies of the underwater coastal slope, cropping out onto the surface as a result of significantly lowered sea-

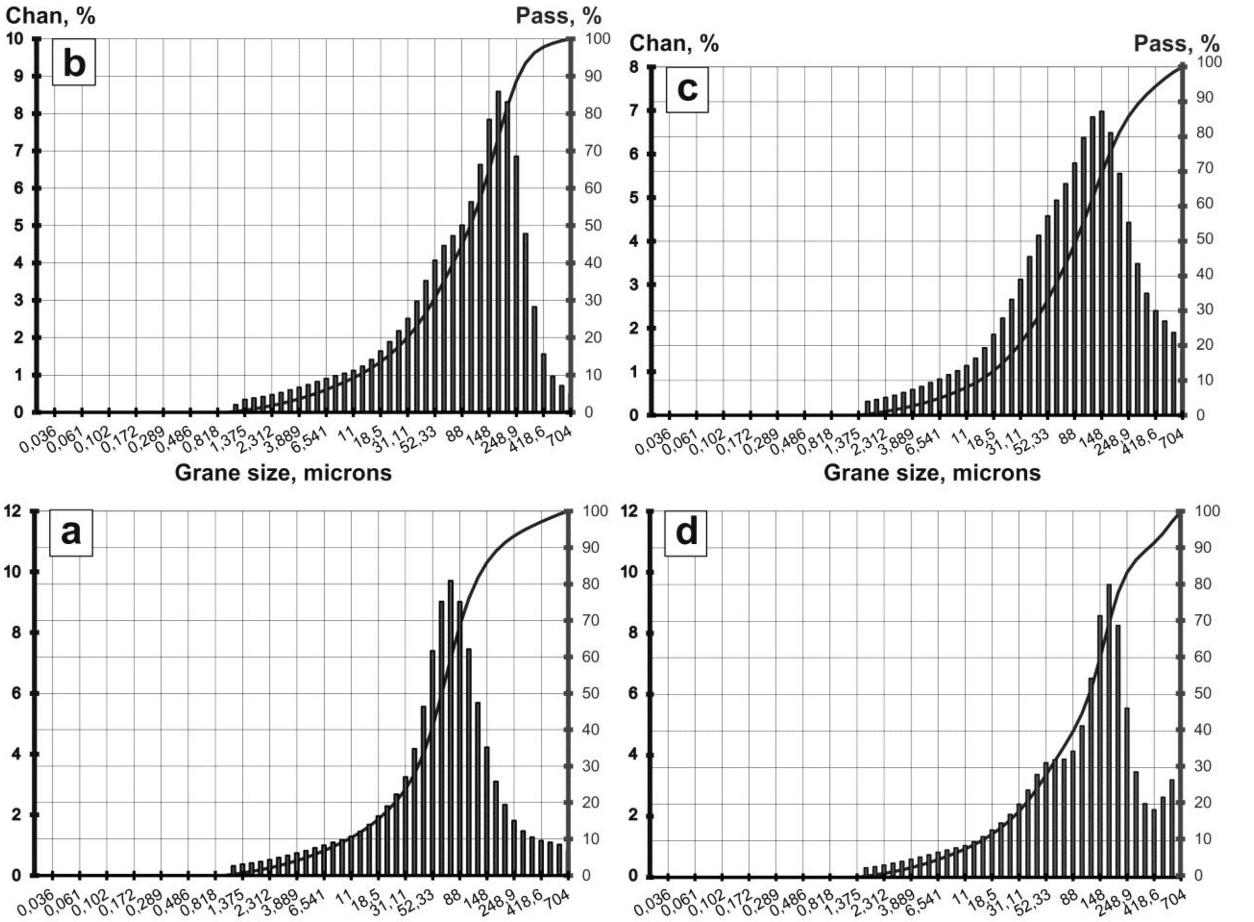

Fig. 1. Particle size distribution in the weakly cemented silty sandstone or sandy silt, enclosing *Psittacosaurus* skeletal remains.

level. The polymodal type of the distribution is typical for the sandstone from another monolith block (with smaller animal) (Fig. 1d).

The mineral composition of siltstone and sandstone from different sections appears to be identical, and it comprises calcite (36%) including pellets, outigenic cement and part of the clasts. Nevertheless, basal type of cementation is not solid, and it is quickly destructed in the water. Scanning electron microscopy investigation allows the determination of two types of the calcareous cement (Fig. 2). The first one was formed in the process of sedimentation of crusts fouling on calcareous clastic grains as a result of biochemogenic precipitation of the microcrystalline calcite from seawater. Crusts are round in shape with a diameter up to 10 microns, and they overlap each other forming microstructures similar to the roof tiles. All fragments of a 'roof tiles' are penetrated by frequent and equally oriented tubular micropores (Fig. 2a). The second type of cement was formed during postsedimentary transformations by perecrystallization of the first type. Well crystallized calcite crystals without any micropores are observed in the interstices between the fragments (Fig. 2b). In some sites, their aggregates form basal type of cementation.

Small concentrations of organic carbon in the rocks and the absence of life traces of the benthic organisms indicate undeveloped trophic base. It is assumed, that the herbivorous dinosaurs would roam on the slope in search of food during spans of low tide, looking for food in the niches of coastal cliff or hiding there from the predators. Probably, the algal mass accumulated in niches due to wave processes attracted the psittacosaurs. Thus, a group of the pasturing animals could be buried under the rock-fall caused by weathering of sediments formed a steep cliff and readily swelled on the wetting. Part of moved sediments occurred above the sea level

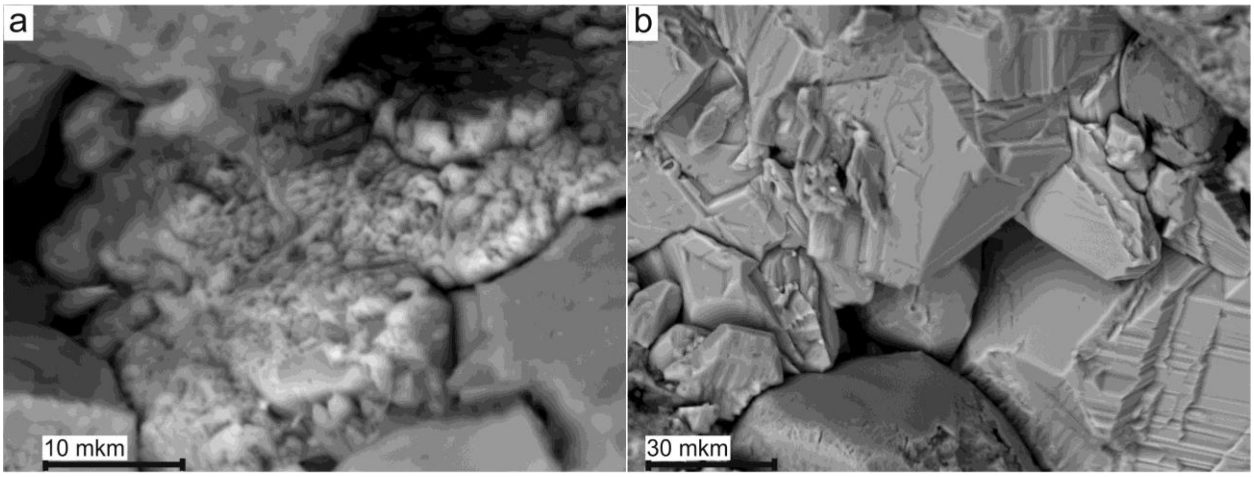

Fig. 2. Types of the calcareous cement.

for a long time that resulted in its transformation into reddish-brown clay silt of the weathering crust. Their color is resulted from the oxidation processes of Fe-, Ti-, Cr- containing minerals (fayalite, amphibole, chromespinellids etc.) presented in clastic parts of the rocks. Several such lenticular horizons ranging in thickness from tens of centimeters to several meters are observed in natural outcrops in Shestakovskii Yar. Apparently, the described events repeatedly took place on the paleobasin coast indicating significant fluctuations in sea level. The obtained results contradict the continental genesis of the Ilek Formation (Khlonova et al., 1990). Classical alluvial rhythms and remains of the root system of ancient plants are not observed in this section, and carbonized plant detritus of different dimensions is rare. At the same time, skeletal remains of dinosaurs, crocodiles, turtles, fish, birds and mammals (representatives of the orders Triconodonta and Symmetrodonta) were revealed. According to many experts, the extinction of the representatives of Symmetrodonta occurred in the Late Jurassic. Thus, the deposits from the Shestakovskii Yar section were probably formed in the latest Jurassic–earliest Cretaceous. Taking it into account, the south-east regions of Western Siberia can be considered as the ancestral homeland of psittacosaurs occupied different regions of Central Asia in the Early Cretaceous.

References

Khlonova, A.F., Papulov, G.N., Purtova, S.I., Strepetilova V.G., 1990. Non-marine Cretaceous of Western Siberia, in: Continental Cretaceous USSR. FEB AS USSR, Vladivostok.

Sverdrup, H.U., Johnson, M.W., Fleming, R.H., 1942. The oceans: Their physics, chemistry, and biology. Prentice Hall, New York.

Session 5
Cretaceous vertebrates of Asia and the Western Pacific

Stable isotope composition of modern and fossil archosaur eggshells as a tracer of animal ecology, living environment and reproductive strategy

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Stable oxygen and carbon isotope compositions of fossil remains from vertebrate mineralized tissues (bones, teeth, scales) have been widely used to infer past ecologies (Clementz and Koch, 2001; Amiot et al., 2010) and environmental conditions (Suarez et al., 2014; Amiot et al., 2015; Domingo et al., 2015; Goedert et al., 2016). Tooth enamel is of primary interest due to its strong resistance to diagenetic processes, and its stable oxygen and carbon isotope compositions of phosphate and carbonate can retain primary isotopic record, even for fossil remains dating back to the early Paleozoic (Trotter et al., 2008). However, some vertebrates such as birds and some dinosaurs are toothless and their bony remains can be more easily altered, thus limiting their use as biological or environmental indicators based on their stable isotope compositions. On the other hand, eggshell remains are abundant in the sedimentary record and have been found in deposits dated back to the Late Triassic. Due to their calcitic nature, oxygen and carbon isotope compositions of fossil bird and dinosaur eggshells ($\delta^{18}O_{calc}$ and $\delta^{13}C_{calc}$) are regularly used to reconstruct paleoenvironmental conditions (Sarkar et al., 1991; Montanari et al., 2013). However, the interpretation of $\delta^{18}O_{calc}$ values of fossil eggshells has been limited to qualitative variations in local climatic conditions as oxygen isotope fractionations between calcite, body fluids and drinking water have not been determined yet.

For this purpose, eggshell, albumen and drinking water of extant birds and crocodilians have been analyzed for their oxygen and carbon isotope compositions. Relative enrichments in ^{18}O relative to ^{16}O between body fluids and drinking water of about +2‰ for semi-aquatic birds and of about +4‰ for terrestrial ones are observed. Surprisingly, no dependence to body temperature on the oxygen isotope fractionation between eggshell calcite and body fluids is observed, suggesting that bird and crocodile eggshells, for which we determined similar fractionation factors between body water and eggshell calcite, precipitate out of equilibrium.

Two empirical equations relating the $\delta^{18}O_{calc}$ value of eggshell calcite to the $\delta^{18}O_{w}$ value of ingested water have been established for terrestrial and semi-aquatic birds.

These various equations have been applied to fossil eggshells and allowed to demonstrate their potential use as a tracer of past environments (in terms of air temperature, aridity), ecology (in terms of aquatic or terrestrial lifestyle) and reproductive strategy (in terms of egg formation periods, either seasonal or all year round).

