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New Data on the Age of the Monakino Unit from the Partizansk Basin, Primorie

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For the first time the Middle Jurassic flora has been established in Primorie. The studied paleofloral assemblage was named Alekseevka assemblage. It characterizes the Monakino unit from the Partizansk coal basin. More than 80 species of fossil plants were identified in the assemblage. The Alekseevka assemblage was compared to the known Middle Jurassic floras. The studied assemblage shows similarities to the flora from the Ananievka unit in southwestern Primorie and flora from the Utano Formation in Japan. The age of the Monakino unit was specified as Middle Jurassic.

The Monakino unit of volcanogenic-terrigenous and coal deposits is recognized in the northern and central parts of the Partizansk coal basin. Its most representative sections are located in the northeast of the basin (Fig.1). The unit overlies the more ancient assemblages with an angular unconformity and consists of two sub-units. The base of the upper sub-unit is built by a member (35 m) of rhythmically interbedded gritstones, rhyolites, tuffites, silt and psammitic tuffs with abundant plant prints, which form the Alekseevka paleofloral assemblage (Fig.2). As fossils, leaf accumulations of ferns, Bennettitales, cycadophytes, conifers, Equisetales are common as polydominant "leaf roofs". Such burial sites were apparently formed on the silted bottom of basins next to these plants habitats. The unit section was described by A.V.Oleinikov [3], the age of the deposits was provisionally defined by S.I.Nevolina and Ye.B.Volynets as Berriassian. A more detailed phytostratigraphic study of the Monakino unit conducted by the present author allowed revision of the age of the flora-bearing deposits to define it as Middle Jurassic [5].

The Alekseevka paleofloral assemblage comprises over 80 species (Table). It is represented by nearly all major plant groups which dominated the Jurassic: equisetums, ferns, Caytoniales, pteridosperms, Bennettitales, cycadophytes, ginkgophytes, Chekanowskiales, conifers; reproductive organs were also detected, whose belonging to any genus or species we failed to specify. Most diverse are ferns (28 species), conifers

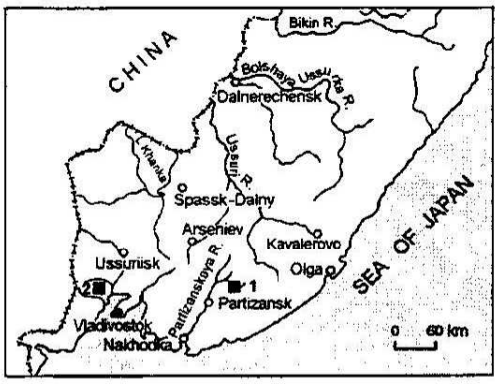

Fig. 1 Sketch-map showing location of fossil flora.

■ - flora sampling sites: 1 - taphocoenoses group of Alekseevka assemblage; 2 – taphocoenosis of Ananievka assemblage.

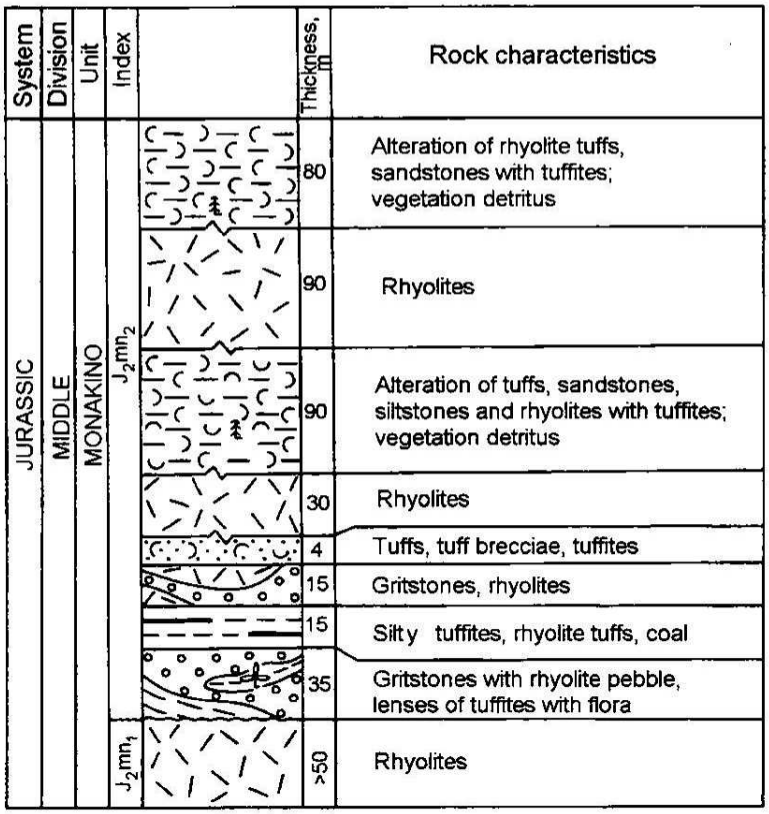

Fig. 2 Stratigraphic column of Monakino unit in Alekseevka R. basin (after A.V.Oleinikov [3]).

