



CONTENTS

SECTION-A PALAEOONTOLOGY AND STRATIGRAPHY

1. Brief introduction to the study of the K-Pg boundary in Jiayin of Heilongjiang, China and its adjacent areas---*Sun G., Dong Z.M., Akhmetiev M.A., Markevich V., Ashraf A.R., Bugdaeva E., Yang H.X., Suzuki S., Sun C.L., Sun Y.W., Ge W.C., Chen Y.J., Dilcher D.L., Nishida H., Golovneva L., Kodrul T., Harding I., Kezina T., Wu W.H., Yang T., Liang F., Feng Y.H.* (1)
2. Cretaceous wildfires, volcanism and impacts: the use and misuse of charcoal-----*Scott A.C.* (5)
3. Recent advance in study of the Upper Cretaceous-Paleogene strata in the Songliao Basin, Northeast China-----*Wan X.Q., Xi D.P.* (9)
4. Late Cretaceous-Early Paleocene palynoflora of sediments associated with Deccan volcanic province: floral response to changing climate and depositional environment-----*Samant B., Mohabey D., Kumar D., Dhobale A., Thakre D.* (11)
5. Late Cretaceous flora of the New Siberia Island (Arctic Russia): new data-----*Herman A.B., Domogatskaya K.V.* (14)
6. Structure of the Cretaceous tectono-stratigraphic complexes of Priamurye-----*Kirillova G.* (16)
7. New member in the Late Cretaceous floral successions from volcanogenous deposits of Lesser Khingan (Khabarovsk Region)-----*Golovneva L.* (19)
8. Tracing the phylogenetic legacy of the key events in the late Mesozoic-----*Schneider H., Liu H.M.* (21)
9. Palynostratigraphy of the Upper Cretaceous-Paleogene Deposits in Western Siberia-----*Lebedeva N.K., Kuzmina O.* (22)
10. A preliminary study of plant-biotic interactions in late Campanian and early Paleocene floras of Amur Region, Far East of Russia-----*Kodrul T., Maslova N., Vasilenko D., Golovneva L.* (25)
11. Reptilian vertebrates from Deccan volcanic associated sediments of Malwa Plateau in context to reptiles across aastrichtian-Palaeogene volcanic eruptions in Main Deccan Volcanic Province, India-----*Mohabey D., Samant B., Dhobale A., Kumar D.* (26)
12. Recent knowledges on Paleocene palyno- and mega-floras from Northeast Honshu, Japan-----*Horiuchi J.* (29)
13. Additional material of *Jiutaisaurus xidiensis* (Sauropoda: Titanosauria) from the Late Cretaceous of Jilin Province (Northeastern China), and its phylogenetic affinities-----*Sekiya T., Wu W.H.* (31)
14. A lambeosaurine hadrosaurid braincase discovered from the Upper Cretaceous Yuliangzi Formation of Jiayin, Heilongjiang, Northeast China-----*Dong N., Wu W.H., Yin Y.L., Yu K.F., Godefroit, P.* (32)
15. Floating leaf cuticular features of an aquatic angiosperm *Quereuxia angulata*-----*Liang F., Sun G., Wu Q., Yang T., Bai S.C.* (33)