References

Amiot, R., Buffetaut, E., Lécuyer, C., Wang, X., Boudad, L., Ding, Z., Fourel, F., Hutt, S., Martineau, F., Medeiros, M.A., Mo, J., Simon, L., Suteethorn, V., Sweetman, S., Tong, H., Zhang, F., Zhou, Z., 2010. Oxygen isotope evidence for semi-aquatic habits among spinosaurid theropods. Geology 38, 139–142.

Amiot, R., Wang, X., Zhou, Z., Wang, X., Lécuyer, C., Buffetaut, E., Fluteau, F., Ding, Z., Kusuhashi, N., Mo, J., Philippe, M., Suteethom, V., Wang, Y., Xu, X., 2015. Environment and ecology of East Asian dinosaurs during the Early Cretaceous inferred from stable oxygen and carbon isotopes in apatite. J. Asian Earth Sci. 98, 358–370.

Clementz, M.T., Koch, P.L., 2001. Differentiating aquatic mammal habitat and foraging ecology with stable isotopes in tooth enamel. Oecologia 129, 461–472.

Domingo, L., Barroso-Barcenilla, F., Cambra-Moo, O., 2015. Seasonality and paleoecology of the Late Cretaceous multi-taxa vertebrate assemblage of "Lo Hueco" (Central Eastern Spain). PloS One 10, e0119968.

Goedert, J., Amiot, R., Boudad, L., Buffetaut, E., Fourel, F., Godefroit, P., Kusuhashi, N., Suteethom, V., Tong, H., Watanabe, M.E., Lécuyer, C., 2016. Preliminary investigation of seasonal patterns recorded in the oxygen isotope composition of theropod dinosaur tooth enamel. Palaios 31, 10–19.

Montanari, S., Higgins, P., Norell, M.A., 2013. Dinosaur eggshell and tooth enamel geochemistry as an indicator of Mongolian Late Cretaceous paleoenvironments. Palaeogeogr. Palaeoclimatol. Palaeoecol. 370, 158–166.

Sarkar, A., Bhattacharya, S.K., Mohabey, D.M., 1991. Stable-isotope analyses of dinosaur eggshells: Paleoenvironmental implications. Geology 19, 1068–1071.

Suarez, C.A., González, L.A., Ludvigson, G.A., Kirkland, J.I., Cifelli, R.L., Kohn, M.J., 2014. Multi-taxa isotopic investigation of paleohydrology in the Lower Cretaceous Cedar Mountain Formation, Eastern Utah, USA: Deciphering effects of the Nevadaplano Plateau on regional climate. J. Sediment. Res. 84, 975–987.

Trotter, J.A., Williams, I.S., Barnes, C.R., Lécuyer, C., Nicoll, R.S., 2008. Did cooling oceans trigger Ordovician biodiversification? Evidence from conodont thermometry. Science 321, 550–554.

Late Cretaceous (Maastrichtian) vertebrate fossils from inland basins of Indian peninsula – their palaeogeographic significance

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The Indian subcontinent had a dynamic geographic and geologic history, i.e., key to understanding major palaeobiogeographic and macroevolutionary events in Earth history, including the Cretaceous–Paleogene (K–Pg) mass extinction event. In Central India, the Upper Cretaceous (Maastrichtian) is represented by the Lameta Formation in Jabalpur, Bagh area in Jhabua and Dhar districts of Madhya Pradesh, Pisdura–Dongargaon area in Chandrapur and Nagpur districts of Maharashtra, and Balasinor–Rahioli area of Kheda and Panchmahal districts of Gujarat. In all these areas, the Lameta Formation is characterised by its vertebrate fossil content, particularly dinosaurs. Several workers described faunal assemblages from the Lameta Formation in these areas from time to time. There are some important features of vertebrate faunal assemblages.

Jabalpur. The Jabalpur Lameta beds are considered to be more significant due to rich preservation of dinosaurian remains. Rich assemblage consists of caudal vertebrae, tooth, coprolites and skulls of Sauropoda, Theropoda, and Ornithopoda, i.e., *Titanosaurus indicus* and *Antarctosaurus septentrionalis* (sauropods); *Indosuchus raptorius*, *I. matleyi*, *Lametasaurus indicus*, *Composuchus solus*, *Laevisuchus indicus*, *Jubbalppuria tenuis*, *Dryptosauroides* (?) *grandis*, *Ornithomimoides mobilis*, and *O. barasimlensis* (theropods); *Brachypodasaurus gravis* (ornithopods) (Lydekker, 1877; Matley, 1924; Huene and Matley, 1933; Chatterjee, 1978; Mohabey, 1987; Jain and Bandopadyay, 1997; Loyal et al., 1998; Demic et al., 2009). Egg nests and eggs are represented by *Megaloolithus dhoridungriensis* (Mohabey, 1996, 1998, 2000, 2001a,b).

Nand–Dongargaon. Dinosaur remains consists of *Titanosaurus indicus*, *T. blandfordi*, *T. colberti*, and *Laplatasurus madagascariensis* (Lydekker, 1890; Chakravarti, 1934; Chatterjee, 1978; Carrano et al., 2010). Egg nests and eggs include *Megaloolithus matleyi* and *M. megadermus* (Jain and Sahini, 1985; Shukla and Srivastava, 2008). The Lameta beds of Maharashtra deposited in alluvial-limnic semi-arid conditions during the Maastrichtian (Mohabey, 1990, 1996; Udhoji and Mohabey, 1991; Mohabey and Udhoji, 1993).

Balasinor–Jhabua. This inland basin is important because of well preservation of skeletal remains, egg nests and eggs of dinosaurs in the Balasinor and Rahioli localities of the Kheda and Panchmahal districts in Gujarat. It is interpreted to be the deposits of sheet washed into palustrine environment (Mohabey, 1998, 2001a,b). Dinosaur remains consist of *Antarctosaurs septentrionalis* (sauropods) and *Rajasaurus narmadensis* (thereopods) (Huene and Matley, 1933; Mohabey, 1987; Wilson and Upchurch, 2003; Wilson et al., 2003). Nests and eggs include *Megaolothus rahioliensis*, *M. phensaniesis*, *M. khempuensis*, *M. megadermus*, and *M. balasinorensis* (Huene and Matley, 1933; Mohabey, 1983, 1998; Khosla and Sahni, 1995). Using oxygen and carbon isotope analysis, fluvial or mostly lacustrine environment of deposition were proposed, particularly for the egg-bearing horizons.

Salbardi basin. The Lameta sedimentation in Salbardi took place after Gondwana sedimentation. The lower part of the Lameta succession is mainly represented by arenaceous and argillaceous sediments that show a change in the energy conditions in the depositing medium. In the upper part, the succession is mostly calcareous, evidencing the shallowing of the basin and alkaline nature of the depositing medium (Roopesh and Srivastava, 2015). Salbardi basin is found to be productive for dinosaurian remains. It contains fragmentary bones preserved in light green-coloured, medium-grained sandstone. Srivastava and Mankar (2013, 2015) have reported fragmentary remains of right ulna of *Titanosaurus colberti*, egg nest and eggs belonging to *Megaloolithus oogenus* of the family Megaloolithidae. Arun and Varsha (Aglawe and Bhadran, 2014; Bhadran and Aglawe, 2015) reported turtle and theropod (abelisaurid?) bones from the same locality.

Comparison of the Salbardi area with other areas of the Lameta Formation occurrence shows that it was nearly similar in size as the Jabalpur, Rahioli and Nand–Dongargaon basins. The dinosaurian remains including bones and eggs are indicative of channel to point bar deposition under sub-arid condition. The study of this new location allows the modification of earlier proposed palaeogeography of Lameta sedimentation in larger geographical extent. In conclusion, a new inland basin has been identified for Lameta sedimentation, i.e. the Salbardi–Belkher (Roopesh and Srivastava, 2015).

References

Aglawe, V.A., Bhadran, A., 2014. First report of turtle bones and occurrence of dinosaurian bones from Lameta Formation, Ghorpend village, Salbuldi area, Betul District, Madhya Pradesh. e-News 30, GSI, CR.

Bhadran, A., Aglawe, V.A., 2015. First report of a Theropod (Dinosauria) from Upper Cretaceous (Maastrichtian) Lameta Formation of Salbardi Basin, Betul District, Madhya Pradesh. Indian J. Geosci. 69, 131–136.

Carrano, M.T., Wilson, J.A., Barrett, P.M., 2010. The history of dinosaur collecting in Central India, 1828–1947. Geol. Soc. London Spec. Publ. 343, 161–173.

Chakravarti, D.K., 1934. On a stegosaurian humerus from the Lameta beds of Jubbulpore. Q. J. Geol. Min. Metall. Soc. India 5, 75–79.

Chatterjee, S., 1978. Indosuchus and Indosaurus, Cretaceous carnosaurs from India. J. Paleontol. 52, 570–580.

Demic, M.D., Wilson, J.A., Chatterjee, S., 2009. The titanosaur (Dinosauria: Sauropoda) osteoderm record: review and first definitive specimen from India. J. Vertebr. Paleontol. 29, 165–177.

Huene, F.B. von, Matley, C.A., 1933. The Cretaceous Saurischia and Ornithischia of the Central Provinces of India. Mem. Geol. Surv. India. Paleontol. Indica 21, 1–74.

Jain, S.L., Bandopadyay, S., 1997. New titanosaurid (Dinosauria: Sauropopda) from the Late Cretaceous of Central India. J. Vertebr. Paleontol. 17, 114–136.

Jain, S.L., Sahni, A., 1985. Dinosaur eggshell fragments from the Lameta Formation at Pisdura, Chandrapur district, Maharashtra. Geosci. J. 2, 211–220.

Khosla, A., Sahni, A., 1995. Parataxonomic classification of Late Cretaceous dinosaur eggshell from India. J. Palaeontol. Soc. India 40, 87–102.

Loyal, R.S., Mohabey, D.M., Khosla, A., Sahni, A., 1998. Status and palaeobiology of the Late Cretaceous Indian theropods with description of new theropod eggshell oogenus and oospecies, *Ellipsoolithus khedaensis* from the Lameta Formation, district Kheda, Gujarat, western India. GAIA 15, 379–387.

Lydekker, R., 1877. Note of new and other vertebrates from Indian Tertiary and Secondary rocks. Rec. Geol. Surv. India 10, 38–41.

Lydekker, R., 1890. Note on certain vertebrate remains from Nagpur district. Rec. Geol. Surv. India XXIII, 20–24.

Matley, C.A., 1924. Note on an armoured dinosaur from the Lameta beds of Jubbulpore. Rec. Geol. Surv. India 55, 142–164.

Mohabey, D.M., 1983. Note on the occurrence of dinosaurian fossil eggs from infratrappean limestone in Kheda district, Gujarat. Curr. Sci. 52, 1194.

Mohabey, D.M., 1987. Juvenile sauropod dinosaur from Upper Cretaceous Lameta Formation of Panchmahal district, Gujarat, India. J. Geol. Soc. India 30, 210–216.

Mohabey, D.M., 1990. Dinosaur eggs from Lameta Formation of Western and Central India: Their occurrence and nesting behaviour, in: Sahni, A., Jolly, A. (Eds.), Cretaceous event stratigraphy and correlation of the Indian non-marine strata. Panjab University, Chandigarh, pp. 18–21.

Mohabey, D.M., 1996. Depositional environment of Lameta Formation (Late Cretaceous) of Nand-Dongergaon inland basin, Maharshtra: The fossil and lithological evidences. Mem. Geol. Soc. India 37, 363–386.

Mohabey, D.M., 1998. Systematics of Indian Upper Cretaceous dinosaur and chelonian eggshells. J. Vertebr. Paleontol. 18, 384–362.

Mohabey, D.M., 2000. Understanding community structure, nesting and extinction of Upper Cretaceous (Maastrichtian) Indian dinosaurs: Evidences from eggs and nests. Gondawana Geol. Magazine 15, 1–23.