Table Correlation of close by age Middle Jurassic floras.

1	2	3	4	5	6	7	8
1.	*Thallites* sp.						
2.	*Equisetites* sp.	+	+	+	+	+	+
3.	*E. endoi* Kon'no		+				
4.	*Klukia* sp.						+
5.	*K. exilis* (Phill.) Racib.						+
6.	*Cyathea sp. nov.1*						
7.	*Ruffordia goeppertii* (Dunk.) Sew.	+	+				
8.	*Phlebopteris* sp.		+		+		
9.	*Adiantopteris toyoraensis* (Oishi) Vassilevsk.		+				
10.	*Acrostichopteris naitoi* Kimura et Ohana	+	+				
11.	*Acrostichopteris* sp.						+
12.	*Dicksonia* aff. *concinna* Heer	+					
13.	*Coniopteris hymenophylloides* (Brongn.) Sew.	+	+	+	+	+	+
14.	*Onychiopsis psilotoides* (St. et W.) Ward	+	+				
15.	*Sphenopteris* sp.						
16.	*Sphenopteris* sp. 1						
17	*Sphenopteris* sp. 2						
18.	*Sphenopteris sp.* nov.1	+					
19.	*Sphenopteris sp.* nov.2						
20.	*Sphenopteris sp. A* Kimura et Ohana	+	+				
21.	*Sphenopteris sp. E* Kimura et Ohana	+	+				
22.	*S. gracilis* Oishi		+				
23.	*Sphenopteris* sp. 5						
24.	*S.* cf. *mclearnii* Bell						
25.	*S.* aff. *latiloba* Font.						
26.	*Cladophlebis* sp.	+	+		+		
27.	*C. naitoi* Kimura et Ohana	+	+				
28.	C. aff.*toyoraensis* Oishi						
29.	*C. toyoraensis* Oishi		+				
30.	*C.* aff. *argutula* (Heer) Font.	+		+		+	
31.	*C. williamsonii* (Brongn.) Brongn.				+		
32.	*Caytonia* sp.						
33.	*Sagenopteris mantellii* (Dunk.) Shenk		+				
34.	*S.phillipsii* (Brongn.) Presl.				+	+	+
35.	*S. petiolata* Oishi	+					
36.	*Pachypteris* sp.	+					+
37.	*Otozamites* sp. (cf. O.klipstenii (Dunk.) Sew.)		+	+	+	+	+
38.	*Dictyozamites* sp.	+					
39.	*Dictyozamites* sp. nov1.						

Table (continued).

1	2	3	4	5	6	7	8
40.	*Dictyozamites* sp. nov. 2.						
41.	*D. tateiwae* Oishi		+				
42.	*D. naitoi Kimura* et Ohana		+				
43.	*D. cf. reniformis* Oishi		+				
44.	*Cycadolepis hypene* Harris	+			+	+	
45.	*Anomozamites fukutomii* Kimura et Ohana		+				
46.	*Ptilophyllum* sp.		+		+	+	+
47.	*Zamites* sp.		+	+	+		
48	*Z. yabei* Oishi		+				
49.	*Nilssonia* sp.			+		+	+
50.	*Nilssonia* sp.1						
51.	*N. compta* (Phill.) Takah.		+				
52.	*N. densinervis* (Font.) Bell		+				
53.	*Nilssonia* sp. 2						
54.	*Pseudoctenis* sp.		+		+	+	+
55.	*Baiera* sp.					+	+
56.	*Pseudotorellia* sp.		+	+	+	+	
57.	*Czekanowskia* sp.		+	+			
58.	*Podozamites* sp.	+			+	+	+
59.	*P. lanceolatus* (L. et H.) Braun	+	+	+	+	+	+
60.	*P. latifolius* (Shenk) Krysht. et Pryn.		+	+		+	
61.	*P.angustifolius* (Eichw.) Heer					+	+
62.	*P. eichwaldii* Shimp.						
63.	*Elatocladus* sp.			+			
64.	*E. constricta* (Feistm.) Oishi		+				
65.	*E.curvifolia* (Dunk.) Teslenko	+	+		+	+	
66.	*Elatides* sp.		+			+	
67.	*Araucarites* sp.		+				
68.	*A. cutchensis* Fiest.		+		+		
69.	*Cunninghamia* sp.						
70.	*Pityophyllum* ex gr. *nordenskioldii* (Heer) Nath.	+	+	+	+	+	
71.	*Brachyphyllum* cf. *toyoraensis* Takah.		+				
72.	*Brachyphyllum* sp	+			+		
73.	*Coniferites* sp.						
74.	*C. marchaensis* Vachr.						
75.	*Leptostrobus* aff. *crassinervis* Heer	+					
76.	*Leptostrobus* sp. 1						
77.	*Tauriania gracilis* Teslenco				+		
78.	*Conithes* sp.p.					+	
79.	*Carpolithes heeri* Tur.-Ket.				+	+	
80.	*C. minor* Pryn.	+			+		+
81.	*Schizolepis* sp.	+					
82.	*Machairostrobus* sp.	+					
83.	*Radicites* sp.	+			+		

