The main stages of paleoflora development in the bodies of water of the Western Siberia in the Neogene

Dmitry Durnikin and Alina Zinovyeva

Altai State University, 61, Lenina Blvd, Barnaul, 656000, Russia

Annotation. The main stages of the bodies of water flora development in the Miocene and Pliocene were examined. The research was based on paleobotanical data, the analysis of paleofloras composition, the taphocenosis, and the continuous series of paleocarpological data. The observed paleoflora in the water bodies of the Western Siberia almost entirely consisted of extinct and very distant from the existing species of flora. It was determined that some elements of the Miocene hydrophilic flora remained almost unchanged up to the present time in the distant shelters (refugia). The paleocarpological data showed that the Miocene reservoirs paleoflora consisted of 208 species; it was represented by 27 families and 49 genera. Ten leading families of that period, according to the recent data, included 176 species. The climate deterioration (cooling, increasing of continentality) affected the thermophilic forms of the Neogene water bodies paleoflora, many species of this flora had disappeared by the beginning of the Quaternary period.

[Durnikin D., Zinovyeva A. **The main stages of paleoflora development in the bodies of water of the Western Siberia in the Neogene.** *Life Sci J* 2014;12(12s):899-903] (ISSN:1097-8135). http://www.lifesciencesite.com. 195

Keywords: the Neogene, the water bodies flora, water and riparian plants, species composition, structure, climate.

Introduction

In order to provide reliable biostratigraphic data, when exploring the continental Tertiary deposits of the majority of the continental deposits (the presence of orthofauna (mammals residues) is very rare there), the methods of paleobotany, particularly paleocarpology, are used. The main object of paleocarpology is diasporidium fossils (seeds, fruits, and other remnants of generative sphere) [1-3].

The most difficult stage of any region flora studying is to restore the historical stages of its development [4-6]. The determination of the main stages of the water bodies flora development on the certain territory is important problem of botanical geography. This way the identification of relict species is done. J. Stoller [7] considered that the determination of a species appearance time in certain flora can be done only if being based on paleobotanical data. Only these data provide the evidence of a species existence on the certain territory, and also, they determine its relict nature. The important role for understanding the flora and vegetation history of the Western Siberia goes to the works and books of the founder of the Soviet paleocarpological school P.A. Nikitin, his son V.P. Nikitin, and P.I. Dorofeyev, as well as many other researchers of the Siberian region paleoflora. The monograph of V.P. Nikitin "The paleocarpology and stratigraphy of Asiatic Russia Paleogene and Neogene" [8] contains analyses of the numerous fossil complexes from hundreds of locations of the Asiatic Russia (mainly from the Western Siberia); traces the history of the flora and vegetation of the Western Siberia and northeastern Russia during the late Paleogene and Neogene. There is also a table of the geochronological spread of over 1,600 species of fossil plants, more than 20% of which (about 360 species) belong to aquatic and shoreline aquatic plants.

Methodology

In this article, all the dating of fossil paleoflora are given according to the schemes used by O.M. Adamenko in "Mesozoic and Cenozoic eras of Steppe Altai" [9]. Also the dating by V.P. Nikitin is used when describing the data of the Western Siberia [8]. The research is based on the materials of the richest in Russia collection fund of paleocarpological laboratory of the Open Joint-Stock Company "Novosibirskgeologiya" (Novosibirsk). The foundation of the collection dates back to the 20s of the last century by the first Russian paleocarpologist – P.A.Nikitin. The data of dozens of wells cores, numerous cuts outcrops along the Om, the Tom, the Vakh, the Ishim, the Uy, the Shish, the Demianka Rivers and other ones in the Western Siberia.