Mohabey, D.M., 2001a. Dinosaurs eggs and dung (fecal mass) from the Late Cretaceous of Central India, dietary implications. Geol. Surv. India, Spec. Publ. 64, 605–615.

Mohabey, D.M., 2001b. Indian dinosaur eggs: A review. J. Geol. Soc. India 58, 479–508.

Mohabey, D.M., Udhoji, S.G., 1993. Palaeoenvironmental interpretation of Lameta Formation (Late Cretaceous) of Nand area, Nagpur district, Maharashtra. Gondwana Geol. Magazine, Spec. Vol. 2, 349–364.

Roopesh S.M., Srivastava, A.K., 2015. Salbardi–Belkher inland basin: A new site of Lameta sedimentation at the border of districts Amravati, Maharashtra and Betul, Madhya Pradesh, Central India. Curr. Sci. 109, 1337–1344.

Shukla, U.K., Srivastava, R., 2008. Lizard eggs from Upper Cretaceous Lameta Formation of Jabalpur, Central India, with interpretation of depositional environments of the nest-bearing horizon. Cretaceous Res. 29, 674–686.

Srivastava, A.K., Mankar, R.S., 2013. A dinosaurian ulna from a new locality of Lameta Succession, Salbardi Area, districts Amravati, Maharashtra and Betul, Madhya Pradesh. Curr. Sci. 105, 900–901.

Srivastava, A.K., Mankar, R.S., 2015. *Megaloolithus* dinosaur nest from the Lameta Formation of Salbardi area, districts Amravati, Maharashtra and Betul, Madhya Pradesh. J. Geol. Soc. India 85, 457–462.

Udhoji, S.G., Mohabey, D.M., 1991. A final report on palaeontological studies of fresh water intertrappean (Lametas) and intertrappean formations in part of Maharshtra (under IGCP Project 216), in: Unpublished Rep. F. S. 1984–85 to 1988–89, pp. 49.

Wilson, J.A., Upchurch, P.A., 2003. Revision of *Titanosaurus* Lydekker (Dinosauria–Sauropoda), the first dinosaur genus with Gondwana distribution. J. Syst. Palaeontol. 1, 125–160.

Wilson, J.A., Sereno, P.C., Srivastava, S., Batt, D.K., Khosla, A., Sahni, A., 2003. A new abelisaurid (Dinosauria–Sauropoda) from the Lameta Formation (Cretaceous: Maastrichtian) of India. Contrib. Mus. Palaeontol. Univ. Michigan 31, l–42.

Results of paleontological excavations 2014–2015 held by the Kemerovo Regional Museum at the Early Cretaceous Shestakovo vertebrate localities

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Introduction

The Russia's largest complex of localities of Early Cretaceous vertebrates is situated near the village Shestakovo (Chebula District, Kemerovo Oblast). In 2013, the Kemerovo Regional Museum (KRM) adopted the program, which included excavation in the Shestakovo 3 locality. In 2014–2015, the excavations were carried out by the joint team of KRM and Borissiak Paleontological Institute of the Russian Academy of Sciences (PIN RAS, Moscow). The result of the excavation was the discovery of site of the unique mass death of at least 12 individuals of *Psittacosaurus sibiricus* and other terrestrial vertebrates (Lopatin et al., 2015).

The Shestakovo is the second paleontological site of Russia, where the burial of complete skeletons of Early Cretaceous dinosaurs was discovered (Maschenko et al., 2014). In addition, the specimens of diverse fauna of terrestrial vertebrates belonging to more than eight groups were found there (Rozhdestvensky, 1960; Leshchinskiy et al., 1997, 2000; Voronkevich, 1998; Alifanov et al., 1999; Efimov and Leshchinskiy, 2000). Since 1953, dozens of identifiable bones, teeth, hundreds of fragments belonging not only to different types of dinosaurs, flying reptiles, amphibians, birds, but also to other groups of reptiles (turtles, crocodiles, lizards, etc.), and Mesozoic mammals were revealed in the Shestakovo site (Leshchinskiy et al., 1997; Maschenko and Lopatin, 1998; Averianov et al., 2002; Lopatin et al., 2010).

Results and discussion

Psittacosaurus sibiricus discovered at the Shestakovo localities is a separated group of *Psittacosurus* dinosaurs endemic to Kuzbass area (Averianov et al., 2006).

Until 2013, the excavations and research of the fossils from the Shestacovo localities were carried out on irregular base by the researchers of PIN RAS, Zoological Institute of the RAS, Saint Petersburg State University and Tomsk State University.

In 2013, a major complex research was carried out by KRM at the Shestakovo locality and adopted to the research program "Paleontological study of fossils in Paleozoic and Mesozoic deposits of the Kemerovo region". The license for the use of subsurface resources aimed at collecting mineralogical, paleontological and other geological samples in the area of "Kiya supporting open–pit", "Kiya–Sertinsky complex", and "Antibes" located in Tisul, Chebula and Mariinsk districts of the Kemerovo Oblast was obtained. In 2015, this license was extended until 2020.

In 2013, KRM fulfilled organizational and managerial works including legal registration of activities at the Shestakovo localities and concluded a partner's agreement with PIN RAS to undertake a joint research of the Shestakovo site. It was considered necessary due to the fact that PIN RAS is the leading specialized scientific organization in Russia conducting paleontological researches as a part of scientific programs and grants offered by the Government of the Russian Federation.

Since 2014, the field works have been carried out in the Chebula District at two localities of Early Cretaceous terrestrial fauna: the Shestakovo 1 (Kiya River bluff), about 500 m downstream from the Shestakovo village, and the Shestakovo 3, about 1.5 km south-east from the Shestakovo village.

The fossils were regularly collected at the slopes of the Kiya River bluff (Shestakovo 1). In the course of these studies, a large number of Late Pleistocene mammals were found including woolly mammoth, Pleistocene bison, woolly rhinoceros, wolf, reindeer, Pleistocene hors. In addition to these, the fossils of Early Cretaceous vertebrates, such as giant dinosaurs (sauropods) and tyrannosaurid dinosaurs were found.

In 2014, KRM started the excavation in the area of 2x8 m with the altitude of 7 m above the road level. In 1 m below the soil, a level of Early Cretaceous alluvial deposits including terrestrial vertebrate fossils was discovered. The bon-bad layer is composed of brownish-red and greenish-gray solid clay. Sculls, fractions of bones and fragments of skeletons of Early Cretaceous vertebrates (*Protosuchia*, *Tagarosuchus kulemzini*, *Lacertilia* (Agamidae) and dinosaur *Psittacosaurus sibiricus*) were found there. The bone-bearing lens was located at the level of 0.3 m under bon-bad layer. The characters of the bone-bearing lens taphonomy demonstrated that the examined piece of about 1 m wide and 4.5 m long is extended from north-east to south-west. The thickness of the lens was approximately 60–70 cm.

The lens is unique including a lot of complete *Psittacosaurus* skeletons presented in anatomic position *in situ*. The taphonomy peculiarities suggest that the death of dinosaur group, consisting of specimen of different ages, was the result of a catastrophe. It is probable that moving along the temporary stream bed they were buried by a mud flow. Such type of a taphonomy has never been previously obtained from the Shestakovo locality or at any other locality in Russia (Averianov et al., 2006; Lopatin et al., 2015).

The field season 2015 revealed the diverse factors of genesis of the Shestakovo deposits and relatively diverse conditions of Early Cretaceous vertebrates' burials. Within the Ilek Formation, the researchers of PIN RAS discovered at least two layers with traces of sand ripple divided with a 10 cm thick layer of siltstone at the 220–240 cm from the basement of the altitude scale of the Shestakovo 3 locality. These layers are preserved areas of a shallow sea lagoon with traces of marine invertebrates (presumably the channels of polychaete worms), where clay deposits containing fossil vertebrates were formed. Such traces were revealed for the first time in the Early Cretaceous lagoon in the Shestokovo site. It is the true evidence of the formation of a part of the Ilek Formation in the soundings of shallow sea.

Conclusion

The scientific description of the discovered paleontological materials obtained during the excavations in 2014–2015 is being performed by the researchers of KRM Department of Nature. Their research activities are systematically announced to museum visitors. The materials serve as the basis of the "Shestakovo Dinosaurs" section of the new exhibition "Kemerovo region as a unique natural monument" opened in August 2015. The fragments and complete skeletons of *Psittacosaurus sibiricus*, *Crocodylomorpha*, the fragments of sauropod skeletons found at Shestakovo 1 as well as the traces of sand ripple from the soundings of shallow sea are exhibited there. A joint exhibition of KRM and PIN RAS has been prepared. The exhibition will be held as a part of the permanent display in the Dinosaur Hall of PIN RAS Paleontological Museum in Moscow.

The project includes: (1) study and restoration of the largest *Psittacosaurus sibiricus* skeleton; (2) creation of a virtual model of *Psittacosaurus sibiricus* on the basis of measuring and scanning of original and restored bones; (3) construction of a volumetric authentic *Psittacosaurus* skeleton supported by a still construction; and (4) preparation of a full-sized plastic copy of the dinosaur.

In the course of the dinosaur's skeleton examination, the scientists study the lifestyle, morphology and some behavioral features of these reptiles. Skeleton model is prepared in the quadrupedal position using the supporting firm construction also showing the ability of bipedal motion, which is the result of ecological peculiarities of dinosaur's habitat and lifestyle.

This exhibition is a significant event in cultural and scientific life, because Russian museums have not yet displayed complete dinosaurs excavated in Russia.

Keywords

Kemerovo Regional Museum, Early Cretaceous, Shestakovo localities, *Psittacosaurus sibiricus*, excavation, field work.

References

Alifanov, V.R., Efimov, M.B., Novikov, I.V., Morales, M., 1999. A new psittacosaur complex of tetrapods from the Lower Cretaceous Shestakovo locality (Southern Siberia). Rep. Acad. Sci. USSR 369, 491–493 (in Russian).

Averianov, A.O., Voronkevich, A.V, Maschenko, E.N., Leshchinskiy, S.V., Fayngertz, A.V., 2002. A sauropod foot from the Early Cretaceous of Western Siberia, Russia. Acta Palaeontol. Polonica 47, 117–124.

Averianov, A.O., Voronkevich, A.V, Leshchinskiy, S.V., Fayngertz, A.V., 2006. A ceratopsian dinosaur *Psittacosaurus sibiricus* from the Early Cretaceous of West Siberia, Russia and its phylogenetic relationships. J. Syst. Palaeontol. 4, 359–395.

Efimov, M.B., Leshchinskiy, S.V., 2000. The first finding of a fossil crocodile skull in Siberia, in: Komarov, A.V. (Ed.), Materials of the Regional Conference of the Geologists of Siberia, Far East, and North East of Russia, Vol. 2. GalaPress, Tomsk, pp. 361–363 (in Russian).

Leshchinskiy, S.V., Voronkevich, A.V., Fayngertz, A.V., Schikhovtzeva, L.G., 1997. Some aspects of taphonomy and stratigraphic position of the localities of the Shestakovo complex of Early Cretaceous vertebrates, in: Podobina, V.M. (Ed.), Questions of geology and palaeontology of Siberia. Tomskii Gos. Univ., Tomsk, pp. 83–90 (in Russian).

Leshchinskiy, S.V., Fayngertz, A.V., Voronkevich, A.V., Maschenko, E.N., Averianov, A.O., 2000. Preliminary results of the investigation of the Shestakovo localities of Early Cretaceous vertebrates, in: Komarov, A.V. (Ed.), Materials of the Regional Conference of the Geologists of Siberia, Far East, and North East of Russia, Vol. 2. GalaPress, Tomsk, pp. 363–366 (in Russian).