(22 species) and cycadophytes (18 species); Caytoniales are represented by 4 species, ginkgophytes and Equisetales, by 2; and Chekanowskiales, by 1 species. The most species-diverse among the ferns are the genera *Cladophlebis*, *Sphenopteris*, *Acrostichopteris* and *Adiantopteris*; among Coniferae – *Podozamites* and *Elatocladus*, and among Cycadophyta – *Dictyozamites* and *Nilssonia*. The absence of the phytoleim precludes definition of *Zamites*, *Ptilophyllum*, *Baiera*, *Pseudotorellia*, *Czekanowskia*, and also of some *Podozamites*, *Elatocladus*, *Araucarites*. Species common throughout the whole Mesophytic are widely reported for the Alekseevka floral assemblage: *Coniopteris hymenophylloides*, *Ruffordia goeppertii*, *Onychiopsis psilotoides*, *Sagenopteris mantellii*, *Podozamites lanceolatus* and *Pityophyllum* ex gr. *nordenskioldii*. The following species are most representative of the Middle Jurassic: *Klukia exilis*, *Osmundopsis prynadai*, *Cladophlebis toyoraensis*, *C. williamsonii*, *Sagenopteris petiolata*, *Otozamites* cf. *klipstenii*, *Dictyozamites naitoi*, *D. tateiwae*, *Nilssonia compta*, *Podozamites latifolius*, *P. echwaldii* and *Coniferites marchaensis*. The typical representatives of Triassic and Early Jurassic (Liasian) floras, *Phlebopteris* and *Pachypteris*, due to their poor preservation have only been defined on a genus level. The assemblage is distinguished by the presence of *Klukia exilis*, *Phlebopteris* sp., *Acrostichopteris naitoi*, *Cladophlebis toyoraensis*, *C. naitoi*, *Zamites yabei*, *Nilssonia compta*, *Czekanowskia* sp., *Podozamites latifolius* and *Elatocladus constricta*.

In species composition, the Alekseevka floral assemblage is close to the assemblage from the Ananievka unit, Razdolnaya R. basin in southwestern Primorie. The *Mytiloceramus*-attested age of the Ananievka unit is defined as Late Aalenian – Callovian [5]. Regretfully, the study of the Ananievka unit is in the initial stage, so far, but by now the striking similarities of these floras are manifest. 23 common species have been identified in them (Table). The most representative species of the both assemblages are the following: *Acrostichopteris naitoi*, *Ruffordia goeppertii*, *Dicksonia* aff. *concinna*, *Coniopteris hymenophylloides*, *Onychiopsis psilotoides*, *Cladophlebis naitoi*, *C.* aff. *argutulata*, *Cycadolepis hypene*, *Nilssonia compta*, *Podozamites lanceolatus*, *Pityophyllum* ex gr. *nordenskioldii*, *Leptostrobus* aff. *crassinervis*, *Brachiphyllum* sp. and *Carpolites minor*. Both the Ananievka and Alekseevka assemblages were dominated by the ferns, and the subdominants were the conifers and cycadophytes.

