American Journal of Plant Biology
2017; 2(2): 43-48
http://www.sciencepublishinggroup.com/j/ajpb
doi: 10.11648/j.ajpb.20170202.11

New Fossil Plant and Insect Records Bearing on Cretaceous Climate of Western Gobi, Mongolia

Valentin Krassilov[1, 2], Dmitry Vassilenko[1], Alexandra Sokolova[1], Sophia Barinova[2, *]

[1]Paleontological Institute, Russian Academy of Sciences, Moscow, Russia

[2]Institute of Evolution, University of Haifa, Mount Carmel, Haifa, Israel

Email address:

vakrassilov@gmail.com (V. Krassilov), damageplants@mail.ru (D. Vasilenko), klumbochka@mail.ru (A. Sokolova), sophia@evo.haifa.ac.il (S. Barinova)

[*]Corresponding author

To cite this article:

Valentin Krassilov, Dmitry Vassilenko, Alexandra Sokolova, Sophia Barinova. New Fossil Plant and Insect Records Bearing on Cretaceous Climate of Western Gobi, Mongolia. *American Journal of Plant Biology.* Vol. 2, No. 2, 2017, pp. 43-48. doi: 10.11648/j.ajpb.20170202.11

Received: October 30, 2016; **Accepted**: December 14, 2016; **Published**: February 22, 2017

Abstract: The paper examines new fossil plant and insect findings in the Cretaceous of the western Gobi as a source of climatologic inference. The isophlebiid dragonflies at the base of the Cretaceous sequence witness to an extension of the Late Jurassic climate warming to the earliest Cretaceous. Climatic fluctuations through the late Neocomian – Cenomanian are indicated by a series of paleofloristic events. The allochtonous localities of *Phoenicopsis* (Czekanowskiales) in the basal members of the Mogotuin Formation, Manlay depression, and Khurendukh Formation, Choyr Basin, are evidence of temperate arboreal vegetation on the bordering basement ridges. A mass occurrence of Otozamites, a thermophilic bennettitalean plant in the upper part of the Mogotuin Formation near its boundary with the redbeds of Manlay Formation heralds a xerothermic trend of climatic evolution. The first appearance of *Sequoia* at the top of the Barun Bayan redbeds marks reversion of the trend at about the Albian – Cenomanian boundary.

Keywords: Fossil Flora, Fossil Insects, Paleoecology, Paleoclimatology, Cretaceous, Mongolia

1. Introduction

The Cretaceous deposits of Mongolia are rich in plant and animal fossils representing a nearly continuous record of ecosystem evolution. In terms of Mesozoic paleophytogeography, the Mongolian terrestrial plant assemblages are intermediate (ecotonal) between the temperate and subtropical vegetation types designated as the *Phoenicopsis* and *Cycadeoidea* zones [1]. In distinction from paleofloristic classifications (e.g., [2]), based on endemic taxa, the ranges of which are partly controlled by migration routes, zonal vegetation types, or biomes, reflect differentiation of global climates and are the major source of evidence bearing on climatic evolution. Owing to its ecotonal situation, Mongolia is a key region for understanding climate change during the Cretaceous.

The current status of Cretaceous stratigraphic divisions and their age assignments are reviewed in [3-6], who recognized the regional formations listed in Figure 1. In addition, a number of local stratigraphic divisions only loosely correlated with the regional formations have been described from isolated depressions, such as the Manlay depression [7] and Choyr Basin [8].

The Early Cretaceous flora described by Krassilov [9] contains about 60 species from 12 major localities of western and eastern Mongolia. A few local fossil plant collections were studied by Jännichen and Kahlert [10] and by Saiki and Okubo [11]. The fossil insect localities are reviewed in Ponomarenko and Popov [12] and none of importance has been added since. However, recent developments in non-marine stratigraphy and paleoclimatology require thorough revision of previous results, as well as in-depth analysis of their climatic implications.

