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Neogene Lake Basins in Southwestern Bulgaria – biostratigraphy, palaeoecology and diatom floristic interrelations

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Н. Огнянова-Руменова, М. Янева, Г. Николов – Неогеновые озерные бассейны в Юго-Западной Болгарии – биостратиграфия, палеоэкология и взаимоотношения диатомей. Впервые сделано восстановление эволюции пресноводных диатомей и механизма их распределения в неогеновой озерной системе Юго-Западной Болгарии. Основная цель работы – определение основных этапов в эволюции мио-плиоценовых диатомейных флористических ассоциаций, развивавшихся в грабеновых структурах региона. Для осуществлния этой цели использовались палеонтологические, биостратиграфические, минералогические, петрологические и седиментологические данные. Приведена характеристика материала из обнажений и буровых скважин около сел Станянцы, Бели бряг и Чукурово, района Софии, Палакарийской долины, Костенецкого района, районов около городов Разлог, Симитли и Сандански, Струмешницкой долины, г. Гоце Делчев, Сатовчанского бассейна и Вылкосел-Туховицкой депрессии. Сделано описание 660 диатомейных видов, разновидностей и форм. Это удивительное разнообразие сопоставимо с морским биологическим разнообразием восточного Паратетисского залива на территории Северо-Восточной Болгарии во время миоцена (546 видов, разновидностей и форм). Самые ранние озерные диатомеи Юго-Западной Болгарии установлены в среднемиоценовых породах Симитлийского бассейна (Симитлийская свита), а возраст самых молодых – раннеплиоценовый. В эволюции и распределении установленных центрических видов среднимиоценовых – плиоценовых диатомей можно выделить три основных этапа. Анализ диатомей, дополненный структурными и геодинамическими исследованиями может выявить влияние разных факторов палеоэкологической обстановки на развитие диатомейной флоры. Авторами установлено, что питательность среды, уровень солености бассейнов, температура и изменения глубин озерного бассейна в значительной степени коррелируются с особенностями диатомейных ассоциаций, установленных на основании литостратиграфических и биостратиграфических исследований и в результате приложения разных статистических методов. Предложенная заключительная модель Софийского бассейна может оказаться полезной при описании колонизации диатомей в озерных бассейнах Юго-Западной Болгарии.

Abstract. Modeling of the evolution of freshwater diatoms and the mechanism of their distribution in the Neogene lake system in Southwestern Bulgaria is accomplished for the first time. The main purpose is the determination of the major stages in the evolution of the Mio-Pliocene diatom floras developed in the graben structures in this realm. Various data were used for the realization of this purpose: palaeontological, biostratigraphical, mineralogical, petrological and sedimentological. Outcrops and core drills from Stanitsi, Beli Breg, Sofia, Chukurovo, Palakaria, Kostenets, Razlog, Simitli, Sandanski, Strumeshnitsa, Gotse Delchev, Satovcha Basins and Valkosel-Tuhovitsa depression were characterized. In total, 660 diatom species, varieties and forms have been described from these lake systems. This surprisingly high diversity is even comparable with marine biodiversity for the Eastern Paratethyan Bay on the territory of Northeastern Bulgaria (546 species, varieties and forms) during the Miocene. The oldest known lacustrine diatoms from the sediments in Southwestern Bulgaria are Middle Miocene in age (Simitli Basin – Simitli Formation), the youngest – Early Pliocene. Three major stages in the evolution and distribution of centric diatom genera can be distinguished during Middle Miocene-Pliocene. Diatom analyses, complemented by structural and geodynamic investigations could demonstrate the impact of

different palaeoenvironmental factors on the development of the diatom flora. We found that the process of nutrient levels, the salt content, temperature and the changes in the depth of the lake correlated significantly with patterns in the diatom assemblages, based on complex of lithostratigraphic and biostratigraphic investigation, as well as different statistical techniques. The inference model of Sofia Basin could be useful in describing the colonization of diatoms in the lacustrine basins on the territory of Southwestern Bulgaria.

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Key words: diatom biostratigraphy, palaeolimnology, Middle Miocene-Early Pliocene, Southwestern Bulgaria.