Lopatin, A.V., Maschenko, E.N., Averianov, A.O., 2010. A new genus of triconodont mammals from the Early Cretaceous of Western Siberia. Dokl. Biol. Sci. 433, 282–285.

Lopatin, A.V., Maschenko, E.N., Tarasenko, K.K., Podlesnov, A.V., Demidenko, N.V., Kuzmina, E.A., 2015. A unique burial site of Early Cretaceous vertebrates in Western Siberia (the Shestakovo 3 locality, Kemerovo Province, Russia). Dokl. Biol. Sci. 462, 148–151.

Maschenko, E.N., Lopatin, A.V., 1998. First record of an Early Cretaceous triconodont mammal in Siberia. Bull. Inst. R. Sci. Nat. Belg., Sci. Terre 68, 233–236.

Maschenko, E.N., Feofanova, O.A., Demidenko, N.V., Kuzmina, E.A., 2014. Looking for a Siberian dinosaur. Sci. Life 11, 74–80 (in Russian).

Rozhdestvensky, A.K., 1960. Locality of Lower Cretaceous dinosaurs in Kuzbass. Paleontol. Zh. 2, 165 (in Russian).

Voronkevich, A.V., 1998. A large representative of the genus *Psittacosaurus* from the locality Shestakovo-3, in: Vyltsan, I.A. (Ed.), Actual questions of the geology and geography of Siberia: Materials of the scientific conference. Vol. 1. Tomskii Gos. Univ., Tomsk, pp. 190–193 (in Russian).

Historical stages of natural science collection formation in the Kemerovo Regional Museum

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In the Kemerovo Regional Museum, there are more than 2.000 depositary items related to natural science collections. These are geological, zoological, botanical and paleontological collections.

The museum and its collections have nearly 100 years of history. In 1926, the Shcheglovsk city (now the Kemerovo city) became the administrative center of the Kuznetsk Uyezd (now the Kemerovo Oblast) (Tivyakov, 1995). This young town and the region witnessed an active construction of industrial enterprises as well as a constant flow of people. There was a need for education and training of workers and young people. To fill this need, some sectors of political education were formed. In particular, a resolution for the formation of the Regional Museum was adopted at the session of a planned meeting under the District Committee of Public Education on September 27, 1927 (Kitova, 1999). It was assumed that the museum will display the materials showing the economic state of the region, its environmental conditions, the history of revolution and ethnography. The museum was opened on October 6, 1929. After renaming of the Shcheglovsk in 1932, the museum got the name Kemerovo City Museum.

Development of museum holdings was started by the members of the Kuznetsk District Society of Local History in 1928 even before the museum opened to the public. By the opening day, the collection exhibits reached about 600 units. In the process of collecting exhibits and creating displays, the priority was given to the industrial and agricultural development of the region. This direction of museum development was determined by the Communist Party and the Soviet government. Years before, the war was resulted in acceleration of industrial development associated with the strengthening of the state's defense potential. In this regard, the main goal of regional museums was to study industrial forces of the country (Ivanova, 1963).

There is little information left on the constitution of the natural science collection formed in the early years of the Kemerovo Regional Museum. Archive was lost, as the museum had repeatedly moved, especially during the Great Patriotic War. That is why many exhibits and documents were lost (Kravtsova, 1999). Only some of the geological and paleontological samples, stuffed animals and skins remained.

A new stage of museum’s history began in 1957, when it was moved to the building on the Sovetsky Avenue (now it is a building number 55) and was reopened after a massive reorganization. Since the early 1960’s, museum workers started to collect new exhibits, their systematization, study and display. Ethnographical, historical and archaeological expeditions were organized, that also provide the collections of natural materials.

In 1970s–80s, the museum staff organized multipurpose expeditions on the territory of the Kemerovo Oblast, where museum materials on specific topics were collected: industry, agriculture, education, culture, environment, everyday life, etc. During this period, the museum organized several expeditions focused on the mineral search and plants collecting for the herbaria, animal skins and stuffed animals were also bought. During 1960s–1980s, the museum worked in close collaboration with geological exploration organizations and coal-mining enterprises. Through such cooperation, the collection was enriched with a large number of geological items. During the exploration and development of mineral deposits, geologists and miners revealed numerous fossils, including mammoth fauna, animal bones, remains of calcareous skeletons of marine invertebrates, petrified wood and leaf imprints.

In the early 2000’s, the number of new contributions decreased. The difficulties derived from the change of enterprises ownership forms as well as the lack of sufficient funds for the purchase of rare and valuable items.

Today, the Kemerovo Regional Museum has developed and adopted scientific concept for the acquisition of exhibits. It is based on the analysis of available collections, the definition of main directions for a long-term acquisition. One of such directions is the collection of paleontological objects and the creation of a new permanent exhibition that reflects the evolution of life on the Kuzbass territory.

The new exhibition should represent the unique geological and paleontological nature monuments of the Kemerovo Oblast and show the formation of the modern image of the region. To achieve this goal, the Kemerovo Regional Museum implemented several projects. The first one was the temporary exhibition called "12 Steps of Evolution" dedicated to the 70th anniversary of the Kemerovo Oblast. The exposition was opened in KRM Department of Nature on October 15, 2012 and consisted of three sections: "The Ancient Inhabitants of the Seas", "Terrible Lizards – the Dinosaurs" and "Ice Age" covering long time interval from the Paleozoic to the Cenozoic. The exhibition displayed paleontological items collected on the territory of Kuzbass and in other regions of the world. Skeletons of *Psittacosaurus sibiricus* Voronkevich et Averianov found near the village Shestakovo were displayed for the first time.

However, most of the exhibition items are owned by Mr. Grebnev, a private collector from Novosibirsk, including fossils of dinosaurs from the Shestakovo locality. In order to create a permanent exhibition, the museum must have its own collection of depositary items. At that time, museum's paleontological collection had almost no fossils representing life forms of Paleozoic and Mesozoic eras. At the same time, it is a promising region for paleontological study, as it is the homeland of some Devonian marine invertebrates and Cretaceous continental fauna. In 2013, the Kemerovo Regional Museum initiated the organization of scientific research of Early Cretaceous deposits containing vertebrates in the Shestakovo locality, one of the largest and most promising dinosaurs burials in Russia (Alifanov et al., 1999; Mashchenko et al., 2014). The museum developed a program of scientific and exhibition research "Paleontological study of fossils in Paleozoic and Mesozoic deposits of the Kemerovo Region", and also got a license for the use of subsurface resources in order to collect geological materials. In 2015, the license was extended until 2020.

The first stage of the implementation of paleontological research program was the organization of excavations in the Shestakovo locality. An agreement between the museum and Borissiak Paleontological Institute of the Russian Academy of Sciences (PIN RAS) was signed to implement joint researches in Shestakovo locality. In 2014, the museum expedition started the excavations in the Shestakovo 3 locality in collaboration with PIN RAS team.

Today, the museum has reached new outstanding results in the research of the Shestakovo locality. During the expeditions of 2014–2015, more than 1.500 paleontological items were collected, and new bone-bearing layers were also discovered with mass burials of skeletons of *Psittacosaurus sibiricus* (Lopatin et al., 2015).

The next stage of the program involves the creation of a scientific center on the basis of the Kemerovo Regional Museum. This year, the department of research and expeditions called "Paleontological Research Laboratory" was established at the museum. The department has modern equipment for mechanical cleaning and chemical treatment of fossils. The members of the department currently organize expeditions to collect paleontological materials and to perform excavations in the Shestakovo locality. They also make preparation of paleontological fossils obtained in the course of excavations as well as prepare them to be displayed.

In the future, we plan to deepen the cooperation and to organize joint work with scientific and educational institutions in the region and the Russian Federation. Thus, the Kemerovo Regional Museum will be a platform for long-term scientific research carried out by scientists and Ph.D. students in the field of paleontology. Moreover, new department will serve as a ground for various cultural and educational activities that contribute to the popularization of paleontology among people.

Keywords

Collection, museum, historical stages, Shestakovo.

References

Alifanov, V.R., Efimov, M.B., Novikov, I.V., Morales, M., 1999. A new psittacosaur complex of tetrapods from the Lower Cretaceous Shestakovo locality (Southern Siberia). Rep. Acad. Sci. USSR 369, 491–493 (in Russian).

Ivanova, O.V., 1963. Museum construction in the time of prewar five-year plans (1928–1941), in: Razgon, A.M. (Ed.), Essays on the history of museology in the USSR. Sovetskaya Rossiya, Moscow, 86–89 (in Russian).

Kitova, L.Y., 1999. History of Kemerovo Regional Museum creation (1920s–1930s). Research: Regional History Yearbook 5, 11–22 (in Russian).

Kravtsova, L.P., 1999. Kemerovo Regional Museum: Meeting the anniversary. Research: Regional History Yearbook 5, 7–11 (in Russian).

Lopatin, A.V., Maschenko, E.N., Tarasenko, K.K., Podlesnov, A.V., Demidenko, N.V., Kuzmina, E.A., 2015. A unique burial site of Early Cretaceous vertebrates in Western Siberia (the Shestakovo 3 locality, Kemerovo Province, Russia). Dokl. Biol. Sci. 462, 148–151.

Maschenko, E.N., Feofanova, O.A., Demidenko, N.V., Kuzmina, E.A., 2014. Looking for a Siberian dinosaur. Sci. Life 11, 74–80 (in Russian).

Tivyakov, S.D., 1995. Administrative and territorial division of Kuznetsk land. Research: Regional History Yearbook 4, 8–9 (in Russian).

Fossil vertebrates from the Late Cretaceous Tamagawa Formation (Turonian) of Kuji City, Iwate Prefecture, northeastern Japan

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The Tamagawa Formation in Kuji Group of Kuji City, Iwate Prefecture of northeastern Japan is the richest geological unit bearing the Late Cretaceous terrestrial vertebrates as well as rich ambers in this country. More than one thousand vertebrate fossils have been found from about the 20 cm thick coaly mudstone layer and overlying 1 m thick marine sandstone bed of the Tamagawa Formation since 2005. Fission track dating carried out in the volcanic tuff layer inter-bedded between the mudstone and marine sandstone units indicates a Turonian age (Tsutsumi, in preparation).

Sharks (elasmobranchs) are known by 110 isolated teeth of *Scapanorhynchus*, *Cretolamna*, *Cretodus*, and *Protolamna* as well as by vertebrae and presumed coprolites from the sandstone bed.

Turtles (order Testudines) are the most abundant vertebrates (441 specimens in total), identified as the Adocidae (genus *Adocus*), Trionychidae, Nanhsiungchelyidae, Lindholmemydidae, and Carettochelyidae. Most of turtle remains are isolated shell elements, whereas few cranial and appendicular materials were collected. *Adocus* sp. from the Tamagawa Formation seems the most derived species of this genus in the possession of extremely wide marginal scales and the loss of cervical scale of carapace. Largest specimen of *Adocus* in this locality suggests an individual with 70 cm long shell.

Crocodiles (order Crocodyliformes) are next abundant group (105 specimens in total). Its amphicoelous vertebrae, osteoderms and dental morphology suggest that they were the members of neosuchian grade, possibly close to the genus *Paralligator*.

Twenty three isolated almost cylindrical teeth of sauropods (order Saurischia) have been collected, whereas other dinosaurs (Theropoda and Ornithischia) are known by few limb bones and isolated teeth. A wing digital bone of medium size pterosaur (order Pterosauria) was found in 2010. Two isolated vertebrae from the sandstone bed are identified as the first known Choristodera from the Upper Cretaceous of Asia.

Except two partially articulated turtle shell of *Adocus*, all terrestrial vertebrate fossils from bone bed inter-bedded by marine sandstone layers are isolated and fragmentary. This occurrence suggests that they were transported by river stream near the mouth. Abundance of sauropod teeth seems unique as the Late Cretaceous biota.