2. Material and Methods

The material for this paper was collected during the field work in the western Gobi in 2008 from a number of well-known and recently discovered localities (Figure 2) yielding a representative collection of fossil plants and insects presently under study in the Paleontological Institute, Russian Academy of Sciences, and the Paleontological Center, Mongolian Academy of Sciences. The paleontological collecting was accompanied by taphonomic observations. The material was morphologically studied under Leica Stereomicroscope. Cuticular preparations and transfers of plant compressions for micromorphological details were studied in transmitted light with Zeiss LM and scanned under Camscan SEM. Digital photodocumentation was performed for all the specimens under study.

Age	Regional Formations	Local formations		Plant and insect events
Cenomanian Albian	Baruunbayan (Barun Bayan)			*Sequoia* Redbeds
Albian Aptian	Khukhteeg (Khukhteg)	Choyr	Khurendukh	*Phoenicopsis* II
		Choyr	Khalzanuul	
Barremian Hauterivian	Shinekhudag (Shin Khuduk)			*Heteroscopus*
		Manlay	Manlay	Redbeds
Valanginian Berriasian	Tsagantsav (Tsagantsab)	Manlay	Mogotuin	*Otozamites* Gnetophytes *Phoenicopsis* I Conglomerates
		Khoot		Isophlebiids

Figure 1. *Stratigraphic position of the climatically controlled fossil plant and insect events against the sequence of the regional and local formations of western Gobi after Barsbold and Khand [6], Kalugina [7], and Nichols et al. [15]; in brackets alternative spellings commonly used in the English language publications.*

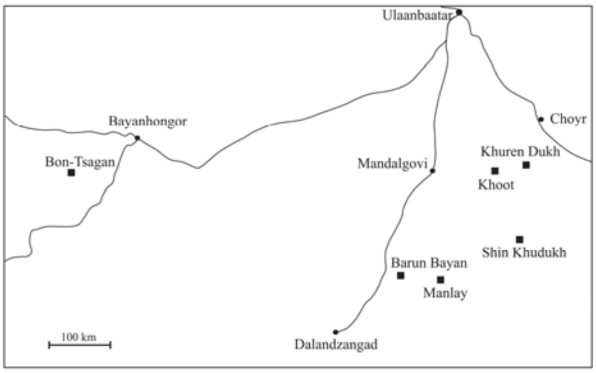

Figure 2. *Map of the fossil plant and insect localities mentioned in the text.*

3. Results

Here we report on the findings of paleoclimatological significance, potentially important for ecostratigraphic correlation. The results are presented as a series of "events" marked by abundant (mass) occurrences of plant and/or insect taxa of climatically controlled distribution and paleoecology.

3.1. Isophlebiid Dragonfly Event

A mass occurrence of isophlebiid dragonflies (Odonata: Isophlebiidae) of the genus *Xeta* (Figure 3) is recorded from a paper-shale outcrop south of the Khoot Coal Quarry (45°41'40.7"N; 107°42'38.2"E). Isophlebiids are considered to be a thermophilic group [13] characteristic of the Late Jurassic thermal maximum that extends to the Berriasian [14]. Notably, isophlebiids are lacking in the famous Shin Khuduk locality of southern Gobi (N 44°42'57.3"; E 107°55'22.5") that instead contains the hemeroscopid dragonflies *Hemeroscopus baissicus* Pritykina (Odonata; Hemeroscopidae), as well as the aeshnids *Baissaeshna* (Odonata: Gomphaeschninae), both known from the temperate – ecotonal Lower Cretaceous localities of Transbaikalia. Still the conspicuous presence of the thermophilic corixid bugs *Diapherinus ornatipennis* Yu. Popov (Corixidae: Heteroptera) suggests a relatively warm climate for the Shin Khuduk time level, which is consistent with paleobotanical records of the araucariaceous conifers and cheirolepids ([9] and new finds).

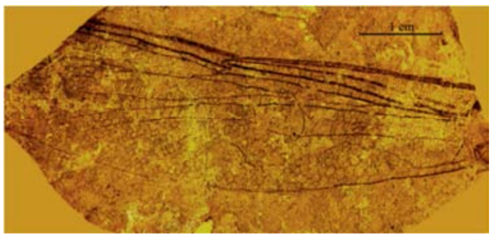

Figure 3. *Xeta sp., wing of a thermophilic isophebiid dragonfly Xeta sp. from the Khoot locality. Scale bar 1 cm.*

3.2. Phoenicopsis Event

Phoenicopsis (Czekanowskiales) is a dominant deciduous tree of the temperate *Phoenicopsis* biome [1] penetrating as an allochtonous element the temperate/subtropical ecotonal area of central – southern Gobi. It was rather common during the mid-Jurassic cooling event, but later was only sporadically found, e. g. in the Bon-Tsagan locality [9]. Our new finds in Khuren Dukh and Manlay (Figure 2) are the mass occurrences representing what we call "Phoenicopsis events."