Introduction

The distribution of diatom species in space and time has long been a focus of a descriptive and applied diatom studies (Edlund, Jahn, 2001). Freshwater diatom biogeography has been neglected as a scientific subject. Across the world there is a prevailing view that freshwater algae are cosmopolitan. The notion has seldom been tested and is unlikely to be true in genetic terms. Nonetheless, some morphospecies of several groups of algae do have a worldwide distribution. Others have restricted distribution and may be regarded as endemic to a region. However there is always the possibility that they will be discovered in far away places (Tyler, 1996). The Eastern European freshwater systems of Neogene are all characterized by outstanding endemism of diatom species (Ognjanova-Rumenova, 1996; Temniskova-Topalova, Ognjanova-Rumenova, 1997; Ognjanova-Rumenova, Metzeltin, 2006; Lange-Bertalot, Metzeltin, 2006; Ognjanova-Rumenova, 2006; Ognjanova-Rumenova, Krstic, in press; Ognjanova-Rumenova, Dumurdžanov, in press). As the material is fossil and specimens are sparsely distributed, identifications very often are made from limited numbers.

Modeling of the evolution of freshwater diatoms and the mechanism of their distribution in the graben structures in Southwestern Bulgaria is accomplished for the first time. This paper represents a partial result of the project NZ 903/1999 'Model of the evolution and colonization of lacustrine diatoms in continental basins in Southwestern Bulgaria during the Miocene'.

Materials and methods

Numerous samples of lacustrine diatom-bearing deposits were collected from 13 Neogene basins in Southwestern Bulgaria (Fig. 1). Some samples were from outcrop material, but the majority were from core-drills. The chronology of diatom-bearing sediments in the study region is based both on absolute ages and more often on the stratigraphical and palaeontological records (pollen, macroflora remains, mollusks, ostracods and mammals).

The samples for diatom analysis were cleaned according to the method described by Огнянова-Руменова (1991). The relative abundance of diatoms was estimated by the Schrader's scale (Schrader 1973). Preparation for scanning electron microscopy followed Hasle & Fryxell (1970) and samples were examined with a Jeol Superprobe 733 and Jeol JSM T300. Ecological spectra were composed on the basis of studies of recent diatoms by the method of Abbott & Van Landingham (1972). The basic environmental factors interpreted in the palaeoecological analyses were the active water reaction (pH), temperature, trophic state, type of habitat and salinity. Index B was used to assess trends in acidification and to derive equations for inferring lake-water pH (Renberg & Hellberg 1982). The extent of diatom preservation provided additional information about palaeoenvironmental change (Flower 1993). The percentage ratio of diatom frustules to chrysophycean stomatocysts was applied as an index of trophic status (Smol 1985).

Principal Component Analysis (PCA) was used to summarize the major patterns of variation of the data. The ordination was implemented by the computer program CANOCO 4.0 (ter Braak & Šmilauer 1998).

Results and discussion

In the nonmarine setting, diatom-bearing sediments occur in lacustrine environments that are rich in nutrients for diatom growth, are not excessively alkaline, and do not have a steady influx of terriogenous material. We found diatom-rich claystone and siltstone, as well as diatomites at several localities in Sofia, Beli Breg, Palakaria, Kostenets, Simitli, Gotse Delchev, and Satovcha Basins (Fig. 1). The other localities in Stanitsi, Chukurovo, Razlog, Sandanski, Strumeshnitsa, and Valkosel-Tuhovitsa Basins are barren of diatoms.

In total, 660 diatom species, varieties and forms have been described from these lake systems. This surprisingly high diversity is even comparable with marine biodiversity for the Eastern Parathetyan Bay on the territory of Northeastern Bulgaria (546 species, varieties and forms) during the Miocene (Тем-

нискова-Топалова, 1994). The diversities and floristic composition of these lake systems display interesting patterns. Until now the development of the different planktonic genera of class Centrophyceae is very important in diatom biostratigraphic subdivision. They are more useful for biostratigraphy than are benthic diatoms, which have a more localized distribution determined by depth, substrata, etc.