Main part

The Miocene water bodies paleoflora of the Western Siberia according to paleocarpological findings consisted of 208 species, and it was represented by 27 families and 49 genera. However, it retained in its structure a great number of the Oligocene elements (67 species), which were dying out under the influence of further climate deterioration (cooling, increasing continentality). At the same time, probably, under the influence of the same conditions, in the depths of the Oligocene reservoirs paleoflora first appear those new and obviously subordinate elements that will become dominating in the Miocene flora. These elements in the future will become the basis of the modern Western Siberia water bodies flora. Out of the general number of the Miocene water bodies paleoflora species (208), 43 species (20.6%) are the existing ones on the territory of the Western Siberia and 37 species (17.7%) are found on the territory of the Ob-Irtysh interfluve. The spectrum of 10 leading families of the Neogene water bodies paleoflora of the Western Siberia is presented in Table 1. In general, the overall species composition of the top ten families of this period includes 176 species, representing 84.6% of the total number of species. The list of the Miocene relicts includes 50 species: *Azolla glabra* P. Nikit., *A. irtyshensis* Dorof., *A. parapinnata* Dorof., *A. turgaica* Dorof., *A. tymensis* Dorof., *Salvinia clavata* Dorof., *S. ornate* Dorof., *Marsilea sarmatica* Dorof., *M. tertiaria* Dorof., *M. maeotica* Dorof., *Brasenia sukaczevii* P.Dorof., etc. The Pliocene reservoirs paleoflora of the Western Siberia consisted of 146 species, it was represented by 31 families and 42 genera, and herewith it retained in its structure a great number of the Miocene elements (89 species). As a part of fossil aquatic vegetation complexes we have determined 25-40% of exotic species, including the Miocene relict thermophilic vegetation (*Azolla aspera* Dorof., *Salvinia intermedia* Nikit.) and also the Pliocene specific forms (*Salvinia glabra* Nikit., *S. tuberculata* Nikit., *Myriophyllum altaicum* V.P. Nikit.).

Table 1. The spectrum of 10 leading families of the Neogene water bodies paleoflora of the Western Siberia

Families (in brackets - the number of species in Neogene)	Miocene		Pliocene	
	Number of genera	Number of species	Number of genera	Number of species
1. Cyperaceae (46)	6	31	5	38
2. Potamogetonaceae (36)	1	29	1	23
3–4. Nymphaeaceae (17)	8	17	1	1
3–4. Sparganiaceae (17)	1	15	1	5
5–6 Azollaceae (13)	1	13	1	6
5–6. Alismataceae (13)	4	9	3	9
7. Halorgaceae (10)	2	6	1	7
8. Salviniaceae (9)	1	9	1	7
9–10. Cabombaceae (8)	1	8	1	2
9–10. Najadaceae (7)	2	4	2	7

The analysis of the leading families of the Neogene basins paleoflora is further provided.

The family *Cyperaceae* is dominating in the Miocene (31 species and 6 genera) as well as in the Pliocene (38 species and 5 genera). *Carex* (14 species) and *Scirpus* (16 species) can be mentioned among the genera with the highest species composition. There are also some sedge found in Barnaul flora, which come from the Miocene group of species: *Dulichium marginatum* (C. et E.M. Reid) Dorof., *Scirpus kipianiae* V.P. Nikit., *S. nikitinii* Balueva, *S. palibinii* P. Nikit., *Eleocharis praemaximowiczii* Dorof., etc.; as well as a group of modern species that first appeared in the Miocene: *Scirpus radicans*, *S. tabernaemontanii*, *Eleocharis palustris*, *Cyperus glomeratus*, *Carex vesicaria,* etc. In addition, a group of modern species now existing on the territory of the Western Siberia, first appeared in the Pliocene can be mentioned: *Scirpus lacustris*, *Eleocharis acicularis*, *E. ovata*, *Cyperus fuscus*, *Carex cyperoides* Murray (=*C. bohemica*), *C. lasiocarpa*, *C. pauciflora*, *C. pseudocyperus*, *C. riparia*, *C. rostrata*. Besides, in the Pliocene there were the representatives of sedge, which do not exist anymore in Siberia: *Scirpus melanospermus* C. A. Mey. (They exist in the European part of Russia, in the steppe regions of the Irtysh and Central Asia), *Scirpus cyperinus* (L.) Kunth , currently it is North American species [10].