The Khuren Dukh (Huren Duh) locality (N 45°50'27.0"; E 108°26'48.0") occurs on the western border of Choyr Basin about 250 km south of Ulaanbaatar. It is a discontinuous outcrop exposing a fining upward sequence of conglomerates, sandstones, and black shales deposited on the granitic basement. The coarse-grained and shaly deposits are assigned, respectively, to the lower and middle members of Khurendukh Formation [8]. *Asteropollis*, a palynological marker for the early – middle Albian, came from the middle member [15].

The leaf compressions and well-preserved dispersed cuticles are found in the cross-bedded sandstone/siltstone alternation of the lower member of the Khurendukh Formation. Both the lithology and taphonomy of dispersed remains imbedded in the rock matrix indicate allochtonous deposition. The leaf fragments are naturally macerated yielding the amphistomatic cuticles with irregular stomatal files (Figure 4). On account of their stomatal topography, the leaves are assignable to Windwardia morphotype of polymorphic *Phoenicopsis* s.l. [16]. The stomatal configurations vary over the leaf surfaces being elongate on the upper cuticle and isometric on the lower cuticle. The material evidently represents a new species that will be formally described elsewhere.

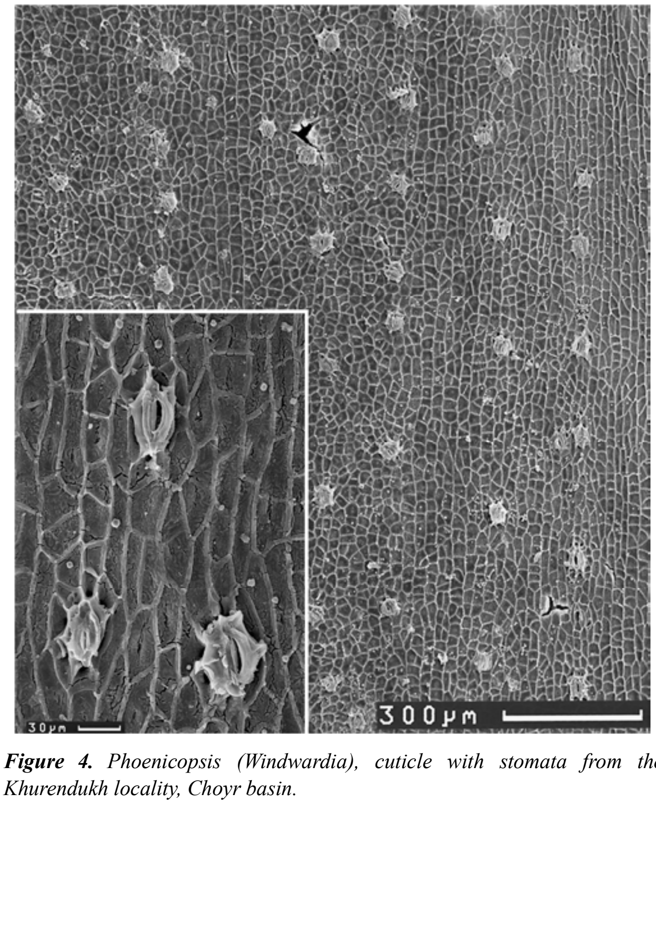

Figure 4. *Phoenicopsis (Windwardia), cuticle with stomata from the Khurendukh locality, Choyr basin.*

The Manlay locality (N 44°06'43.0"; E 106°56'43.6") occurs at the base of Mogotuin Paleozoic Ridge near Manlay Village. It comprises several plant-bearing horizons confined to the shaly intercalations of the coarse-grained Mogotuin Formation (detailed lithological description in Kalugina [7]. The age assignments of Mogotuin shales and the overlying Manlay redbeds are controversial, ranging from the early Neocomian to the late Neocomian – Aptian [5]. The leaves and occasional leafy short-shoots of *Phoenicopsis* come from the lower shale horizon in association with *Czekanowskia* and fragmentary *Ginkgoites mongolicus* Krassilov.