16. Unique sets of exine features in morphology and ultrastructure of oculata and triprojectate pollen from Zeya-Bureya Basin-----*Tekleva M., Polevova S., Bugdaeva E., Markevich V., Sun G.* (34)
17. Sporoderm ultrastructure of *Molaspora aspera* from a Cenomanian deposit in western France-----
----- *Zavialova N., Batten D.* (36)
18. Relict Mesozoic taxa in the Paleocene floras of the Koryak Upland-----
-----*Zolina A., Golovneva L., Grabovskiy A.* (38)
19. The diversity of Cupressaceae (Conifer) in the Paleocene of Jiayin, Heilongjiang, China and its
environmental significance-----*Cui Y.M., Wang Y.D., Wang Y.F.* (40)
20. Cretaceous and Paleogene biotas from Pakistan and paleobiogeographic link-----
-----*Malkani M.S., Sun G.* (41)
21. *Phoenicopsis (Leptostrobales)* in the Cretaceous of North Asia-----
-----*Nosova N., Golovneva L., Grabovskiy A., Gnilovskaya A.* (44)
22. Last theropods, mesoeucrocodyles and pterosaurs from Indo-Pakistan subcontinent (South Asia)
became extinct at the latest Cretaceous mass extinction-----*Malkani M.S.* (46)
23. How many titanosaurs were coexisting in Indo-Pakistan landmass?-----*Malkani M.S.* (51)
24. New data on the Early Cretaceous Flora of Transbaikalia-----
-----*Bugdaeva E., Yadrishchenskaya N., Markevich V., Kurilenko A.* (56)
25. Early Cretaceous flora of Primorye region (Russia)-----*Volynets E.* (59)
26. Pollen and macrofossils of angiosperms from the Lower Cretaceous of southern Primorye, Russia-----
-----*Golovneva L., Volynets E., Bugdaeva E., Markevich V.* (62)
27. Bivalve assemblage from the nonmarine Sinuiju Formation of the DPR Korea: Correlation and
age-----*So K.S., Won C.G., Jon S.H.* (65)
28. Stratigraphy and biota of the Sinuiju Formation (Lower Cretaceous) in DPR Korea-----
-----*Won C.G., So K.S., Jon S.H., Ma J.* (67)
29. The insect fossils from the Lower Cretaceous of Sinuiju region, the DPR Korea-----
-----*Jon S.H., Won C.G., So K.S., Li C.J.* (70)
30. Brief introduction on the dinosaurs from Kyrgyzstan-----*Bakirov A.* (72)
31. Recent discoveries of vertebrate remains in Cretaceous amber deposits from Myanmar-----
-----*Xing L.D., McKellar R.C., O'Connor J.K.* (77)
32. *Sequoioxylon zhangii* sp. nov. (Sequoioideae, Cupressaceae s.l.), a new coniferous wood from the
Upper Cretaceous in Heilongjiang Province, Northeastern China-----
-----*Tian N., Zhu Z.P., Wang Y.D., Marc Philippe M., Chou C.Y., Xie A.W.* (79)
33. Palaeoclimate perturbations and palaeo-CO₂ variations--recent palaeobotanical evidence from
China-----*Wang Y.D., Tian N., Jiang Z.K., Ding Q.H., Yang X.J., Zhou N.* (80)
34. Tree ring phototropism and implications for the rotation of North China Block-----*Jiang
Z.K., Liu B.P., Wang Y.D., Huang M., Kapitany T., Tian N., Cao Y., Lu Y.Z., Deng S.H.* (81)
35. Jurassic bennettitalean reproductive structures from China-----*Popa M., Wang Y.D.* (82)



Pollen and macrofossils of angiosperms from the Lower Cretaceous of southern Primorye, Russia

Lina Golovneva ^{1*}, Elena Volynets ², Eugenia Bugdaeva ², and Valentina Markevich ²

¹ Komarov Botanical Institute RAS, St. Petersburg, 197376, Russia

² Federal Scientific Center of the East Asia Terrestrial Biodiversity, FEB RAS, Vladivostok, 690022, Russia

(*Corresponding author: Lina_Golovneva@mail.ru)

The appearance of angiosperms significantly changed the composition of terrestrial floras during the Cretaceous. However the spatial and temporal patterns of their early evolution are still poorly constrained, due to a small number of well-studied extended sections of the Lower Cretaceous deposits. Here we present a pollen and macrofossil angiosperm record from nonmarine deposits of the Partizansk and Razdolnaya coal basins (southern Primorye). These successions allow to trace angiosperm distribution from the Barremian up to middle Albian and provides new data about diversification of early flowering plants in Eastern Asia (Fig. 1). Age of the stratigraphic units is based on palynological data and mollusks from the middle Albian marine interbedding.