Fauna and flora of the Kuji Group are one of the most expectable examples of both non-marine and marine vertebrates of the Late Cretaceous in Japan. Our excavation will be continued in the coming years for more plentiful results.

The Lower Cretaceous continental vertebrate fauna from the Shestakovo locality (West Siberia): Results of 20-year research

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The year of 2013 witnessed the 60th anniversary of the discovery of the Lower Cretaceous continental vertebrates in the Shestakovo site. Several localities are situated on the right bank of the Kiya River in the vicinity of the Shestakovo village (Chebula District of the Kemerovo Oblast).

The discovery was not easy. A.R. Anan'yev, assistant professor of Tomsk State University (TSU), mentioned: "In spite of careful search, neither plant, nor animal fossils are not found in the Ilek Formation" (Anan'yev, 1948).

In 1953, a geologist A.A. Mossakovskiy and assistant professor of TSU I.V. Lebedev discovered the incomplete skeleton and the skull with forelimb of the small ornitischian dinosaur referred to *Psittacosaurus* at the base of the Shestakovo section (Rozhdestvenskiy, 1960).

In the early 1960s, A.A. Bulynnikova and L.Ya. Trushkova (1967) found the remains of a larger dinosaur, which was sent to A.K. Rozhdestvenskiy (Paleontological Institute) for identification.

The further findings of the Early Cretaceous vertebrates from the Shestakovo site were made only in 1994, when E.N. Maschenko discovered a phalanx of sauropod dinosaur and the molariform of the theromorph tritylodont in the talus of the Shestakovo outcrops. The last one was the first tritylodontid from the Lower Cretaceous. Previously, they assumed to be extinct in the Jurassic. In 1995, the members of the Department of Paleontology and Historical Geology of TSU, prospecting in Tegul'det depression of West Siberia, found the bones of the large dinosaurs in the outcrop of Shestakovo steep bank. Besides, several new sites were discovered (Shestakovo 2, 3; Smolenskii Yar; Ust'-Kolba) (Saev and Leshchinskiy, 1997).

The Shestakovo complex of vertebrate localities is rather well studied. The data on its geological structure (Fayngerts and Leshchinskiy, 2000) and taphonomic features (Voronkevich, 2000) are presented in several papers. Each locality is characterized by specific features of sedimentation, and therefore special burial conditions. Microvertebrate assemblage from the Shestakovo 1, being the typical section for the Ilek Formation, provides a complete overview of the composition of vertebrate fauna. It was formed in alluvial conditions, while the Shestakovo 3 characterized by complete skeletons, their fragments in anatomical position and separate bones and teeth represents the crevasse splay facies.

At present time, the following taxa are revealed in the complex of the Shestakovo 1: Palaeonisciformes indet., Sinamiidae indet., *Kiyatriton leshchinskiyi*, Caudata indet., *Kirgizemys* sp., Choristodera indet., Xenosauridae indet., Parmacellodus sp., Scincomorpha indet., Gekkota indet. (Averianov and Voronkevich, 2002; Skutschas, 2006, 2014; Skutschas and Vitenko, 2015), *Tagarosuchus kulemzini*, *Kyasuchus saevi* (Efimov and Leshchinskiy, 2000), Pterodactyloidea indet., Ornithocheiridae indet., Troodontidae indet., Dromaeosauridae indet., Therizinosauroidea indet., Theropoda indet., Titanosauriformes indet., Stegosauridae indet., Ornithopoda indet., Hypsilophodontidae indet., *Psittacosaurus sibiricus* (Averianov et al., 2002, 2003, 2004, 2006; Averianov and Sues, 2007), *Mystiornis cyrili* (Kurochkin et al., 2011), *Evgenavis nobilis* (O'Connor et al., 2014), *Xenocretosuchus sibiricus*, *Sibirotherium rossicus* (Tatarinov and Maschenko, 1999; Maschenko et al., 2002; Lopatin et al., 2009), Gobiconodontidae (Lopatin and Averianov, 2015), *Acinacodus tagaricus*, *Yermakia domitor*, *Kiyatherium cardiodens* (Lopatin et al., 2005, 2010).

The composition of this vertebrate assemblage is heterogeneous and includes vertebrates with Jurassic (e.g., paramacellodid lizard, "protosuchian" and shartegosuchid crocodyliforms, tritylodonts, docodont mammals) and Cretaceous (e.g., "macrobaenid" turtles, dromaeosaurid and troodontid theropods, ceratopsian *Psittacosaurus sibiricus*) affinities (Leshchinskiy et al., 2001). Thus, the presence of refugium in the south-east of West Siberia is proposed.

There is still a potential for describing new taxa of vertebrates from the Shestakovo section. Since the first years of the research, the large bones of sauropod were washed out from the Shestakovo 1 outcrop. The pedal ungulal phalanx of a therizinosaurid was found at the same place in 2010. There are still undescribed taxa of theropods of large, medium and small size represented by fragmentary materials. Only preliminary results are published on turtles and lizards. Only small portion of Shestakovo 3 perspective area was excavated in the past years.

References

Anan'ev, A.R., 1948. Geology of Mesozoic deposits near Ust'-Serta village on Kiya River. Uch. Zap. Tomskogo Gos. Univ. 10 (in Russian).

Averianov, A.O., Sues, H.-D., 2007. A new troodontid (Dinosauria: Theropoda) from the Cenomanian of Uzbekistan, with a review of troodontid records from the territories of the former Soviet Union. J. Vert. Paleontol. 27, 87–98.

Averianov, A.O., Voronkevich, A.V., 2002. A new crown-group salamander from the Early Cretaceous of Western Siberia. Russ. J. Herpetol. 9, 209–214.

Averianov, A.O., Voronkevich, A.V, Maschenko, E.N., Leshchinskiy, S.V., Fayngertz, A.V., 2002. A sauropod foot from the Early Cretaceous of Western Siberia, Russia. Acta Palaeontol. Polonica 47, 117–124.

Averianov, A.O., Leshchinskiy, S.V., Skutschas, P.P., Rezvyi, A.S., 2003. Pterosaur teeth from the Lower Cretaceous of Russia and Uzbekistan. Sovrem. Gerpetol. 2, 5–11 (in Russian).

Averianov, A.O., Leshchinskiy, S.V., Skutschas, P.P., Fayngertz, A.V., Rezvyi, A.S., 2004. Dinosaurs from the Early Cretaceous Ilek Formation in West Siberia, Russia, in: Second European Association of Vertebrate Paleontologists Meeting: Abstracts of papers. Moravian Museum, Brno, p. 6.

Averianov, A.O., Voronkevich, A.V, Leshchinskiy, S.V., Fayngertz, A.V., 2006. A ceratopsian dinosaur *Psittacosaurus sibiricus* from the Early Cretaceous of West Siberia, Russia and its phylogenetic relationships. J. Syst. Palaeontol. 4, 359–395.

Bulynnikova, A.A., Trushkova, L.Ya., 1967. Continental Cretaceous deposits of eastern and central parts of the Western Siberian lowland, in: Martinson, G.G. (Ed.), Stratigraphy and palaeontology of Mesozoic and Palaeogene–Neogene continental deposits of the Asiatic part of the USSR. Nauka, Leningrad, pp. 40–46 (in Russian).

Efimov, M.B., Leshchinskiy, S.V., 2000. The first finding of a fossil crocodile skull in Siberia, in: Komarov, A.V. (Ed.), Materials of the Regional Conference of the Geologists of Siberia, Far East, and North East of Russia, Vol. 2. GalaPress, Tomsk, pp. 361–363 (in Russian).

Fayngerts, A.V., Leshchinskiy, S.V., 2000. Early Cretaceous Chulym-Enisey paleobasin: Conditions of sedimentation and habitat of vertebrate fauna, in: Sreda i zhizn' v geologicheskom proshlom, Tez. dokl. Novosibirsk, pp. 47–48 (in Russian).

Kurochkin, E.N., Zelenkov, N.V., Averianov, A.O., Leshchinskiy, S.V., 2011. A new taxon of birds (Aves) from the Early Cretaceous of Western Siberia, Russia. J. Syst. Palaeontol. 9, 109–117.

Leshchinskiy, S.V, Voronkevich, A.V., Fayngertz, A.V., Maschenko, E.N., Lopatin, A.V., Averianov, A.O., 2001. Early Cretaceous vertebrate locality Shestakovo, Western Siberia, Russia: A refugium for Jurassic relicts? J. Vert. Paleontol. 21, 73A.

Lopatin, A.V., Averianov, A.O., 2015. *Gobiconodon* (Mammalia) from the Early Cretaceous of Mongolia and revision of Gobiconodontidae. J. Mammal. Evol. 22(1), 17–43.

Lopatin, A.V., Maschenko, E.N., Averianov, A.O., Rezvyi, A.S., Skutschas, P.P., Leshchinskiy, S.V., 2005. Early Cretaceous mammals from Western Siberia: 1. Tinodontidae. Paleontol. J. 39, 523–534.

Lopatin, A.V., Averianov, A.O., Maschenko, E.N., Leshchinskiy, S.V., 2009. Early Cretaceous mammals of Western Siberia: 2. Tegotheriidae. Paleontol. J. 43, 453–462.

Lopatin, A.V., Averianov, A.O., Maschenko, E.N., Leshchinskiy, S.V., 2010. Early Cretaceous mammals of Western Siberia: 3. Zhangheotheriidae. Paleontol. J. 44, 573–583.

Maschenko, E.N., Lopatin, A.V., Voronkevich A.V., 2002. A new Early Cretaceous mammal from Western Siberia. Dokl. Biol. Sci. 386, 475–477.

O'Connor, J.K., Averianov, A.O., Zelenkov, N.V., 2014. A confuciusornithiform (Aves, Pygostylia)-like tarsometatarsus from the Early Cretaceous of Siberia and a discussion of the evolution of avian hind limb musculature. J. Vert. Paleontol. 34, 647–656.

Rozhdestvensky, A.K., 1960. Locality of Lower Cretaceous dinosaurs in Kuzbass. Paleontol. Zh. 2, 165 (in Russian).

Saev, V.I., Leshchinskiy, S.V., 1997. New findings of dinosaurs in Siberia, in: Podobina, V.M., Savina, N.I., Kuznetsova, K.I., Muzylev, N.G. (Eds.), Biostratigraphy and microorganisms of the Phanerozoic of Eurasia. Geos, Moscow, p. 268 (in Russian).

Skutschas, P.P., 2006. Biostratigraphy of the Late Mesozoic tetrapod assemblages of Siberia, in: Rozanov, A.Yu., Lopatin, A.V., Parkhaev, P.Yu. (Eds.), Classical and new methods: Second All-Russian school – 2005. Moscow, pp. 87–96.

Skutschas, P.P., 2014. *Kiyatriton leshchinskiyi* Averianov et Voronkevich, 2001, a crown-group salamander from the Lower Cretaceous of Western Siberia, Russia. Cretaceous Res. 51, 88–94.

Skutschas, P.P., Vitenko, D.D., 2015. On a record of choristoderes (Diapsida, Choristodera) from the Lower Cretaceous of Western Siberia. Paleontol. J. 49, 507–511.

Tatarinov, L.P., Maschenko, E.N., 1999. A find of an aberrant tritylodont (Reptilia, Cynodontia) in the Lower Cretaceous of Kemerovo Region. Paleontol. Zh. 4, 85–92 (in Russian).

Voronkevich, A.V., 2000. Taphonomic features of burial of vertebrates' remains in the deposits of Ilek Svita, in: Komarov, A.V. (Ed.), Materials of the Regional Conference of the Geologists of Siberia, Far East, and North East of Russia, Vol. 2. GalaPress, Tomsk, pp. 359–360 (in Russian).