The plant remains are rather poorly preserved precluding a species-level comparison with the Khuren Dukh material. Yet the taphonomic environments are rather similar. In both cases deposition of plant material took place in a high energy environment enhancing transportation of plant debris from remote sources. Since *Phoenicopsis* is lacking in the fossil plant assemblages of lacustrine paper-shales that are the most widespread type of plant-bearing deposits in Mongolia, its occurrence among the wash-out debris in the coarse-grained basal members at Khuren Dukh and Manlay is evidence of transportation from upslope vegetation.

Phoenicopsis is ubiquitous over the coal basins of northern Asia and represents a major type of lowland vegetation thriving under a humid temperate climate. Lowland communities commonly occur at a higher elevation south of their core area. However, the mid-Cretaceous landscapes of Gobi are traditionally reconstructed as open with scanty riparian vegetation. The *Phoenicopsis* events are therefore important as evidence of arboreal upland vegetation descending downslope during the cooler phases of climatic cycles [17].

3.3. Otozamites Event

Most distinctive for the Mesozoic subtropical vegetation are Cycadeoidea (Bennettitales) and allied genera of short bulky (pachycaul) stems and pinnate leaves of *Zamites*, *Ptilophyllum*, *Otozamites*, and allied morphotypes. Not only the stems, but also the leaf types are unknown in the temperate Mesozoic realm. *Phoenicopsis* and *Otozamites* are antipodal in their distribution, but co-occur in the ecotonal floras of Transbaikalia and Gobi, although never in a single bed assemblage. In the *Cycadeoidea* zone, *Otozamites* is recorded from all major fossil plant localities. Yet only mass occurrences of this bennettitalean leaf morphotype are here designated as "*Otozamites* events."

Of two species described from Mongolia, the better studied *O. lacustris* Krassilov from Bon-Tsagan and Manlay has its stomata deeply sunken in the aerenchyma-like spongy tissue [9]. Our new finds add to the morphological variation and paleoecology of this peculiar species.

In Manlay depression, the shaly sequence member of Mogotuin Formation contains the abovementioned *Phoenicopsis* locality near the base, followed by a gnetophyte assemblage in the middle, and *Otozamites* in the uppermost shale layers below a discontinuity separating them from the Manlay Formation. Detached leaf pinnules are the most common fossils on the bedding planes of the shale laminas. Their shapes and dimensions vary from minute semiorbicular to much larger elongate or lanceolate, with distinct or inconspicuous basal auricles, perhaps shed at different developmental stages (Figure 5). Their abundance and association with aquatic insects attests to proximity to the lacustrine deposition site.

The aerenchyma-like tissue with large intercellular spaces beneath the lower epidermis was interpreted [9] as adaptation to periodic submersion, which implies fluctuant water level of the Cretaceous Lake of Manlay [7]. At the same time, the abundance of pinnules on the bedding planes indicates their simultaneous shedding, supposedly an adaptation to seasonal drought spells.

The occurrence of *Otozamites* at the top of Modotuin sequence near the base of Manlay redbeds is consistent with paleoecological interpretation of similar events in the redbed sequences of the Russian Far East and China and elsewhere as evidence of increased aridity [18].

Figure 5. *Otozamites lacustris Krassilov, detached pinnules from the Manlay locality. Scale bar 1 cm.*

3.4. Sequoia Event

The Barun-Bayan locality (N 44°26'15.1"; E 105°06'29.5") is confined to a gray siltstone horizon at the top of a thick redbed sequence with occasional graybed intercalations increasing upsection. The plant assemblage contains conifer remains assigned on the basis of their seed cone morphology to the extant genus *Sequoia* (Taxodiaceae) (Figure 6). The associated plant remains are angiosperm leaves of *Araliaephyllum*, *Ettingshausenia* and a few other morphotypes (to be described).