The Family Aulacoseiraceae has the oldest fossil record among the freshwater diatoms (Ambwiani et al., 2003), implying that it was the first to cross the marine-freshwater ecotone in the Cretaceous. The group appears to have two surges of genus-level diversification during its history: first – in the Eocene with genus *Eoseira*, and second in the Oligocene-Miocene with *Miosira*, *Alveolophora*, and *Pseudo-*

Fig. 1. Schematic map of Southwestern Bulgaria with location of the sample sites

List of diatom sample localities:
Sofia Basin, Novi Iskar Formation, core-drills: C-1; C-14; C-20; C-47; C-51; C-52; C-1032; C-1113; C-1127; C-1128.
Beli Breg Basin, Kaisiinitsa Formation, outcrops.
Stanintsi Basin, Belozem and Zainitsa Formations, outcrops.
Chukurovo Basin, unnamed unit, outcrop.
Palakaria Basin, Alino Formation, outcrop and core-drills: C-225, C-329.
Kostenets Basin, Gabrovitsa Formation, core-drills: C-2; C-3.
Simitli Basin, Simitli Formation, core-drills: C-177, C-187.
Razlog Bazin, Godlevo Formation, outcrop.
Strumeshnitsa Basin, unnamed unit, outcrops.
Sandanski Basin, Delchevo, Sandanski and Kalimantsi Formations, outcrops.
Gotse Delchev Basin, Baldevo Formation, core-drills: C-10, C-14, C-23, C-28, C-31; C-32, outcrops, open coal mine "Kanina", Nevrokop Formation, outcrops.
Satovcha Basin, Sivik Formation, outcrop
Valkosel-Tuhovitsa depression, Tuhovishta and Slashten Members, Valkosel Formation, outcrops.

alulacoseira (Wolf, Edlund, 2005). Curiously, it is only the oldest of these genera, *Aulacoseira*, that has survived to the present. Additional phylogenetic analyses, including the full range of Miocene Aulacoseroid diversity are needed to fully elucidate the evolutionary relationships in this important freshwater group. In our material most of the species, belonged to genus *Aulacoseira*, were investigated by scanning electron microscope. All data, connected with rimoportulae – variation in form, number, position on the valve mantle and ringleist could be used in species determination, taxonomy and evolution (Crawford, Likhoshway, 1998; Likhoshway, Crawford, 2001).

A key for the determination of the extinct genera belonged to family Stepahnodiscaceae is composed, based on morphological evolution. Pattern of the morphological evolution can be described by change of the cribrum position in areola; change of stria morphology; change of the strucrture of marginal fultoportulae on the valve mantle; change of the number of rimoportulae. The newly described genus *Tertiariopsis* was also included in the biochronological scheme (Khursevich et al., 2002).

Generally, the lake diatom flora may be divided into '*Actinocyclus*' and '*Aulacoseira*' dominated ones (Temniskova-Topalova, Ognjanova-Rumenova, 1997), but this scheme has been developed, because recently different diatom genera and species, belonged to class Centrophyceae have been newly described. The main stages in the biochronological scheme in the region of the Balkan Peninsula was published previously (Ognjanova-Rumenova, 2000).

The oldest known lacustrine diatoms from the sediments in Southwestern Bulgaria are Middle Miocene in age (Simitli Basin – Simitli Formation), the youngest – Early Pliocene. Three major stages in the evolution and distribution of centric diatom genera can be distinguished during Middle Miocene-Pliocene:

1) the Middle Miocene stage – ancient representatives of *Aulacoseira*, *Ellerbeckia*, *Melosira* and *Actinocyclus;*

2) the Late Miocene stage – active development of *Actinocyclus*, *Aulacoseira*, and accompanying species of *Concentrodiscus*, *Thalassiosira, Hyalodiscus*, *Mesodictyon Tertiariopsis* and systematic diversity of *Cyclotella* and *Stephanodiscus*;

3) the beginning of Pliocene stage – dominance of *Cyclotella*, *Stephanodiscus*, *Aulacoseira*, some *Cyclostephanos* and *Pliocaenicus* species. Species of *Actinocyclus* disappeared;