The Alekseevka paleofloral assemblage shows similarities (40 genera and species) to flora from the marine layers of the Toyora Group, Utano Formation, Japan [13, 14]. The age of the Utano Formation was set by the ammonite and inoceram occurrences as Late Toarcian – Bathonian [12]. The same species of major plant groups (Table) are noted in both, in particular, among the ferns the following genera are characterized by

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Symbols: 1- ordinal number; 2 – species of fossil plants from Alekseevka paleofloral assemblage; 3- Ananievkian flora; 4 – flora from Utano Formation, Japan; 5 – Karatakhian flora; 6 – Karatauan flora; 7 – Mangyshlakian flora; 8 – Tkvarchelian flora, Georgia.

species similarities: *Adiantopteris*, *Acrostichopteris*, *Onychiopsis*, *Cladophlebis* and *Sphenopteris*; remains of the relic fern *Phlebopteris* and the pteridosperm *Pachypteris* were detected; Caytoniales in both assemblages are represented by the species *Sagenopteris petiolata*; cycadophytes are illustrated by common species of the genera *Dictyozamites* (*D. tataeiwae*, *D. naitoi*, *D.* cf. *reniformis*), *Nilssonia* (*N. compta*, *N. densinervis*), *Anomozamites fukutomii* and *Zamites yabei*. The species compositions of the conifer genera *Podozamites*, *Brachyphyllum*, *Araucarites* and *Elatocladus* are also much the same. However, such warm-loving cycadophyte genera as *Ctenozamites*, *Pterophyllum*, *Cycadites*, *Williamsonia* and *Taeniopteris*, and the ginkgophyte genus *Ginkgo* are absent in the Alekseevka assemblage as distinct from the Utano flora. On the whole, with the ferns dominating the Alekseevka assemblage, the conifers are subdominant; cycadophytes are representative, whereas the Utano flora is reported as cycadophyte-subdominated. This is most likely attributable to the fact that the Utano floral assemblage is formed of plants which grew under warmer climatic conditions.

In its taxonomic composition, the Alekseevka paleofloral assemblage has much in common with the Middle Jurassic floras from the Karatau, Mountainous Crimea, Mangyshlak and Tkvarcheli.

The Alekseevka floral assemblage is related to that from Karatau [2] by the fern-conifer vegetation. They have the following common taxons: *Cladophlebis* aff. *argutula*, *Otozamites*, *Zamites*, *Nilssonia*, *Pseudotorellia*, *Czekanowskia*, *Ptilophyllum* ex gr. *nordenskioldii*, *Elatocladus* and *Brachyphyllum* (see Table). The principal distinction is a predominance in Karatauan flora of genera and species typical of the Middle Asian paleofloral province.

The dominance of the ferns and conifers with subordinate cycadophytes (Table) makes the Alekseevka assemblage close to Mountainous Crimean flora [6]. Common Pteridophyta genera are recognized in them: *Phlebopteris*, *Cladophlebis* and *Coniopteris*; the genera of Caytoniales: *Sagenopteris phillipsii*; cycadophytes: *Zamites*, *Otozamites* and *Ptilophyllum*, and the species *Cycadolepis hepene*. At the same time, Mountainous Crimean flora shows a diversity of species of the relic ferns *Phlebopteris* and *Dictyophyllum*; cycadophytes are few (5 species; in the Alekseevka assemblage, 18), and pteridosperms and *Czekanowskia* have not been detected. The Alekseevka paleofloral assemblage is illustrated by 5 species of the genus *Podozamites* (in the Crimea – 1), 4 species of the genus *Elatocladus* (in the Crimea – 3); representatives of the genus *Pagiophyllum* are absent.

The Alekseevka assemblage is related to Mangyshlakian flora [4] by the fern dominance, but in the latter relic Liasian species are exceedingly abundant, and *Sagenopteris phillipsii* of Caytoniales and the genus *Pachypteris* of pteridosperms (Table) are reported; both assemblages show a diversity of cycadophytes, particularly the genus *Nilssonia*. In general, they total 18 common forms.

Certain similarities (Table) are noted between the Alekseevka paleofloral assemblage and the Middle Jurassic flora of the Tkvarcheli basin [1]. They display

Certain similarities (Table) are noted between the Alekseevka paleofloral assemblage and the Middle Jurassic flora of the Tkvarcheli basin [1]. They display affinity due to the presence of the ferns *Klukia exilis*, *Osmundopsis prynadai* and *Coniopteris hymenophylloides*, Caytoniales: *Sagenopteris phillipsii*, and pteridosperms (genus *Pachypteris*). At the same time, Tkvarchelian flora holds relic ferns (*Marratia* and *Clatropteris*) in greater abundance, which are not noted in the Alekseevka assemblage; also more diverse are cycadophytes, the genera *Ptilophyllum*, *Ctenozamites*, *Pseudocycas*, *Ctenis*, *Paracycas*, etc. [1]. The conifers in Tkvarchelian flora are solitary, whereas in the Alekseevka assemblage they are dominant along with the ferns.

