

Diatoms from Middle Miocene Continental Deposits of Primorye

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Abstract

Diatoms from Middle Miocene deposits of Khanka Lake's northwestern shore (Primorye) were studied using light and scanning microscopes. The analyses of diatom flora composition and species diversity showed that there was a dominance of several taxa that made possible the recognition of two diatom complexes. The lower complex differs from the upper one by higher species diversity, by presence of many subtropical diatoms and absence of pronounced dominant species. Differences between the complexes can be explained by the progressing climatic cooling and predominance of fluvial-lakustrine sedimentation over the typically lake one due to development of a wide system of river valleys.

Keywords

Miocene, Diatoms, Stratigraphy, Paleoclimate

1. Introduction

Diatom unicellular algae with external siliceous frustules are widely used in biostratigraphy and paleoclimatic reconstructions due to their sensitivity to environmental changes (Jousé, 1962; Douglas, Smoll, 1999; Pushkar, Cherepanova, 2001; Pushkar et al., 2013). Not only ecological structure of diatom paleocenosis and number of valves found in sediments, but also morphological features of phenotypes can at the same time be considered as a reaction of taxa on variations in living conditions (Cherepanova et al., 2010).

The Middle Miocene diatoms-containing continental deposits are wide spread on the territory of the Russian Federation. They have been studied in areas of the Russia's east geographically close to Primorye: West Siberia Lowland, near Lake Baikal, Transbaikalia and in the south of Far East Region (Glezer et al., 1974). The most thoroughly investigated are diatoms from sedimentary rocks of the Vitim Plateau; here, Middle Miocene diatom complex with dominating *Aulacoseira* Thwaites and *Tetracyclus* Ralfs has been recognized (Rasskazov, 2007). Diatoms from the coeval deposits of Tunkinskaya basin were studied by Cheremisinova (1973). Among multiplicity of species found there, there were determined genera *Aulacoseira* and *Coscinodiscus* Ehrenberg. Likhoshvay E.V. later carried out additional researches of diatoms from these deposits and has specified species which were belonged to several taxa (Likhoshvay et al., 1997).

The objective of the present study was diatom flora from sedimentary strata of the Khanka depression (Primorye) which evolution was going in changing climate environments of the Middle Miocene.

2. Materials and Methods

Material for studying represented 35 samples selected personally by the author from the Middle Miocene sedimentary rocks of erosion scarp on the Khanka Lake's western shore among settlements Turiy Rog and Novokachalinsk (**Figure 1**), as well as samples which were kindly given by Prof. V.S. Pushkar. All of them are rich in the well-preserved diatom flora.

The sedimentary rocks of the erosion scarp are composed of gravel, sandstone, thin-laminated tuffaceous siltstone and diatomite; they occur among underlying coal-bearing beds of Upper Oligocene age and the overlapping Upper Pliocene clays.

The suggestion to reckon this new stratigraphic unit to the Miocene sedimentary complex was given by B.I. Pavlyutkin (Pavlyutkin et al., 2004) based on the integrated study of sufficiently thick band of sediments (more than 200 m) which were naturally outcropped on the Khanka Lake's western shore. Stratigraphic thickness of the strata is presented by the well-exposed suite of the same name. At the present time stratigraphic position of the studied strata remains a subject of discussion between geologists and paleobotanists. According to Decisions of the 4-th Interdepartmental stratigraphy meeting (The resolution..., 1994), this rock unit has been referred to the Bikinsky stratigraphic unit rather than to the Tavrichansky or Prikhankaisky horizons.

Within the stratum, three types of rocks are distinguished: pebbles in a sandy clay matrix, composed weathered rock and thin-layer tuffaleuroilite with rare pebbles. Rock layers are gently bended (up to 2°) to the south and southeast. They are underlain, with an uncertain contact, by the poorly carboniferous deposits of the Upper Oligocene and are overlapped by red clays of the Upper Pliocene.

Technical processing of samples and their preparation for analyzing under a light microscope was in accordance to a generally accepted procedure (Glezer et al., 1974). If there was a lack of diatom valves in sediments, the samples were exposed to heavy cadmium liquid treatment (density—2.6).

Taxonomic analysis of diatom flora, investigation of ecological structure of paleocenosis, measuring of diameter and height of bending valves have been conducted with the help of Axio Lab.A1 and Axioskop 40 Carl Zeiss light microscopes, at magnification x 2000, and with the use of immersion liquid. Fine structure of diatom shells was analyzed using the Carl Zeiss EVO 40 scanning microscope (magnification, up to x 15000) owned by Institute of Soil Biology FEB RAS.