The species: *Carex communis* V. Nikit. and *C. paucifloraeformis* V. Nikit. (the extinct species of sedge) were typical during the Neogene, apparently they were the combined ones; the first one used to have nuts, which are similar to the nuts of the modern Siberian *C. rostrata*, the second one is obviously closer to the cold-loving Eurasian *C. pauciflora* and which is its probable ancestor. The nuts of various kinds of *Cyperus* (more often of *C. glomeratus*, and less often of *S. fuscus*) are present in almost every fossil of the Barnaul seed type flora, whereas in the older or younger floras the species of this genus are relatively rare. The highest species diversity of pondweed (*Potamogetonacea*) is observed in the Miocene: 29 species (they take the first place among the other hydrophytes species). 10 of these species are the Miocene relicts (*P. russanovii* Dorof., *P. palaealpinus* V.P. Nikit., *P. astrictus* V.P. Nikit., *P dravertii* Dorof., etc.), also, we observe the first appearance of modern species now growing in the Western Siberia: *P. alpinus*, *P. filiformis, P. pectinatus, P. pusillus, P. trichoides, P. vaginatus.*

In the Pliocene *Potamogetonaceae* is represented by one genus and 23 species, and it possesses the second highest number of water bodies flora species. It is the most numerous family among the hydrophytes during the Miocene. The pondweed found in the Barnaul flora can be divided in to the following groups: the group of the Miocene species: *P. besczeulicus* Dorof., *P. decipiens* V. Nikit., *P. minimus* Dorof., *P. jacuticus* Dorof.*,* the group of the modern species, which appeared in the Miocene (they have already been mentioned), and the group of the modern species appeared in the Pliocene: *P. obtusifolius* Mert. et Koch., *P. praelongus* Wulf., *P. zosterifolius* Schum. (=*P. compressus* L.), *P. perfoliatus* L., *P. acutifolius* Link., *P. oxyphyllus* Miq., *P. tepperi* A. Benn. In the present time, the last three species do not grow in Siberia; *P. acutifolius* exists only in the European part of Russia, and *P.*

oxyphyllus is the Far East species which occurs in Primorye. It is important to underline that the endocarps of the various pondweed are very typical for fossil floras of the Barnaul type.

The family *Nymphaeaceae* in the Miocene is represented by 15 species and 7 genera. Starting with the Oligocene there are only six species of the water bodies flora left, but there are the new species and genera appearing during this time: *Irtyshenia tenuicostata* Dorof., *Nikitinella tavdensis* Dorof., *Palaeoeuryale sukaczewii* Dorof., *Pseudoeuryale dravertii* Dorof (they are the Miocene relicts), etc. The first discoveries of *Nuphar pumila* and *N. lutea*., growing in the Western Siberia, are dating back the Miocene. Only one species, *Nuphar pumila,* is surviving till the Pliocene. Such a reduction of the Nymphaeales species diversity is possibly connected with the development of the arid climate and, as a result, with a significant reduction of water bodies areas and their numbers. It is also possible that this reduction accursed because of exiguous factual paleobotanical material.