The history of discovery and research of the Shestakovo locality of Early Cretaceous vertebrates

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Research history of the Shestakovo locality of Early Cretaceous vertebrates was started in the first part of 50th years of the last century. In 1953, a geologist A.A. Mossakovsky (Geological Institute of the Academy of Sciences of the USSR, Moscow) discovered fragments of a fore limb of medium-sized herbivorous dinosaur. The fossils were found near the Shestakovo village in the precipice of the Kiya River (center of the Shestakovskii ravine location, also known as the Shestakovo 1). In the same year, the docent of Tomsk Polytechnic Institute I.V. Lebedev found a cranium and a fore limb belonging to other specimen of the same species of dinosaurs.

The fragments discovered by A.A. Mossakovsky and I.V. Lebedev were transferred to the Paleontological Institute of the Academy of Sciences of the USSR. Afterwards, these fragments were identified as remains of a dinosaur of the genus *Psittacosaurus* (Rozhdestvensky, 1955).

After delivery of skeleton to Moscow, A.K. Rozhdestvensky (expert on dinosaurs from the Paleontological Institute) was sent to Shestakovo to prospect the locality, but he could not make excavation, because bone-bearing layers were inaccessible due to high water level. A.K. Rozhdestvensky was forced to perform the geological investigation of the Shestakovskii ravine as well as the nearest precipices and outcrops along the Kiya River and its feeder, the Serte River (Rozhdestvensky, 1960).

Since the finding of the first remains of *Psittacosaurus* until the early 90th, no special investigations have been carried out in the neighborhood of the Shestakovo village. At the same time, there is a mention in the literature about the finding of big bones in the Shestakovo 1 (Bulynnikova and Trushkova, 1967). It may be suggested that these remains could belong to a dinosaur from sauropods (Averianov et al., 2002). It is unknown what has happened with this finding.

Systematic investigations of the Shestakovo locality were started in the early 90th. In 1994, E.N. Maschenko from the Paleontological Institute of the Russian Academy of Sciences (PIN RAS) discovered teeth of tritilodontid, sometimes ago identified as *Xenocretosuchus sibiricus* Tatarinov et Matchenko (Tatarinov and Maschenko, 1999), and phalange of sauropod (Averianov et al., 2002). Next year he found a fragment of jaw of Mesozoic mammal *Gobiconodon borissiaki* Trofimov (Maschenko and Lopatin, 1998).

Since 1995, the staff of Tomsk State University (TSU) has performed excavation and stratigraphical operations resulted in the discovery of two new bone burial locations (Shestakovo 2 and Shestakovo 3) (Saev and Leshchinskiy, 1997).

In 1995–1996, the group of Tomsk paleontologists found the fragments of foot and vertebrae of sauropod, jointed fragments of *Psittacosaurus* skeleton as well as other paleontological materials (Leshchinskiy et al., 1997; Voronkevich, 1998; Efimov and Leshchinskiy, 2000; Averianov et al., 2002). A spread of remains in the even-aged layer of Early Cretaceous blankets on the limited area lets to associate three localities in the united complex (Leshchinskiy et al., 1997; Alifanov et al., 1999).

In 1997, the research group from PIN RAS in collaboration and under financial support of the Museum of Natural History (North Arizona, USA) worked under the direction of V.R. Alifanov in the Shestakovo locality (Alifanov et al., 1999). In this expedition, *Psittacosaurus* skeleton and single bones of the same species of dinosaurs were found, but these materials have not yet been published.

Since 1997, the staff of PIN RAS has performed washing of bone-bearing layers of the Shestakovo locality to find the micro balances of terrestrial vertebrates. As a result of these investigations carried out for more than 10 years, the extensive paleontological material was obtained (Averianov et al., 2003; Lopatin et al., 2005, 2009, 2010a,b). In addition, the staff of TSU periodically collected fossil remains of different groups of terrestrial vertebrates at the Shestakovo 3 (O'Connor et al., 2014). These works continued until 2012.

In 1999, A.V. Voronkevich (TSU) found two complete *Psittacosaurus* skeletons in anatomic synarthrosis at the Shestakovo 3. These skeletons became the base for the detachment and description of the separate species named *Psittacosaurus sibiricus* Voronkevich et Averianov (Leshchinskiy et al., 2000). Until that moment, this species was considered as a form of *Psittacosaurus mongoliensis* Osborn (Voronkevich, 1998; Alifanov et al., 1999).

Thus, during the research of Early Cretaceous vertebrates from the Shestakovo locality, the rich fauna including more than 25 species was discovered (Averianov et al., 2006). It was established that it includes a large number of relic forms, which were typical for the Late Jurassic epoch. It allows us to suggest that a refugium existed in this territory in the Early Cretaceous (Leshchinskiy et al., 2001).

A new stage in the study of the Cretaceous fauna of the Shestakovo localities began in 2014, when employees of the Kemerovo Regional Museum in cooperation with the staff of PIN RAS resumed excavations in that area. As a result of this work, a new bone-bearing lens with a large burial of *Psittacosaurus* skeletons and other paleontological materials were discovered (Lopatin et al., 2015). Currently, the excavations at the Shestakovo 3 and the washing of the Ilek Formation rocks at the Shestakovo 1 are performed.

Keywords

Cretaceous, West Siberia, Shestakovo locality, history of discovery.

References

Alifanov, V.R., Efimov, M.B., Novikov, I.V., Morales, M., 1999. A new psittacosaur complex of tetrapods from the Lower Cretaceous Shestakovo locality (Southern Siberia). Rep. Acad. Sci. USSR 369, 491–493 (in Russian).

Averianov, A.O., Voronkevich, A.V, Maschenko, E.N., Leshchinskiy, S.V., Fayngertz, A.V., 2002. A sauropod foot from the Early Cretaceous of Western Siberia, Russia. Acta Palaeontol. Polonica 47, 117–124.

Averianov, A.O., Leshchinskiy, S.V., Skutschas, P.P., Rezvyi, A.S., 2003. Pterosaur teeth from the Lower Cretaceous of Russia and Uzbekistan. Sovrem. Gerpetol. 2, 5–11 (in Russian).

Averianov, A.O., Voronkevich, A.V, Leshchinskiy, S.V., Fayngertz, A.V., 2006. A ceratopsian dinosaur *Psittacosaurus sibiricus* from the Early Cretaceous of West Siberia, Russia and its phylogenetic relationships. J. Syst. Palaeontol. 4, 359–395.

Bulynnikova, A.A., Trushkova, L.Ya., 1967. Continental Cretaceous deposits of eastern and central parts of the Western Siberian lowland, in: Martinson, G.G. (Ed.), Stratigraphy and palaeontology of Mesozoic and Palaeogene–Neogene continental deposits of the Asiatic part of the USSR. Nauka, Leningrad, pp. 40–46 (in Russian).

Efimov, M.B., Leshchinskiy, S.V., 2000. The first finding of a fossil crocodile skull in Siberia, in: Komarov, A.V. (Ed.), Materials of the Regional Conference of the Geologists of Siberia, Far East, and North East of Russia, Vol. 2. GalaPress, Tomsk, pp. 361–363 (in Russian).

Leshchinskiy, S.V., Voronkevich, A.V., Fayngertz, A.V., Schikhovtzeva, L.G., 1997. Some aspects of taphonomy and stratigraphic position of the localities of the Shestakovo complex of Early Cretaceous vertebrates, in: Podobina, V.M. (Ed.), Questions of geology and palaeontology of Siberia. Tomskii Gos. Univ., Tomsk, pp. 83–90 (in Russian).

Leshchinskiy, S.V., Fayngertz, A.V., Voronkevich, A.V., Maschenko, E.N., Averianov, A.O., 2000. Preliminary results of the investigation of the Shestakovo localities of Early Cretaceous vertebrates, in: Komarov, A.V. (Ed.), Materials of the Regional Conference of the Geologists of Siberia, Far East, and North East of Russia, Vol. 2. GalaPress, Tomsk, pp. 363–366 (in Russian).

Leshchinskiy, S.V, Voronkevich, A.V., Fayngertz, A.V., Maschenko, E.N., Lopatin, A.V., Averianov, A.O., 2001. Early Cretaceous vertebrate locality Shestakovo, Western Siberia, Russia: A refugium for Jurassic relicts? J. Vert. Paleontol. 21, 73A.

Lopatin, A.V., Maschenko, E.N., Averianov, A.O., Rezvyi, A.S., Skutschas, P.P., Leshchinskiy, S.V., 2005. Early Cretaceous mammals from Western Siberia: 1. Tinodontidae. Paleontol. J. 39, 523–534.

Lopatin, A.V., Averianov, A.O., Maschenko, E.N., Leshchinskiy, S.V., 2009. Early Cretaceous mammals of Western Siberia: 2. Tegotheriidae. Paleontol. J. 43, 453–462.

Lopatin, A.V., Averianov, A.O., Maschenko, E.N., Leshchinskiy, S.V., 2010a. Early Cretaceous mammals of Western Siberia: 3. Zhangheotheriidae. Paleontol. J. 44, 573–583.

Lopatin, A.V., Maschenko, E.N., Averianov, A.O., 2010b. A new genus of triconodont mammals from the Early Cretaceous of Western Siberia. Dokl. Biol. Sci. 433, 282–285.

Lopatin, A.V., Maschenko, E.N., Tarasenko, K.K., Podlesnov, A.V., Demidenko, N.V., Kuzmina, E.A., 2015. A unique burial site of Early Cretaceous vertebrates in Western Siberia (the Shestakovo 3 locality, Kemerovo Province, Russia). Dokl. Biol. Sci. 462, 148–151.

Maschenko, E.N., Lopatin, A.V., 1998. First record of an Early Cretaceous triconodont mammal in Siberia. Bull. Inst. R. Sci. Nat. Belg., Sci. Terre 68, 233–236.

O'Connor, J.K., Averianov, A.O., Zelenkov, N.V., 2014. A confuciusornithiform (Aves, Pygostylia)-like tarsometatarsus from the Early Cretaceous of Siberia and a discussion of the evolution of avian hind limb musculature. J. Vert. Paleontol. 34, 647–656.

Rozhdestvensky, A.K., 1955. New data on psittacosaurs – Cretaceous ornithopods. Questions Geol. Asia 2, 783–788 (in Russian).

Rozhdestvensky, A.K., 1960. Locality of Lower Cretaceous dinosaurs in Kuzbass. Paleontol. J. 2, 165 (in Russian).

Saev, V.I., Leshchinskiy, S.V., 1997. New findings of dinosaurs in Siberia, in: Podobina, V.M., Savina, N.I., Kuznetsova, K.I., Muzylev, N.G. (Eds.), Biostratigraphy and microorganisms of the Phanerozoic of Eurasia. Geos, Moscow, p. 268 (in Russian).

Tatarinov, L.P., Maschenko, E.N., 1999. A find of an aberrant tritylodont (Reptilia, Cynodontia) in the Lower Cretaceous of Kemerovo Region. Paleontol. Zh. 4, 85–92 (in Russian).

Voronkevich, A.V., 1998. A large representative of the genus *Psittacosaurus* from the locality Shestakovo-3, in: Vyltsan, I.A. (Ed.), Actual questions of the geology and geography of Siberia: Materials of the scientific conference. Vol. 1. Tomskii Gos. Univ., Tomsk, pp. 190–193 (in Russian).

Reinvestigation of an Early Cretaceous eutherian mammal *Endotherium niinomii*

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Various mammalian fossils have been discovered from the Lower Cretaceous (Aptian–Albian) Fuxin Formation in western Liaoning Province, northeastern China. They include eutriconodontans (three described species of two genera and a few other undescribed species), multituberculates (four described species of three genera and a few other undescribed species), at least one undescribed species of spalacotheriids, and eutherians (*Endotherium niinomii* and other undescribed species) (Shikama, 1947; Kusuhashi et al., 2009a,b, 2010, 2015).