In the eastern Asia, Sequoia first appeared in the late Albian [18], but its mass occurrences attesting to ecological dominance have been recorded since the Cenomanian and through the Late Cretaceous. In the Barun Bayan assemblage, both leafy shoots and cones of *Sequoia* are fairly abundant, enabling us to designate a "*Sequoia* event." Our data therefore suggest the early Late Cretaceous, rather than Early Cretaceous age. The Barun Bayan assemblage represents a distinct stage of floristic evolution in Mongolia, of critical importance for understanding the climatic evolution.

Currently surviving in the mountainous conifer rainforests of the western Pacific coastal ranges, the coastal redwoods *Sequoia* sempervirens and *Sequoiadendron giganteum* represent a nearly extinct group of Cretaceous and Tertiary conifers that formed extensive lowland forests over the vast territories of Siberia, Russian Far East and Kazakhstan. Their most prominent angiosperm broadleaf associates are platanoids in the temperate realm and lauroids in the subtropical zone justifying designation of the Late Cretaceous *Seqouia* – platanophyllous and Sequoia - laurophyllous biomes [19]. The latter are associated with thick coal deposition in the northern Sakhalin and elsewhere, hence suggesting a humid subtropical climate.

Neither *Sequoia* itself, nor its extinct progenitotial genera, have been ever recorded from the Early Cretaceous of Mongolia, which makes its autochthonous origin unlikely. Rather, the absence of phylogenetic precursors suggests a migratory appearance of *Sequoia* in the region. At the Barun Bayan locality, Sequoia is accompanied by both platanophyllous and laurophyllous broadleaves, which is fully consistent with ecotonal aspect of the regional vegetation. However, the redwood community indicates a radical change from subtropical redbed climate of pronounced seasonal dryness towards more humid and equable conditions. A climate change like this must have inflicted a major restructuring of terrestrial ecosystems at about the Albian – Cenomanian boundary.

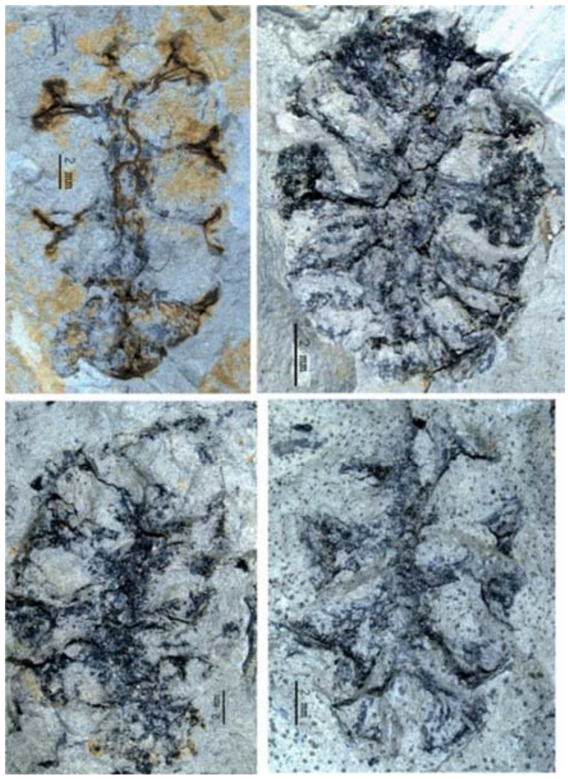

Figure 6. *Sequoia sp., seed cones from the Barun Bayan locality.*

4. Discussion

Cretaceous climates of continental interiors are subject of a lingering discussion. Open landscapes with sand dunes are traditionally reconstructed for the Gobi Province of Mongolia, whereas Sloan and Baron [20] have interpreted the results of climate modeling as indicating that regardless of topography and other conditions, continental interiors would have cold winter temperatures even during the globally warm periods.

Our paleoclimatic inferences are based on mass occurrences (rather than occasional records) of plant and insect species [21], the climatic requirements of which are deduced from their paleogeographic distribution and extant ecological equivalents. Plant-insects interaction is the new approach with using of the plant taphonomy, paleoecology and paleogeographic inference [22] in the face of the ongoing global climate change [23].