A comparison between the Alekseevka paleofloral assemblage and the Middle Jurassic flora of Yorkshire, England [7, 8, 9, 10, 11] demonstrates a number of common features: abundance of ferns (particularly, of the families Dicksoniaceae and Schizaceae, and also of the formal genera *Cladophlebis* and *Sphenopteris*), and a diversity of gymnosperms: caytonials, cycadophytes, ginkgophytes, Czekanowskiales, and conifers. The distinctions that they hold are expressed in a greater abundance of the genera of relic ferns in the Yorkshire flora, and among the cycadophytes dominates the genus *Otozamites* (in the Alekseevka assemblage, it is *Dictyozamites*); among the conifers, the community *Podozamites – Brachiphyllum* is plentiful (in the Alekseevka assemblage, it is *Elatocladus*); and besides, a variety in the family Czekanowskiacea is noted.

Thus, a comparison between the Alekseevka paleofloral assemblage and the close in age floras from elsewhere enables definition of the age of the deposits from the Monakino unit characterized by its flora as Middle Jurassic (Bathonian). Incidentally, taxonomic composition of the Alekseevka assemblage is most close to floras from the Toyota Group of the Utano Formation, Japan, and to the Ananievka unit from western Primorie.

REFERENCES

1. Delle, G.V., *Paleobotanika* Vyp.VI : 53-132 (1967).
2. Doludenko, M.P. and Orlovskaya, E.R., *Yurskaya flora Karatau* (Jurassic flora of Karatau) (Moscow: Nauka, 1976).
3. Oleinikov, A.V., Kovalenko, S.V., Nevolina, S.I., Volynets, Ye.B. and Markevich, V.S., in: *Kontinentalny mel SSSR* (Continental Cretaceous in the USSR) (Vladivostok: DVO AN SSSR, 1990): 114-126.
4. Prosviryakova, Z.P., *Yurskaya flora Mangyshlaka i yeyo znacheniye dlya stratigrafii* (Jurassic flora of Mangyshlak and its implications for stratigraphy) (Moscow-Leningrad: Nauka, 1966).
5. *Resheniya chetvyortogo mezhvedomstvennogo regionalnogo soveshchaniya po dokembriyu i fanerozoyu yuga Dalnego Vostoka i Vostochnogo Zabaikaliya (Khabarovsk, 1990). Skhema 33* (Resolutions of the 4th Interdepartmental Regional Conference on Precambrian and Phanerozoic in the south of the Far East and

Eastern Transbaikal Region. Khabarovsk 1990. Scheme 33) (Khabarovsk: KhGGP, 1994).
6. Teslenko, Yu.V. and Yanovskaya, G.G., *Sredneyurskaya flora Gornogo Kryma* (Middle Jurassic flora of the Mountainous Crimea) (Kiev: Naukova Dumka, 1990).
7. Harris, T.M., *The Yorkshire Jurassic flora. I. Thallophyta – Pteridophyta* (L.: Brit. Mus. Natur. Hist., 1969).
8. Harris, T.M., *The Yorkshire Jurassic flora. II. Caytoniales, Cycadales and Pteridosperms* (L.: Brit. Mus. Natur. Hist., 1964).
9. Harris, T.M., *The Yorkshire Jurassic flora. III. Bennettitales* (L.: Brit. Mus. Natur. Hist., 1969).
10. Harris, T.M., *The Yorkshire Jurassic flora. V. Coniferales* (L.: Brit. Mus. Natur. Hist., 1079).
11. Harris, T.M., *The Yorkshire Jurassic flora.* IV (L.: Brit. Mus. Natur. Hist., 1974).
12. Kimura, T., *Bull. Tokyo Gakuk. Univ. Sect. IV* :39, 87-115 (1987).
13. Kimura, T. and Ohana, T., *Bull. Nat. Sci. Mus. Ser. C*, 13 N 2: 41-76 (1987).
14. Kimura, T. and Ohana, T., *Bull. Nat. Sci. Mus. Ser. C*, 13 N 3 :115-148 (1987).

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