The number of eutherian specimens collected from the Fuxin Formation reaches 40% of the total collection. It implies that they were a dominant group of the mammalian fauna in East Asia at that time. Another dominant group is multituberculates, also constituting 40%. This faunal composition is very different from that of the Jehol Group, which is also distributed in western Liaoning but is slightly older than the Fuxin Formation; multituberculates and eutherians were obviously minor elements in the mammalian fauna from the group (Meng, 2014). Eutherians from the Fuxin Formation, therefore, might provide the information about early diversification of the group in East Asia.

Endotherium niinomii is a eutherian mammal reported from the Fuxin Formation by Shikama (1947). Unfortunately, the important part of the type specimen including molars was lost sometime after his observation, and the specimen was not sufficiently described and illustrated in the paper. Therefore, the species is rarely mentioned in recent papers on Mesozoic eutherians, and sometimes treated as a *nomen dubium* (e.g., Kielan-Jaworowska and Cifelli, 2001). However, the coaly rock containing the remaining part of the type specimen is still housed in the Dalian Museum of Natural History, and the impressions of the missing parts are preserved on it. We reexamined the morphology of the type specimen based on the impressions and the original description of Shikama (1947), preceding to the study on our eutherian specimens from the Fuxin Formation.

The dentaries of *Endotherium niinomii* are relatively slender and highly probably had five premolars and three molars. The entoconid and hypoconulid of lower molars are not closely twinned. These features imply that Shikama's (1947) attribution of the species to the Eutheria is reasonable. The species also has following characteristics: sizes of lower molars diminish distally; the height difference between the trigonid and talonid of lower molars are moderate and smaller than those of other Early Cretaceous eutherians; lower molar cusps are blunt; the protoconid is the largest among the trigonid cusps; the paraconid is as tall as the metaconid. This suite of characters is enough diagnostic among Cretaceous eutherians, and we thus consider that *E. niinomii* is a valid species.

References

Kielan-Jaworowska, Z., Cifelli, R.L., 2001. Primitive boreosphenidan mammal (?Deltatheroida) from the Early Cretaceous of Oklahoma. Acta Palaeontol. Polonica 46, 377–391.

Kusuhashi, N., Hu, Y.-M., Wang, Y.-Q., Hirasawa, S., Matsuoka, H., 2009a. New triconodontids (Mammalia) from the Lower Cretaceous Shahai and Fuxin formations, northeastern China. Geobios 42, 765–781.

Kusuhashi, N., Hu, Y.-M., Wang, Y.-Q., Setoguchi, T., Matsuoka, H., 2009b. Two eobaatarid (Multituberculata; Mammalia) genera from the Lower Cretaceous Shahai and Fuxin formations, northeastern China. J. Vert. Paleontol. 29, 1264–1288.

Kusuhashi, N., Hu, Y.-M., Wang, Y.-Q., Setoguchi, T., Matsuoka, H., 2010. New multituberculate mammals from the Lower Cretaceous (Shahai and Fuxin formations), northeastern China. J. Vert. Paleontol. 30, 1501–1514.

Kusuhashi, N., Wang, Y.-Q., Li, C.-K., Jin, X., 2015. Two new species of *Gobiconodon* (Mammalia, Eutriconodonta, Gobiconodontidae) from the Lower Cretaceous Shahai and Fuxin formations, northeastern China. Hist. Biol. 28, 14–26.

Meng, J., 2014. Mesozoic mammals of China: Implications for phylogeny and early evolution of mammals. Nat. Sci. Rev. 1, 521–542.

Shikama, T., 1947. Teilhardosaurus and Endotherium, new Jurassic Reptilia and Mammalia from the Husin Coal-Field, south Manchuria. Proc. Japan Acad. 23, 76–84.

Vitakri Dome of Pakistan – a richest graveyard of titanosaurian sauropod dinosaurs and mesoeucrocodiles in Asia

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Titanosauriform/early titanosaurian sauropod dinosaurs from Pakistan

Brohisaurus kirthari is found in the lowest part of the Upper Jurassic of the Sembar Formation from Kirthar Range, Khuzdar District, Balochistan. It is based on some poorly recognized postcranial elements. It shows apparent pneumaticity in thoracic ribs and a strongly anteroposteriorly compressed femoral midshaft.

Titanosaurian sauropod dinosaurs from Pakistan

Khetranisaurus barkhani is characterized by slightly broad to sub squarish midcaudals. Its centrum is unique among Pakiforms having broad ventral centrum width than dorsal centrum width (Fig.1).

Sulaimanisaurus gingerichi is characterized by long and squarish mid caudals, and it is based on fragmentary caudal vertebrae and many referred vertebrae and bones from Sangiali, Shalghara and Mari Bohri localities.

Pakisaurus balochistani is based on four associated tall caudal centra and also attributed many fragmentary, associated and articulated bones and pieces of bones belong to crania/skull, vertebrae, ribs, sternal, scapulae, humerai, radius, ulnae, ilia, femora, tibia, fibula, foot bones, osteoderms, pieces of coprolite, etc.

Marisaurus jeffi is based on six heavy and slightly tall to squarish midcaudals. The ratio of mid-dorsal width to mid-ventral width of mid and posterior caudals is about 1.5. It is attributed by cranial and postcranial materials.

Balochisaurus malkani were relatively most stocky and large bodied with stocky limbs. It is based on seven associated heavy and broad to squarish (heart shape mid caudals) caudal vertebrae and also attributed many fragmentary, associated and articulated bones and pieces of bones like postcrania, osteoderms, pieces of coprolite, etc. The ratio of mid-dorsal width to mid-ventral width of mid and posterior caudals is about 2.

Gspsaurus pakistani is based on most complete relatively large skull. The anterior dentary symphysis seems to be weak. The anterior portions of dentary rami are V-shaped. It has relatively long, narrow, slightly oval, slender and slightly recurved teeth.

Saraikimasoom vitakri rostrum is of generally long, narrow and moderate shallow shape (with 40° inclinations from horizontal). The anterior portions of upper and lower jaws are broadly arched forming U-shape. Teeth are long, narrow and slender. A tooth slenderness index seems to be 3–5. Its teeth are robust and straight relative to *Gspsaurus*. It shows dental formula 4, 13/11–17(?). The teeth row of left upper jaw seems to be complete, and it gives the best information on the Titanosauria at a global level. Generally, the titanosaurs were considered as bearing a *Diplodocus*-type skull, but moderate incline and moderate long well developed skulls are now found in Pakistan (Fig. 1).

Nicksaurus razashahi is based on axial and limb elements and includes a pair of femora (left full femur, right partial femur), a pair of stocky distal tibiae, partial humerus parts; proximal radius, five teeth in jaw ramus, chevron, cervical/dorsal centrum (Fig. 1). The very broad nature of holotypic caudals shows its relation to the family Saltasauridae.

Maojandino alami is a titanosaurian sauropod with a thickest, broad and long neck, short tail, heavy and stocky body. The holotypic materials include about 6 cervical, 4 dorsal, and 10 caudal vertebrae along with partial left femur, partial left and right tibiae, partial radius, a pair of partial distal scapulae, partial sternal plate/ilia, some neural arch and lamina covered partially by yellow brown muds, etc. (Fig. 1). Although they are fragmentary and disarticulated, they are associated, because all of this material is found within one site of the same locality. *M. alami* may belong to the family Balochisauridae of titanosaurian sauropods.