The author uses here a classification of diatoms accepted by Russian diatomologists (Glezer et al., 1992), considering revision made for a number of species and genera (Kuzmin et al., 2009; Krammer, 1991; Krammer, Lange-Bertalot, 1991; Khursevich, 1994; Williams, 1989, 1996).

3. Results and Discussion

The analysis of taxonomic composition of flora, its species diversity and a dominance of several taxa allows distinguishing two diatom complexes within the Novokachalinskaya suite (**Figure 1**).

The lower diatom complex is confined to the bottom and middle parts of the sequence (points 9146-9149) and is characterized by relatively high diversity: 75 species that belong to 41 genera, lack of pronounced domination of any kind of species except two: *Aulacoseira praegrnulata* (Jousé) Simonsen var. *praegrnulata* f. *praegrnulata* (**Figure 2(K)**) and *A. praegrnulata* var. *praeislandica* f. *praeislandica* (Simonsen) Moisseeva (**Figure 2(M)**), which form tuffaceous diatomite layers.

This complex has been first described by V.S. Pushkar and M.V. Cherepanova (Pavlyutkin et al., 2004). Repeated sampling and redefining of species diversity has given clearer view of stratigraphic occurrence of diatoms in the sequence. It concerned first of all the matter of distribution of curvata forms of ancient *Aulacoseira*. In the Novokachalinsky complex, this form is represented by *A. praegrnulata* var. *praeislandica* f. *curvata* (Jousé) Moisseeva (*A. praegrnulata* var. *praegrnulata* f. *curvata* (Jousé) Simonsen (**Figure 2(N)**)—to a lesser extent) and by *A. italica* var. *italica* f. *curvata* (Pant.) Dav. which are first appeared in this stratigraphic interval.

Secondly, new species of genus *Actinocyclus* Ehrenberg (**Figure 2(G)**) and may be first *Mesodictyon* Theriot et Bradbury (**Figure 2(L)**) are distinguished here. *Mesodictyon* were earlier referred to a genus *Coscinodiscus* (Jousé, 1952; Moisseeva, 1971) and later to *Pontodiscus* Temniskova-Topalova et Sheshukova-Poretzkaya (Temniskova-Topalova et al., 1981; Moisseeva, 1995) and were considered as typical representatives of late Miocene and Pliocene only.

Characteristic complex of diatoms from the lower layers of stratigraphic sequence of Novokachalinskaya suite is represented by: *Actinella brasiliensis* Grunow (**Figure 2(C)**), *Aulacoseira praegrnulata* var. *praegrnulata* f.

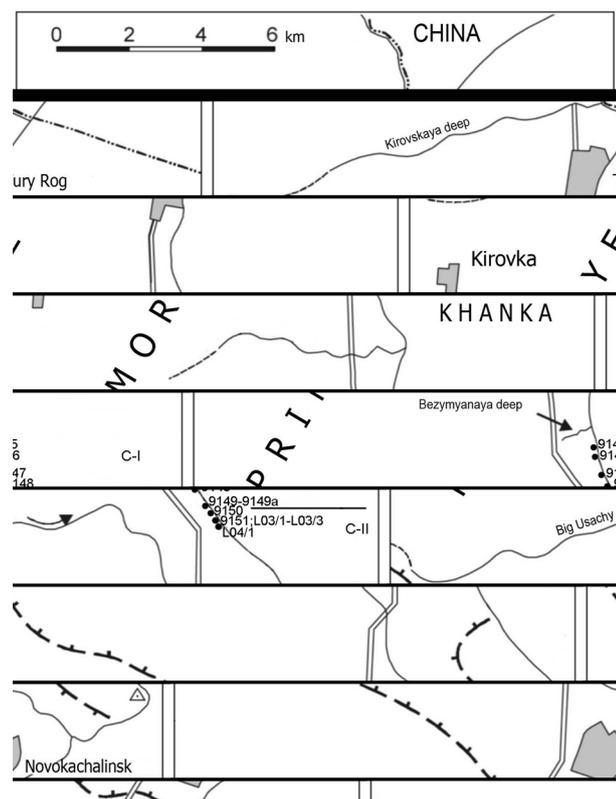


Figure 1. The stratotype of Novokachalinskaya suite (by Pavlyutkin et al., 2004) with this paper author's modifying: 9145-9151, L03/1-L03/3, L04/1—location of the sampling points; C-I—lower complex, C-II—upper complex.