The ancient angiosperm pollen was recorded in the Starosuchan Formation (the Barremian or Barremian-Aptian) of the Partizansk coal basin (Kovaleva et al., 2016). It is represented by *Tricolpites* sp. and *Asteropollis asteroides*. From the Aptian (or lower Albian) Severosuchan Formation *Tricolpites* sp., *Asteropollis asteroides*, and *Cyclusphaera psilata* were reported. In the Razdolnaya coal basin first angiosperm pollen appears only in the upper part of the Lipovtsy Formation, in the upper Aptian or lower Albian (Kovaleva et al., 2016; Volynets et al., 2016; Volynets, Bugdaeva, 2017). This assemblage includes *Clavatipollenites hughesii*, *Retitricolpites georgiensis*, *Quercus sparsus*, *Tricolpites micromunus*, *T. vulgaris*, and *T. variabilis*. In the lower-middle Albian Frentsevka and Galenki formations angiosperm pollen become more diverse and is represented by monosulcate *Clavatipollenites incisus*, *C. hughesii*, tricolpate *Tricolpites variabilis*, *Retitricolpites georgiensis*, *Fraxiniopollenites variabilis*, and *Asteropollis asteroides* with branched sulcus (Markevich, 1995). The Aptian-middle Albian angiosperm assemblages of southern Primorye are rather similar and are characterized by presence of monoaperturate pollen of monocot or “magnoliid” affinity and by the of tricolpate pollen of eudicot affinity. During this interval angiosperm pollen represents only a minor component of the total palynoflora (less than 5%).

The ancient angiosperm macrofossils also were recorded in the Starosuchan Formation. Samyлина (1961) described the fruits of *Nyssidium orientale* from this unit. However these fossils have no follicular characters and their affinity not only to *Cercidiphyllum*-like plants, but to angiosperms in general, is doubtful (Golovneva, Zolina, 2018).

The Aptian Lipovtsy and Severosuchan formations contain undoubted angiosperm fossils. Krassilov (1967) described fruits *Onoana nicanica* from the Lipovtsy Formation. In addition, small simple and palmately lobed leaves were found in the upper part of this formation from the Podgorodnenka coalfield (Volynets, Bugdaeva, 2017). Three-lobed leaves of *Araliaephyllum luciferum* come from the upper part of Severosuchan Formation (Kryshtofovich, 1929; Golovneva, 2018). All Aptian leaves are very small (1.5–3.5 cm).

The Frentsevka and Galenki formations contain more diverse assemblages of small-leaved angiosperms described by Krassilov (1967). In the the Razdolnaya coal basin leaves and fruit were found near Konstantinovka village. This assemblage includes *Cercidiphyllum suffunense*,



Laurophyllum sp. and *Pandanophyllum ahmertii*. Last species was found by Kryshstofovich and represented by linear leaves of monocot affinity.

Stage		Razdolnaya (Suifun) coal basin	Partizansk (Suchan) coal basin	
			Western part	Eastern part
Cenomanian	lower	Korkino Group	Romanovka Fm	Romanovka Fm
	upper		Kangauz Fm	Kangauz Fm
Albian	middle	Galenki Fm <i>Cercidiphyllum suifunense</i> , <i>Laurophyllum</i> sp., <i>Dicotylophyllum</i> spp. <i>Pandanophyllum ahmertii</i>	Frentsevka Fm <i>Achaenocarpites capitellatus</i> , <i>Ternariacarpites floribundus</i> , <i>Jixia pinnatipartita</i> , <i>Asiatifolium elegans</i>	Frentsevka Fm <i>Sapindopsis</i> sp.
	lower		<i>Araliaephyllum ussuriensis</i> , <i>Artocarpidium</i> sp., <i>Sapindopsis angusta</i>	
Aptian	upper	Lipovtsy Fm <i>Onoana nicanica</i>	Severosuchan Fm	Severosuchan Fm <i>Araliaephyllum luciferum</i>
	middle	<i>Dicotylophyllum</i> spp.		
	lower			
Barremian		Ussuriysk Fm		Starosuchan Fm <i>Nyssidium orientale</i>
Hauterivian				
Valanginian				Klyuchi Fm

Fig. 1. Distribution of angiosperm macrofossils in the Lower Cretaceous deposits of the Partizansk and Razdolnaya coal basins.

Leaves of *Araliaephyllum ussuriensis*, *Artocarpidium* sp. and *Sapindopsis* cf. *angusta* were found on northern shore of the Palets Cape (the Ussuri Bay) in the black siltstones of the Frentsevka Formation, and leaves of *Sapindopsis* with dentate margin were found in the 3-th Kamenka River valley near Partizansk city. Species from the Galenki Formation have simple, entire-margined leaves with pinnate venation, and species from the Frentsevka Formation have palmately or pinnately lobed leaves with entire or dentate margin. Leaf sizes from this horizon are somewhat larger and reach 5–10 cm.