In ascending stratigraphic order, the mass occurrences of thermophilic isophlebiid dragonflies (Odonata: Isophlebiidae) at the base of Cretaceous sequence at Khoot are interpreted as an extension of the Late Jurassic thermal maximum. Dragonflies are rare or lacking at the Manlay stratigraphic level, reappearing as different families (Heteroscopidae) in the Shin Khuduk assemblages that contain also the thermophilic corixids.

The allochtonous leaf remains and dispersed cuticles of *Phoenicopsis* (Czekanowskiales), a dominant element of temperate Mesozoic realm, are found in the coarse-grained basal members of the Khurendukh Formation, Choyr Basin and Mogotuin Formation, Manlay depression, providing evidence of temperate arboreal vegetation on basement ridges bordering the mid-Cretaceous sedimentary basins of the southern Gobi.

A mass occurrence of *Otozamites lacustris* Krassilov, a thermophilic bennettitalean plant, in the upper part of Mogotuin Formation near its boundary with redbeds of Manlay Formation marks a xerothermic trend of the climate change. The leaf histology of this species suggests periodic submersion caused by water level fluctuations in the Cretaceous Lake of Manlay, whereas shedding of pinnules accumulated on the bedding planes is ascribed to seasonal dryness.

The first appearance of *Sequoia* as a mass occurrence of leafy shoots and cones accompanied by the platanophyllous and laurophyllous angiosperms is recorded from gray siltstones at the top of the Barun Bayan redbed sequence.

5. Conclusion

Our data do not support climate modeling as indicating open landscapes, except for the redbed episodes, for which paleobotanical evidence is scanty so far. The co-occurrence of autochthonous thermophilic and allochtonous temperate elements indicate a steep altitudinal gradient that can be considered as a typical feature of Cretaceous climatic conditions over the continental interiors. Increase of temperate elements is related to elevation of highlands over the basis of erosion on the one hand and to the upland – lowland shifts of altitudinal vegetation belts on the other. Therefore, the upper part of Mogotuin Formation near its boundary with redbeds of Manlay Formation marks a xerothermic trend of the climate change. The finding of Sequoia as a dominant tree of the widespread Late Cretaceous temperate to humid subtropical redwood forests signifies a radical climate change at about the Albian – Cenomanian boundary.

Acknowledgements

We thank Prof. R. Barsbold, the Director of the Paleontological Center, Mongolian Academy of Sciences and Prof. A. Rosanov, the Director of the Paleontological Institute, Russian Academy of Sciences for their courteous help and advice in organizing the international field trip to Gobi Desert. This work was partly supported by Israeli Ministry of Absorption.

References

[1] V. A. Krassilov, “Phytogeographical classification of Mesozoic floras and their bearing on continental drift,” Nature, vol. 237, pp. 49–50, 1972.

[2] V. A. Vakhrameev, Jurassic and Cretaceous floras and climates of the Earth. Cambridge: Cambridge University Press, 1991, 340 pp.

[3] Y. Khand, D. Badamgarav, Y. Ariunchimeg, and R. Barsbold, “Cretaceous system in Mongolia and its depositional environments,” in Cretaceous environments of Asia, H. Okada and N. J. Mateer, Eds. Amsterdam: Elsevier, 2000, pp. 49–79.

[4] Y. Khand, B. Sames, and E. Schudack, “New ostracod species from the non-marine Cretaceous of Mongolia.” Revista Espanola de Micropaleontologia, vol. 39, pp. 71–80, 2007.

[5] R. Barsbold, “Introduction.” in: IGSP 507 Fieldtrip on Cretaceous non-marine sediments and dinosaur localities in Ulaan Nuur depression, South Mongolia. Guidebook. South Gobi, Mongolia, R. Barsbold, Ed. Ulaanbaatar: Paleontological Center, Mongolian Academy of Science, 2008, pp. 4–7.

[6] R. Barsbold, and Y. Khand, “The non-marine Cretaceous of Mongolia.” in Paleoclimates in Asia during the Cretaceous. 3rd International Symposium of the IGCP Project 507, Abstarct Volume, Y. A. Ariunchimeg and Y. Khand, Eds. Ulaanbaatar: Palentological Center, Mongolian Academy of Science, 2008, pp. 13–16.