praegratulata, *A. praegratulata* var. *praeislandica* f. *praeislandica*, *Ellerbeckia arenaria* var. *teres* (Brun) R.M. Crawford (**Figure 2(H)-(J)**), *Fragilariforma bicapitata* (Mayer) D.M. Williams et Round (**Figure 2(A)**), *Fragilaria miocenica* Jousé var. *miocenica* (**Figure 2(B)**), *Gomphonema miocenica* Moiss., *Melosira undulata* (Ehr.) Kütz. var. *undulate* (**Figure 2(D)**), *Miosira jouseana* (Moisseva) Krammer, Lange-Bert. et Schiller (**Figure 2(O)**), *M. areolata* (Moisseva) Khurs., *Staurosira construens* Ehrenb. (**Figure 2(E)**), *S. venter* (Ehrenb.) Kobayasi (**Figure 2(F)**), *S. elliptica* (Schumann) D.M. Williams et Round, *Tetracyclus glans* (Ehrenb.) Mills. Age data obtained for this complex range in the interval of 18.1 – 14.9 Ma (Pavlyutkin et al., 1993, 2004).

The analysis of ecological structure of the complex suggests a conclusion about sublittoral environment of its formation in a sufficiently warm running-water pond.

The upper diatom complex (points 9150, 9151, L03/1-L03/3, L04/1) differs from the lower one by the absence of many subtropical species (*Actinella brasiliensis*, *Cymbella australica* (A. Schmidt) Cleve, *Desmognium guianense* Ehrenb., *D. rabenhorstianum* Grunow) and the growth of diversity and frequency of bottom-living diatoms, especially genera *Tetracyclus* (**Figure 3(C), (F)-(H)**), *Staurosira* Ehrenberg, *Planothidium* Round et. L. Bukhtiyarova which are typical rheophil forms. Among *Tetracyclus* flora, there is a predominance of *Tetracyclus clypeus* (Ehr.) Li Jia-Ying (**Figure 3(D), (E)**) (up to 62% - 70%). Another feature of the upper complex is that planktonic *Miosira jouseana* is missed out here, whereas *M. areolata* (**Figure 3(A)**) is abundant (frequency up to 4). In fact, this interval of sediments can be considered an acme-zone for *Miosira areolata*. Dominant role belongs to planktonic species *Aulacoseira praegratulata* (Jouse) Moiss. and *Melosira undulata* (Ehr.) Kuetz.

Compared to the lower complex, the upper one has got poor species diversity, indistinct morphological boundaries within polymorphic species belonging to genera *Aulacoseira*, *Melosira* C. Agardh, *Tetracyclus*, and a pronounced dominant species. All this is an evidence of more stable conditions for diatom living.

The both complexes are characterized by high polymorphism among *Tetracyclus*, which is rare for sedimen-