An extraordinarily well-preserved autochthonous angiosperm herbaceous community was discovered from Frentsevka Formation near Bolshoy Kuvshin Cape in Bolshoy Kamen town (Krassilov, Volynets, 2008; Golovneva et al., 2018). The angiosperm assemblage includes *Achaenocarpites capitellatus*, *Ternariacarpites floribundus*, *Jixia pinnatipartita*, *Asiatifolium elegans* and several new undescribed species. The last two species are common with the Chengzihe flora from northern China (Sun, Dilcher, 2002), which previously were considered to be Hauterivian–early Barremian in age. More recent investigation indicates a younger age, from the Aptian to early Albian (Sha et al., 2003).

The locality Bolshoy Kuvshin is significantly different from other Aptian–middle Albian angiosperm sites of southern Primorye, where angiosperm can be diverse, but their remains occur rarely and irregularly. In this locality each species is represented by hundreds specimens. The majority of specimens are represented by fragments of branching stems with attached leaves or fruits or by



almost complete plants with roots. Plants were small (10–30 cm high) and very delicate. Their complete preservation in rather coarse sediment indicates the absence of long water transport. They were buried *in situ* or very close to their original location. The plant remains are often folded, rolled and cross bedding planes. The angiosperms were accompanied by ferns (*Onychiopsis psilotoides*, *Birisia* sp.), which are represented by almost entire young plants. This implies that the fern-angiosperm herbaceous community was a pioneer, reflecting the early succession stage and adapted to colonize fresh sediments in periodically flooded areas. Our data support Hickey and Doyle's (1977) interpretation of early angiosperms as riparian weeds.

Acknowledgements: The present study was supported by the Russian Foundation for Basic Research (project 19-04-00943).

References:

- Golovneva, L.B., 2018. Diversity of palmately lobed leaves in the early-middle Albian of eastern Russia. *Cretaceous research* 84, 18–31.
- Golovneva, L.B., Zolina A.A. 2018. Fossil evidence of initial radiation of Cercidiphyllaceae. *Palaeobotany* 9, 54–75.
- Golovneva, L., Alekseev, P., Bugdaeva, E., Volynets, E., 2018. An angiosperm dominated herbaceous community from the early–middle Albian of Primorye, Far East of Russia. *Fossil Imprint* 74, 165–178.
- Hickey, L.J., Doyle, J.A., 1977. Early Cretaceous fossil evidence for angiosperms evolution. *The Botanical Review* 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), Russia. *Journal of Pacific Geology* 10(1), 50–62.
- Krassilov, V.A., 1967. Early Cretaceous flora of southern Primorye and its significance for the stratigraphy. Nauka, Moscow, 264 pp. (in Russian).
- Krassilov, V., Volynets, Y. 2008. Weedy Albian angiosperms. *Acta Palaeobotanica* 48(2), 151–169.
- Kryshtofovich, A.N., 1929. Discovery of the oldest dicotyledons of Asia in the equivalents of the Potomac Group in Suchan, Ussuriland, Siberia. *Izvestiya Geologicheskogo Komiteta* 48(9), 1357–1390. (in Russian).
- Markevich, V.S., 1995. Cretaceous Palynoflora of Northern East Asia. Dal'nauka, Vladivostok, 180 pp. (in Russian).
- Samylina, V.A., 1961. New data on the Lower Cretaceous flora of the southern Primorye. *Botanicheskiy Zhurnal* 46(5), 634–645. (in Russian).
- Sha, J., Matsukawa, M., Cai, H., Jiang, B., Ito, M., He, C., Gu, Z., 2003. The Upper Jurassic–Lower Cretaceous of eastern Heilongjiang, northeast China: stratigraphy and regional basin history. *Cretaceous Research* 24, 715–728.
- Sun, G., Dilcher, D.L., 2002. Early angiosperms from the Lower Cretaceous of Jixi, eastern Heilongjiang, China. *Review of Palaeobotany and Palynology* 121, 91–112.
- Volynets, E.B., 2005. The Aptian–Cenomanian flora of Primorye. Part 1: Floral assemblages. *Stratigraphy and Geological Correlation* 13, 613–631.
- Volynets, E.B., Bugdaeva, E.V., 2017. The Aptian-Cenomanian flora of the Razdolnaya Coal Basin (Primorye region, Russia). *Island Arc*, 26: e12171.