[7] N. S. Kalugina, Ed., “The Early Cretaceous Lake Manlay.” Transactions of the Loint Soviet–Mongolian Paleontological Expedition, vol. 13, pp. 1–93, Moscow: Nauka, 1980. (in Russian).

[8] M. Ito, M. Matsukawa, S. Saito, and D. J. Nichols, “Facies architecture and paleohydrology of a synrift succession in the Lower Cretaceous Choyr Basin, souseastern Mongolia.” Cretaceous Research, vol. 27, pp. 226–240, 2006.

[9] V. A. Krassilov, “Early Cretaceous flora of Mongolia.” Palaeontographica, vol. 181B, pp. 1–43, 1982.

[10] H. Jännichen, and E. Kahlert, "Über eine mesozoische Flora aus Mongolischen Volksrepublik." Geologie, vol. 21, pp. 964–1001, 1972.

[11] K. Saiki, and A. Okubo, "Lower Cretaceous flora of the Choyr Basin, Mongolia." Cretaceous Research, vol. 27, pp. 252–261, 2006.

[12] A. G. Ponomarenko, and Ju. A. Popov, "Localities of insect fossils in the Mongolian People Republik." in Paleontology and Stratigraphy of Mongolia. N. N. Kramarenko, Ed. Transactions of the Loint Soviet–Mongolian Paleontological Expedition, vol. 3, pp. 137–144, Moscow: Nauka, 1976. (in Russian).

[13] L. N. Pritykina, "New dragonflies from Lower Cretaceous deposits of Transbaikalia and Mongolia." in Mezozoic and Cenozoic faunas, floras and biostratigraphy of Mongolia. R. Barsbold, and E. I. Vorobyeva, Eds. Transactions of the Loint Soviet–Mongolian Paleontological Expedition, vol. 4, pp. 81–96, Moscow: Nauka, 1977. (in Russian).

[14] V. A. Krassilov, "Climatic changes in Eastern Asia as indicated by fossil floras. 1. Early Cretaceous." Palaeogeography, Palaeoclimatology, Palaeoecology, vol. 13, pp. 261–273, 1973.

[15] D. J. Nichols, M. Matsukawa, and M. Ito, "Palynology and age of some Cretaceous nonmarine deposits in Mongolia and China." Cretaceous Research, vol. 27, pp. 241–251, 2006.

[16] R. Florin, "Die fossilen Gingkophyten von Franz-Josef-Land, nebst Erörterunger über vermeintliche Cordaitales mesozoischen Alters. 1. Spezieller Teil." Palaeontographica, vol. 81B, pp. 1–173, 1936.

[17] V. A. Krassilov, Terrestrial palaeoecology and global change. Sophia: Pensoft, 2003, 464 pp.

[18] E. V. Bugdaeva, Ye. V. Volynets, V. V. Golozubov, V. S. Markevich, and G. L. Amelchenko, "Flora and geological events of the Mid-Cretaceous time (Alchan Basin, Primorye)." Vladivostok: Dalnauka, 2006, 205 pp. (in Russian).

[19] V. A. Krassilov, "The Cretaceous flora of Sakhalin." Moscow: Nauka, 1979, 184 pp. (in Russian).

[20] C. Sloan, and E. J. Barron, ""Equable" climates during Earth history? " Geology, vol. 18 (6), pp. 489–492, 1990.

[21] V. A. Krassilov, A. P. Rasnitsyn, "Plant - Arthropod interactions in the Early Angiosperm history." Pensoft, Brill, Sophia – Moscow and Leiden – Boston, 2008, 229 pp.

[22] V. Krassilov, A. Berner, and S. Barinova, "Jurassic flora of the Negev Desert: Plant taphonomy, paleoecology and paleogeographic inference." Palaeogeography, Palaeoclimatology, Palaeoecology, vol. 378, pp. 1–12, 2013.

[23] V. A. Krassilov, S. Barinova, and S. Rybnikov, "Rotation forcing of tectonics and climate". Earth Science, vol. 3 (3), pp. 68–75, 2014.