The Miocene flora is very reach with the representatives of the *Azollaceae* family (13 species). *Azolla aspera, A. monilifera, A. suchorukovii* Dorof., *A. tomentosa* P. Nikit., *A. tuberculata* P. Nikit., and *A. ventiricosa* Dorof inhabit the water bodies of the Western Siberia since the Oligocene. During the Miocene the new representatives of the family *Azollaceae* are appearing in the water bodies flora, those which are not found during the other periods of the Cenozoic: *A. glabra* P. Nikit., *A. irtyshensis* Dorof., *A. parapinnata* Dorof., *A. turgaica* Dorof., and *A. tymensis* Dorof. In the Pliocene this family is represented by six species, which date back to the previous periods. The genus *Azolla* is presented in the Barnaul Flora of the Western Siberia with the megaspore of the both modern sections. The geologically elder section of *Rhizosperma* includes *Azolla aspera*, a species of the wide vertical spread (since the Late Oligocene), and *A. pseudopinnata*, which typical megaspores have not been discovered deeper and higher than the deposits of the Upper Pliocene (although in the European part of Russia this species also occurs in the Miocene). The greatest number of species represents *Sparganiaceae* in the Miocene: 15 species, three of them exist nowadays in the Western Siberia (*Sparganium hyperboreum*, *S. minimum* и *S. simplex.).* During the Pliocene the number of *Sparganiaceae* species is getting reduced to 5. Apparently, it can be explained by some cooling and glaciation of the northern part of the Western Siberia (Demyanskaya era). In the Miocene, as well as in the Pliocene the family *Alismataceae* is represented by 3 genera and 9 species. However, during these epochs the certain changes of species are observed. Some Miocene species are disappearing (*Sagisma turgidum*, *S. parnassiforme*, *Caldesia proventitia*, *Alismataria aemulans*), while the new Pliocene ones are replacing them: *Caldesia exilis* Dorof., *Alisma wahlenbergii* (Holub) Juz, (nowadays, the last species is widely spread in the European part of Russia, on the coast of the Gulf of Finland and Lake Seliger), and *Sagittaria sagittifolia* (widely spread in the Western Siberia). The Miocene *Haloragaceae*, as well as the Oligocene families are represented by 2 genera and 6 species: (*Myriophyllum debilis*, *M. elongatum* V.P. Nikit., *M. omoloicum* Dorof., *M. omoloicum* Dorof., *M. aldanicum* V.P. Nikit. (the Miocene relict), *Proserpinaca pterocarpa, P. reticulate.* In the Pliocene is already missing the extinct in Siberia the Miocene genus - *Proserpinaca*, so the family is represented by a single genus - *Myriophyllum* (seven species). The modern *M. spicatum* and *M. verticillatum* appear only in Siberia during the Pleistocene. The dominating species of Barnaul flora is *Myriophyllum altaicum* VP Nikit., its nuts according to the shape, size and ornamentation features occupy an intermediate position between the Eurasian Neogene *M. praespicatum* and the modern *M. spicatum*, which nowadays is widespread in Siberia.

The family *Salviniaceae* was widely represented in the Miocene: nine species, including *S. intermedia* and *S. sibirica* which occur massively. During this period the new species appear in the waters of the Western Siberia: *S. clavata* Dorof., *S. glabra P. Nikit., S. natans, S.* ornata Dorof., and S. tuberculata P. Nikit. Out of all these species only *S. natans* has survived further climate changes, and now it is spread in the Western Siberia. This species exists in the Novosibirsk region, the Altai Territory, the Tomsk region and adjacent territories of Kazakhstan. In the Pliocene genus includes six species. There are very characteristic species of salvinia for the Barnaul flora: S. glabra (first appeared in the Pliocene) and *S. tuberculata,* which, as well as *Azolla pseudopinnata* Nikit., can be described as a the group of the leading forms of Siberian Upper Pliocene*. S. clavata* and *S. ornata* are the Miocene relicts. In the Miocene seed complexes the seeds of *Brasenia (Cabombaceae*) appear; three new species for the Western Siberia can be observed, they are: *B. sukaczevii P. Dorof., B. orientalis* VP Nikit., and *B. reidii* Dorof. Only two species of the Pliocene brasenia out of eight ones from the Miocene remain on the territory of the Western Siberia - *B. orientalis* and *B. chandleri.*

The family *Najadaceae* appears in the Miocene. Relatively important role of *Najadaceae* in the composition of the Miocene hydrophilic flora is explained by the density of the lake-river network.

The last peak of its development is associated with the Pleistocene. The *Najadaceae* of the Western Siberia in the Pliocene is represented by two genera and seven species. In the Barnaul flora type the seeds of *N. minor (= Caulinia minor)* were found the first time ever. Currently, in the Western Siberia, this species is rare, but it can be also found in the Kemerovo region and the Altai Territory, it is listed in the Red Book of Altai Krai.

The Miocene cattail (*Typhaceae*) are represented by six species; *T. tavdensis* and *T. tymensis*, which remain from the previous period. There are four new species appearing: *T. besczeulica* Dorof., *T. longa* VP Nikit., *T. pliocenica* Dorof., and *T. sibirica* Dorof. All of them disappear in the Western Siberia during the Pliocene. In the Pliocene seed complexes the seeds of modern *Typha angustifolia* can already be found.

In the Western Siberia during the Miocene the first discoveries of megaspores of *Marsileaceae* (genus *Marsilea*) were observed. These are *Marsilea maeotica* Dorof., *M. sarmatica* Dorof. and *M. tertiaria* Dorof. Currently, only a single member of this family (*Marsilea strigosa)* was found in the Western Siberia, the Altai region, the Blagoveshchensk district, neighborhood of Lake Kuchuk.