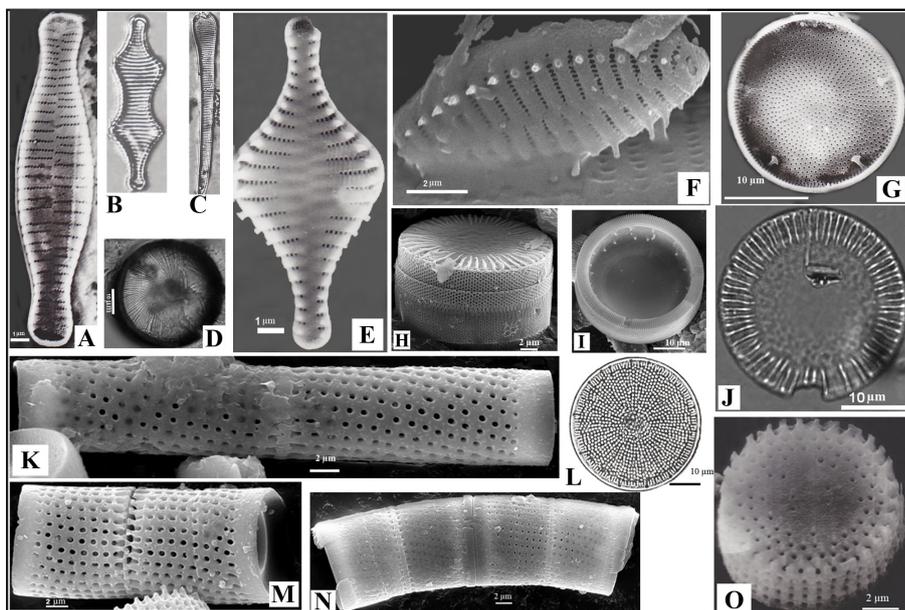


Figure 2. Some representatives of the lower diatom complex. (A) External view of *Fragilari-forma bicapitata*, SEM (scanning electron microscope). (B) External view of *Fragilaria miocenica* var. *miocenica*, LM (light microscope) $\times 1000$. (C) External view of *Actinella brasiliensis*, LM $\times 1000$. (D) External view of *Melosira undulata* var. *undulate*, LM. (E) External view of *Staurosira construens*, SEM. (F) External view of *Staurosira venter*, SEM. (G) Internal view of *Actinocyclus gorbunovii*: a valve with a several labiate processes, SEM. (H) *Ellerbeckia arenaria* f. *terres*—a valve mantle with a cingulum, SEM. (I) *Ellerbeckia arenaria* f. *terres*—internal surface with a ring of tubulate processes, SEM. (J) External view of *Ellerbeckia arenaria* f. *terres*, LM. (K) *Aulacoseira praegr anulata* var. *praegr anulata*—a valve mantle, SEM. (L) External view of *Mesodictyon foveis*, SEM. (M) *Aulacoseira praegr anulata* var. *praegr anulata* f. *praegr anulata*—a valve mantle, SEM. (N) *Aulacoseira praegr anulata* var. *praegr anulata* f. *curvata*—a valve mantle, SEM. (O) External view of *Miosira jouseana*, SEM.

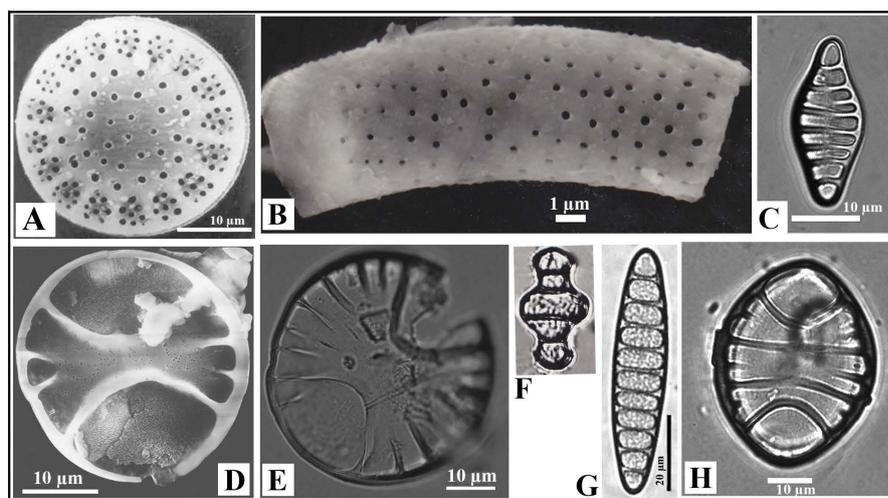


Figure 3. Some representatives of the upper diatom complex. (A) External view of *Miosira areolata*, SEM. (B) *Aulacoseira taiganosica*—a valve mantle, SEM. (C) External view of *Tetracyclus ellipticus* var. *lancea*, LM. (D) Internal surface of *Tetracyclus clypeus*, SEM. (E) Internal surface of *Tetracyclus clypeus*, LM. (F) External view of *Tetracyclus lacustris* var. *lacustris*, LM $\times 1000$. (G) *Tetracyclus* sp., LM. (H) External view of *Tetracyclus excentricum*, LM.

tary rocks of other age in Primorye, and by presence of only here found *Aulacoseira taiganosica* (Figure 3(B)) Lupikina et Ozorn., that can be considered as an important reference feature for these deposits.

From the position of paleogeography, a contrast between two complexes can be explained by the progressing fall of temperature and predominance of fluvial-lakustrine sedimentation over the typically lake one due to development of a wide system of river valleys. The low degree of absolute dominance under sufficient species diversity and high uniformity level is a marker of fast changing in environmental conditions. It is possible that at this time span the winter monsoon starts prevailing under the summer one that affected the nature of lake basins watering.

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