The applicability of fossil diatom thanatocoenoses to assist in Neogene stratigraphy is dependant on palaeoenvironmental changes in the lake history. Diatom analyses, complemented by structural and geodynamic investigations could demonstrate the impact of different palaeoenvironmental factors on the development of the diatom flora. Complex lithostratigraphic and biostratigraphic investigation of diatoms, chrysophycean stomatocysts, and mollusk fauna was performed on a borehole C-14, from peripheral zone of the Sofia Basin, where the sedimentation process had been the longest (Ognjanova-Rumenova et al., 2008). Different statistical techniques were used to combine all palaeontological, biostratigraphical, mineralogical, petrological and sedimentological data for this model core – Detrended Correspondence Analysis (DCA), Canonical Correspondence Analysis (CCA) and Partial Canonical Correspondence Analysis (PCA). We found that the process of nutrient levels, the salt content, temperature and the changes in the depth of the lake correlated significantly with patterns in the diatom assemblages. Three different trophic phases could be recognized in the sediment deposition of Novi Iskar Formation, Sofia Basin. This inference model may be useful in describing the colonization of diatoms in the lacustrine basins on the territory of Southwestern Bulgaria.

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Резюме. Н. Огнянова-Руменова, М. Янева, Г. Николов – Неогенски езерни басейни в Югозападна България – биостратиграфия, палеоекология и флористични диатомейни взаимоотношения. Модел на еволюцията и механизмът на разселването на кремъчните водорасли в неогенската езерна система на Югозападна България се представя за първи път. Основна цел е да се разграничат главните етапи в еволюцията на мио- плиоценските диатомейни флори, развивали се в грабеновите понижения на територията на Югозападна България. Използвани са разнообразни данни – палеонтоложки, биостратиграфски, минералого-петрографски и седиментоложки. Описани и опробвани са разкрития и сондажи на Станински, Белобрежки, Софийски, Чукуровски, Костенецки, Палакарийски, Разложки, Симитлийски, Сандански, Струмешнишки, Гоце Делчевски, Сатовчански басейн и Вълкосел-Туховишко понижение. Установената диатомейна флора е много богата – 660 вида, вариетета и форми, и това изключително разнообразие може да се сравни само с интересната морско-бракична диатомейна флора от седиментите на Евксинския басейн, Североизточна България. Определени са три етапа в развитието на планктонните родове от клас Centrophyceae през мио- плиоцена: 1. **среден миоцен** – древни представители на *Aulacoseira*, *Ellerbeckia, Melosira, Actinocyclus*; 2. **късен миоцен** – масово развитие на *Aulacoseira* и *Actinocyclus*, придружаващи видове от родовете *Concentrodiscus, Thalassiosira, Hyalodiscus, Mesodictyon, Tertiariopsis* и поява на *Cyclotella* и *Stephanodiscus*; 3. **ранен плиоцен** – доминиране на видове от родовете *Cyclotella, Stephanodiscus* и *Aulacoseira,* поява и развитие на *Cyclostephanos* и *Pliocaenicus.* Род *Actinocyclus* изчезва. През късния миоцен и ранния плиоцен семейство Stephanodiscaceae е представено от интересни родове, известни само във фосилно състояние и имащи важно биостратиграфско значение – *Concentrodiscus, Mesodictyon, Tertiariopsis* и *Pliocaenicus.* Използвайки сравнителната таксономия е създаден ключ за тяхното определяне. Той се основава на морфологичната еволюция на черупката и обхваща следните характеристики: форма на черупката и дъното; разположение на ареолите, израстъците с опора, лабиатните израстъци, и строеж на алвеолите. Комбинирането на диатомейния анализ със структурни и геодинамични изследвания дава възможност да се проследи влиянието на палеоекологичните фактори върху развитието на диатомейната флора. Приложени са разнообразни статистически техники, за да се обединят всички данни (палеонтоложки, биостратиграфски, минералого-петрографски и седиментоложки) при проведения палеоекологичен анализ на моделен сондаж С-14 в Софийския басейн. Бе установено, че трофичността, солеността, промени на температурата и смените в дълбочината на басейна са най-значителните фактори, определящи развитието на диатомейните ансамбли.