The family *Ceratophyllaceae* in the water bodies of the Western Siberia during the Neogene is represented by two modern species of hornworts: *Ceratophyllum demersum* and *Ceratophyllum submersum*.

The family *Ranunculaceae* during the Miocene is represented by *Ranunculu*s *sceleratoides, R. priscus, R. aquatilis, R. repens,* and *R. reptans.* During the Pliocene the new species appear: *R. sceleratus* L. (the seed of this plant are found abundantly during the Pliocene) and *R. flammula* L. (the both species are present in the modern flora of Siberia). After achieving the maximum peak of development in the Miocene (six species), the Pliocene *Hydrocharitaceae* has only three species left, which are coming from the Miocene. They are: the modern *Hydrocharis morsus-ranae* L., *Stratiotes intermedius* Chandl., and *S. tavdensis* (Dorof.) V.P. Nikit. The seeds of *Stratioites intermedius* Chandl., are rare in the Barnaul flora type of the Miocene (especially the late one).

The family *Lemnaceae* during the Neogene is represented by two genera (*Lemnospermum* and *Lemna*). In the Western Siberia the modern *Lemna trisulca* can be found (there are more than 50 locations in the Neogene collections) and *L. tertiaria* Dorof. (the species is represented in 28 collections of the West Siberian). The seeds of modern *L. minor, L. gibba L.* and *Spirodela polyrriza* also appear in the deposits of the Pleistocene. The duckweed roach *(L. gibba)* does not grow up nowadays in Siberia, but it is widely spread in Europe, Asia, North and South America. The seeds of *Acorus tertiarius (Araceae*) appear in the Miocene seed paleocomplex of the Western Siberia. Those seeds are presented in 36 collections.

Pistia sibirica Dorof disappears in Siberia during the Pliocene. Nowadays *Pistia* is the only existing modern species of the genus, and it is represented by *P. stratioites* L. It is a quite big plant, floating on the water surface; it is common to freshwater reservoirs of tropical regions of the globe: South and Central America (up to Florida and Texas), Africa, Madagascar, India, the Philippines. The genus *Acorus*: the calamus seeds of Barnaul paleoflora probably belong to extinct species, those which are close to *A. tertiarius*. V.P. Nikitin [8] points out that the genus *Trapa (Trapaceae*) during the Cenozoic in Siberia is represented with residues (leaves and fruit-nuts prints) of the four species, three of which: *Trapa baluevae* VP Nikit., *T. irtyshensis* Dorof., and *T. obiensis* V.P. Nikit. are relicts of the Miocene. The fruits of now existing *Trapa natans* occur in paleocomplex of the Miocene and the subsequent periods of the Cenozoic. This species is not found in the waters of the south of the Ob-Irtysh interfluve.

Conclusion

The greater or lesser geological antiquity of fossil floras can be defined in several ways. Unfortunately, after numerous attempts of the continental Cenozoic horizons mapping of Asiatic Russia using the levels of the common scale, the results remain hypothetical. Indeed, even in the Mediterranean the debates are still very tense about the scope and limits of the Neogene tiers, about the relationship between marine and continental horizons. The correlation of the Cenozoic sediments of the Northern Asia and Europe dramatically hampered because of its weak paleontological study [11-16]. The analysis of successive evolutionary transformations of the Western Siberia Neogene flora, which are definitely related to climate changes and general physiographic conditions, allowed tracing the development of the Neogene flora phasing. It was proved that in the history of the Tertiary flora of the Western Siberia three major phases can be pointed out: Eocene before turgayskiy, which is characterized with a spread of broadleaved-coniferous forests close to the subtropical evergreen trees and shrubs; the next one begins in the early Oligocene and ends in the late Miocene by Turgayskiy phase when the moderately thermophilic mesophilic forest flora was dominating. The third, the modern floral stage begins during the Eopleistocene when only a few mainly local exotic and single relict species of the post turgayskiy period were surviving in the flora of a particular area; when the nowadays climate and vegetation of the Western Siberia have already formed.