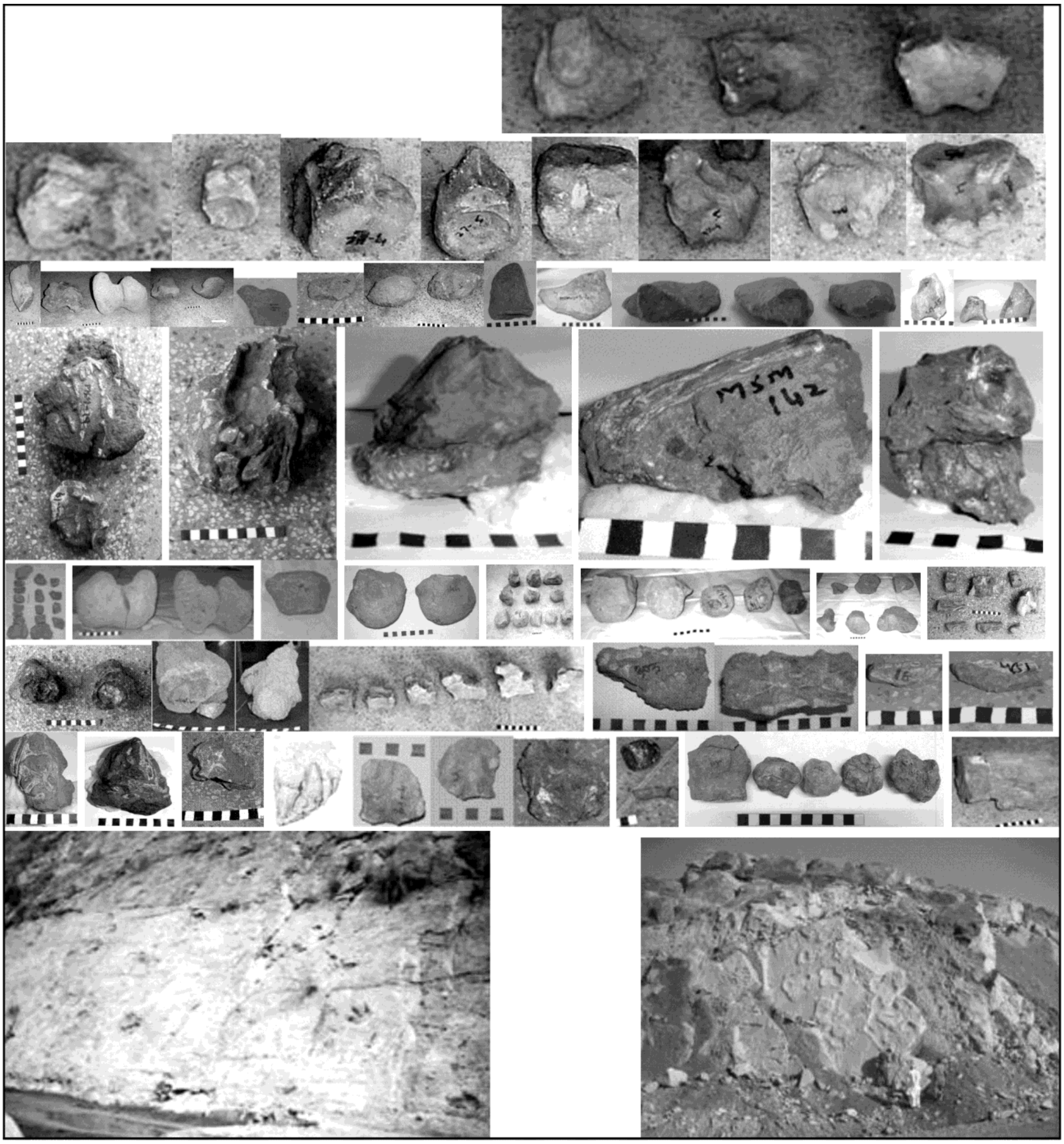

Figure 1. Row 1, Line drawing of Pakisauridae (1st 3 vertebra) and Balochisauridae (last 2 vertebra), 3 vertebra of *Pakisaurus balochistani*; **Row 2,** 1 vertebra in 2 views of *Sulaimanisaurus gingerichi*, 1 vertebra in 3 views of *Khetranisaurus barkhani*, 1 vertebra of *Marisaurus jeffi* and 1 vertebra in 2 views of *Balochisaurus malkani;* **Row 3,** Proximal femur of *Pakisaurus balochistani* bevelved proximally, 2 diversity of distal femora, 2 diversity of proximal tibiae, mosaic and ellipsoid type osteoderms of Gondwanan titanosaurs affinity, bulb with long root/cone osteoderm show Laurasian titanosaurs affinity, 2 type of distal scapula representing less and more wide gauge titanosaurs; trispinous distalmost caudal show special tail for defending, eating and mating; **Row 4,** skulls of *Gspsaurus pakistani* (2 photo) and *Saraikimasoom vitakri* (3 photo); **Row 5,** limb and axial elements of *Nicksaurus razashahi* (4 photo), axial and limb elements of *Maojandino alami* (3 photo), limb and axial elements of *Brohisaurus kirthari* (1 photo); **Row 6,** limb and axial elements of abelisaurian large theropod *Vitakridrinda sulaimani (4 photo)*, a pes of noasaurian small theropod *Vitakrisaurus saraiki* (1 photo with two views), holotype and referred dentaries of pterosaur *Saraikisaurus minhui*; **Row 7,** rostrum (2 photo) and teeth (1 photo) of *Induszalim bala*; snout of *Pabwehshi pakistanensis*, anterior dentary with symphyses of *Sulaimanisuchus kinwai*, and holotypic rib and referred possible egg of *Khuzdarcroco zahri*, five pieces of coprolites, and *Baradarakht goeswangai* gymnosperm wood fossil; **Row 8,** tracks of a herd of titanosauriforms (*Malakhelisaurus mianwali*) confronted by a running large theropod (*Samanadrinda surghari*); two tracks of a couple of small theropods (*Himalayadrinda potwari*) showing converging and again diverging tracks; a herd of *Pashtosaurus zhobi* titanosaurs with good preservation of a pes and many manus without claw. Scale each black or white digit is 1cm.

New locomotion style of titanosaurs from Pakistan

Less and more wide-gauge movements originally appeared in Balochisauridae and Pakisauridae (titanosaurian sauropods) from Pakistan. The distal scapula in *Pakisaurus* (and possibly other taxa of Pakisauridae) is deflected laterodorsally creating more wide gauge movements, while the distal scapula in *Marisaurus* (and probably, *Balochisaurus*) of Balochisauridae is straight or inclined slightly medially with less wide gauge movements. The features like proximal femur deflected medially, femoral eccentricity, laterally beveled and fibular condyle of femur, broad sacrum and ilia, laterodorsally deflected distal scapula and large sternal plates are the basic elements resulted in wide-gauge movement parten of Pakiforms.

Tail features of titanosaurs from Pakistan

A specific fossil tail with trispinous distalmost caudal centrum, found in Pakistan for the first time, provides a new look on Titanosauria. It has been found in the uppermost Cretaceous Vitakri Formation (Sulaiman Basin, Pakistan). Fossil tail of titanosaurs from Pakistan is unique. It seems to be robust and relatively short, and it may serve for different purposes being a good defending tool from its foe, balancing body as a third support while searching food in tall tree, and mating. So far, this discovery shows an endemic nature of Pakisauridae and Balochisauridae.

Osteoderms and dermal plates of dinosaurs from Pakistan – the fossils reported from Asia for the first time

Malkani (2003) reported four types of osteoderms of titanosaurs from Pakistan, for the first time from Asia. Osteoderm scutes of mosaic type are assigned to *Marisaurus*, large dermal armor of ellipsoid type is assigned to *Balochisaurus*, and large dermal armor of ellipsoid type with median cut is assigned to *Pakisaurus*. Some other bulb and root type osteoderms are also found in Pakistan.

Coprolites of dinosaurs from Pakistan

Diverse coprolites of dinosaurs are found in India, but some small rounded to surrounded, spongy/vesicular pieces of coprolites with diameter of 5–7 cm are revealed in Pakistan (Fig. 1). These coprolite pieces are spongy. No grassy material is visible by naked eye.

Eggs of dinosaurs from India and Pakistan

Well preserved and diverse eggs of dinosaurs were reported from India. The snake bones are found in one nest. Nevertheless, no well recognized eggs are found in Pakistan.

Theropod dinosaurs from Pakistan

Vitakridrinda sulaimani is a large bodied abelisaurian, based on a pair of left and right proximal femora as well as basioccipital condyle alongwith partial braincase. It has referred many vertebrae and limb bones. *Vitakrisaurus saraiki* is a small-sized noasaurian based on isolated pes. The large ratio between phalanges II–2 and II–1 and proximally narrow metatarsal II (in dorsal view) also suggest noasaurids affinities, while phalanx II–2 is longer than *Velocisaurus* (compared to phalanx II–1). Many smaller bones and phalanges are found just below the claw, which may be the bones of left pes of *Vitakrisaurus* or may belong to the birds or other flying reptiles like pterosaurs. The noasaurids are represented by *Composuchus*, *Jubbulpuria*, *Laevisuchus*, *Masiakasaurus*, *Noasaurus*, *Ornithomimoides*, *Velocisaurus*, and *Vitakrisaurus*.

Footprints and trackways of dinosaurs from Pakistan – the fossils reported from Asia for the first time

A herd of early titanosaurs (*Malakhelisaurus mianwali*) has been revealed in Pakistan confronted by a running large theropod (*Samanadrinda surghari*), that represents a confrontation scenario. A couple of small theropods have been also found (*Himalayadrinda potwari*) (Fig. 1). The footprints and trackways of the titanosaur *Pashtosaurus zhobi* are found on the thick sandstone bed of the latest Cretaceous Vitakri Formation (Balochistan, Pakistan). This discovery is significant, because the bones and footprints are found in the same horizon and the same basin.

Pterosaur from the Latest Cretaceous Vitakri Formation of Pakistan

Saraikisaurus minhui is based on dentary ramus with eight teeth. This ramus shows internal pneumatic texture/structure. The teeth are oval to suboval, some overlapped. The total length of preserved dentary ramus is 5.8 cm. The dentary is slender. A dentary without teeth and some limb bones with thick hollow and thin peripheral bone and small size show their assignment to pterosaur or bird (Fig. 1).

Mesoeucrocodiles from Pakistan

Pabwehshi pakistanensis is based on rostrum and articulated partial dentary. The *Sulaimanisuchus kinwai* is based on anterior dentary and splenial. The *Induszalim bala* is based on rostrum (Fig. 1), which shows anteriorly/anterodorsally directed external nares, very high/very deep and narrow rostrum, the laterally compressed teeth of ziphodont type (oval to D-shape, heterodont in size), and thick rostral elements. In *Induszalim*, the snout depth is equal to width, while in *Pabwehshi* the depth is ¾ of width. In *Induszalim*, the maxillary ramus is relatively far away/down to palatal contact, while in *Pabwehshi* the maxillary ramus is just close to the palatal contact. In *Induszalim*, the large teeth dia is relatively more than *Pabwehshi* tooth diameter, and there are pits with anteroposterior lineation on the lateral side of maxillary ramus. *Pabwehshi* has no lineation. *Induszalim* shows marked boundary/contact between palatal shelves and maxillary wall, but *Pabwehshi* shows no boundary/contact between palatal shelves and maxillary wall. *Induszalim* is similar to *Pabwehshi* in having saggital torus on palatal shelves. The *Khuzdarcroco zahri* is based on one partial rib and referred half egg.

References

Malkani, M.S., 2003. Pakistani Titanosauria; are armoured dinosaurs? Geol. Bull. Univ. Peshawar 36, 85–91.

Lithostratigraphy and biota of the Late Cretaceous dinosaur bearing Lameta and intertrappean sediments along Salbardi fault in Betul and Amravati districts of Central India

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The Deccan volcanic associated sediments are designated as the infratrappean (Lameta Formation) occurring just below the earliest volcanic flow in the basin and the intertrappean deposited between the flows during the break in the volcanic activity. The sediments forming the Lameta Formation are deposited in different inland basins including the Salbardi basin in the Amravati District of Maharashtra and the adjoining Betul District of Madhya Pradesh in Central India. The Lameta sediments (Maastrichtian) rests over the Archaean basement or Gondwana Group of rocks, and are overlain by Deccan volcanic sequence with intertrappean sediments deposited at different stratigraphic levels. The Gondwana shows faulted contact with Lameta and Deccan trap. A thick pile of Deccan volcanic flows are present in the area, and they are classified as the Satpura Group to the north and the Sahyadri Group to the south of Salbardi fault. The associated intertrappean beds in the area lithologically comprise chert, cherty and nodular limestone, clay, shale, cherty and tuffaceous shale.

The 14 m thick Lameta Formation in the lower part comprises 5–6 m thick conglomeratic and pebbly green to grey sandstone associated with clay pockets in the basal part, and medium to coarse grained sandstone, which is concretized in the upper parts covered with thin veneer of chert. The 6–7 m thick calcretes formed after the sandstone are nodular to massive at different levels, with thin chert partings. The calcretes at the top are mostly capped by chert (silcretes). Dinosaur and turtle bones are present in the green sandstone, whereas the nests and eggs are recorded in the upper part of the sequence in the calcretes. Parataxonomically, the eggs are of *Megaloolithus* affinity.

To the south-west of Salbardi village, the good outcrops of intertrappean beds up to 2 m thick are exposed in the localities at Hiradehi and Topidhana. The sediments comprise black and gray chert, clay, shale, cherty shale and shaly marly limestone. Molluscs mainly represented by *Physa*, *Paludina*, *Lymnea*e and *Unio* are present in the sediments with scarce wood fragments. During the palynological study, different types of pennate diatoms characterised by rectangular elongate and square shape were recovered from the Topidhana sections, whereas mycorrhizal fungi, cuticles of plants and other microflora were recovered from the Hiradehi sections.

Early Cretaceous fossil sites in Kalasin Province, Thailand

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Since the 1980s, Thai–French Research Projects on the Mesozoic vertebrates of Thailand have resulted in the discovery of many dinosaur localities ranging in age from Late Triassic to Early Cretaceous. After the discovery, the study of the dinosaurs of Thailand has increased considerably.

Thai dinosaurs, recorded non-marine Mesozoic environments, are quite abundant on the Khorat Plateau. The Khorat Group is a rock group that is represented by the deposits of the Khorat Plateau in the northeastern part of Thailand, ranging in age from 100 to 230 million years. This red bed has yielded 16 species of dinosaurs, including the allosaurid or metriacanthosaurid (*Siamotyrannus*) and the oldest known sauropod (*Isanosaurus*) in the world. In Northeast Thailand, dinosaurs are abundant in the Sao Khua Formation containing various theropods and sauropods. The Kalasin Province is one of the most important areas for dinosaur discovery in Thailand. Dinosaur bones, other vertebrate fossils and dinosaur trackways are found in three Cretaceous formations: the Sao Khua Formation, the Phra Wihan Formation, and the Khok Kruat Formation.

More than 700 pieces of bones and five new species are found in the Sao Khua Formation (Early Cretaceous) at Phu Khum Kao hill of Kalasin Province. One of the specimens is the most complete dinosaur skeleton found to date in Thailand. It was named as a "dinosaur's graveyard". The Phu Faek Park is other place in the Kalasin Province that discovered theropod footprints of various sizes. No skeletal remains of dinosaurs have yet been found in the Phra Wihan Formation (Early Cretaceous). The last Cretaceous fossil site is located beside of the Lam Pao River. The large bone of sauropod, teeth of spinosaurid and accompanying vertebrate fossil fauna are found here.

The discovery of fossil sites in this area provides the important paleontological data for the study of dinosaur successions in Thailand. Consequently, Department of Mineral Resources has developed large dinosaur museum and paleontology institute, which become the significant tourist attraction and learning center of Thailand and Southeast Asia.

Keywords

Thai dinosaurs, Khorat Group, Mesozoic vertebrates.

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