Inference

While studying the history of development of the water bodies flora in the south of the Western Siberia, the following conclusions were made: the development of the reservoirs flora went mostly autochthonous; it means that it has appeared out of the Eocene-Oligocene local flora. The core of reservoirs flora got formed in the Pliocene-Pleistocene, as well as due to the thermophilic elements of ancient Mediterranean flora. Later it was developing here in the Western Siberia and it reached its development peak during the Upper Miocene, the Lower Pliocene (208 species). At all stages of its history, the simultaneous participation of European-Siberian, Siberian and Japanese, Siberian and American or common moderately Holarctic elements was observed. This testifies the common Paleogene-Neogene basis of all local floras of the temperate zone of the northern hemisphere; and also the movements (migration) of individual plants, their groups or even entire formations, which were settling down on a new territory, they were getting included into the local formations and together with them were giving the beginning to a new flora, which sometimes considerably differed from the original one.

Corresponding Author:
Dr. Dmitry Durnikin
Altai State University, 61, Lenina Blvd, Barnaul, 656000, Russia

References

1. Bayer, C., 2003. Neuradaceae. In the Families and Genera of Vascular Plants, Vol. 5., Eds., K. Kubitzki. Berlin/Heidelberg/New York: Springer, pp. 325-328.
2. Gess, S.K. and F.W. Gess, 2004. Distributions of flower associations of pollen wasps (Vespidae: Masarinae) in southern Africa. Journal of Arid Environments, 57: 17-44.
3. Judd, W.S. and R.G. Olmstead, 2004. A survey of tricolpate (eudicot) phylogenetic relationships. American Journal of Botany., 91: 1627-1644.
4. Durnikin, D.A., 2010. Influence of natural and anthropogenic factors on the hydrophilic flora of water ecosystems of the southern part of the Ob-Irtysh interfluve. Contemporary Problems of Ecology, 3(4): 374-380.
5. Durnikin, D.A. and A.E. Zinovyeva, 2013. Singularity of Flora in Southern Water Basin of OB-Irtysh Interfluve of Western Siberia. World Applied Sciences Journal. 22(3): 337-341.
6. Durnikin, D.A. and A.E. Zinovyeva, 2013. Effect of Limiting Abiotic Factors on the Distribution of Plants in Aquatic Ecosystems of the Southern Part of the Ob-Irtysh Interfluve. Middle-East Journal of Scientific Research. 16(3): 352-356.
7. Stoller, J., 1921. Die Pflanzenwelt des Quartars in Potonie-Gothan. Lehrbuch der Paläobotanik, 2 Aufl., 3: 407-422.
8. Nikitin, V.P., 2006. Paleocarpology and stratigraphy of Paleogene and Neogene of Asiatic Russia. Novosibirsk: Academic. "Geo", pp: 229.
9. Adamenko, O.M., 1974. Mesozoic and Cenozoic Steppe Altai. Novosibirsk: Nauka, pp: 167.
10. Simpson, D.A. and C.A. Inglis, 2001. Cyperaceae of economic, ethnobotanical and horticultural importance: A checklist. Kew Bulletin. 56: 257-360.
11. Thieret, J.W., 1982. The Sparganiaceae in the southeastern United States. Journal of the Arnold Arboretum , 63: 341-356.
12. Minc, L.D., 1997. Vegetation of the Great Lakes Coastal Marshes and Wetlands of MN, WI, OH, PA, and NY. A Data Summary Submitted to Michigan Natural Features Inventory, January, 12: 60.
13. Thomas, W.E. and R.H. Maxwell, 2009. Distribution records of southern Indiana vascular plants III. Proceedings of the Indiana Academy of Science, 118: 31-38.
14. Anderberg, A.A. and G. El-Ghazaly, 2000. Pollen morphology in Primula sect. Carolinella (Primulaceae) and its taxonomic implications. Nordic Journal of Botany, 20: 5-14.
15. Judd, W.S. and R.G. Olmstead, 2004. A survey of tricolpate (eudicot) phylogenetic relationships. American Journal of Botany, 91: 1627-1644.
16. Anderberg, A.A. and G. El-Ghazaly, 2000. Pollen morphology in Primula sect. Carolinella (Primulaceae) and its taxonomic implications. Nordic Journal of Botany, 20: 5-14.

8/13/2014