Acta Bot. Croat. 74 (2), 345–361, 2015

CODEN: ABCRA 25
ISSN 0365-0588
eISSN 1847-8476
DOI: 10.1515/botcro-2015-0023

Stratigraphic and taxonomic significance of siliceous microfossils collected from the Turiec Basin, Western Carpathians (Slovakia)

Nadja Ognjanova-Rumenova[1*], Radovan Pipík[2]

[1] Geological Institute, Bulgarian Academy of Sciences, Acad. G. Bonchev str. 24,
1113 Sofia, Bulgaria

[2] Geological Institute, Slovak Academy of Sciences, Ďumbierska 1,
974 01 Banská Bystrica, Slovak Republic

Abstract – This study provides the first biostratigraphic data of siliceous microfossils from Turiec Basin, Slovakia. The fossil diatom flora consists of 42 species and varieties, belonged to 22 genera. The diatom assemblage studied from the Turiec Basin bears a strong resemblance to assemblages from non-marine diatomaceous sediment of Miocene age from Rüdenschwinden, a village of the eastern slope of the Hohe Rhön (Central Germany), non-marine sediments of the early Late Miocene from the village of Szilagy (South Hungary), as well as from Bes Konak Basin, Turkey. The investigated profile is generally dominated by *Alveolophora jouseana*. The similarities and differences within the taxonomy of certain species belonging to the genera *Aulacoseira*, *Alveolophora* and *Miosira* are discussed. The accompanying species are species of the genus *Fragilaria* Lyngbye sensu lato from class Fragilariophyceae. The most interesting taxa belong to the genus *Staurosirella – S. grunowii*, *S. leptostauron*, *S. martyi*. Among them are two very unusual taxa identified only to genus. Ecological data for the diatom taxa and the diatom frustules/chrysophycean stomatocysts ratio are used in an attempt to reconstruct in detail the palaeoecological conditions at the time of sediment deposition.

Key words: *Alveolophora* (Bacillariophyceae), biostratigraphy, Late Miocene, palaeoecology, siliceous microfossils, Turiec Basin

Introduction

The Central and South-Eastern European freshwater and brackish systems of the Neogene are often chracterised by outstanding endemisms (Harzhauser and Mandic 2008). Neogene non-marine diatoms for this area were documented and illustrated by early workers (Ehrenberg 1854, Grunow 1882, Pantocsek 1892, 1905). During the last decades more of these described diatom taxa have been considered in a stratigraphic context (Řeháková

---

[*] Corresponding author, e-mail: nognjan@geology.bas.bg

1971, 1980, Hajós 1985). Recently many papers have appeared on the origin, evolution and phylogeny of lacustrine diatoms during the Neogene period (Stachura-Suchoples and Williams 2009, Williams and Kociolek 2010, Ognjanova-Rumenova and Crawford 2012, Khursevich and Kociolek 2012, etc.). Many of them are concerned with the inventory, description and typification of various diatom species from raw materials, housed in different European diatom collections: Ehrenberg (Berlin), Pantocsek (Budapest), Hustedt (Bremerhaven), Grunow (Vienna), etc.

The present paper analysies the non-marine Miocene diatom assemblage present in the sediments of Turiec Basin, Western Carpathian region of Central Europe. Emphasis is given to the centric genera *Melosira* Agardh, *Miosira* Krammer, Lange-Bertalot et Schiller and *Alveolophora* Moisseeva et Nevredtinova owing to their stratigraphic importance and difficult taxonomical problems. Palaeoecological interpretation of the environmental history is also given.

Material and methods

The Turiec Basin of Slovakia is one of the Western Carpathian intermontane basins that formed during the Middle and early Late Miocene as a results of the Alpine orogeny and its relationship to the Carpathian Mountains (Pipík et al. 2012). The sedimentary Neogene fill of the basin reaches up to 1,250 m and could have been episodically connected at that time with the back-arc Carpathian basins. The oldest deposits are represented by the Middle Miocene sedimentary, volcano-sedimentary and volcanic andesitic complex (Pipík et al. 2012). The Turiec Basin fill is composed of the Turiec Group with the very complicated positions of various lithostratigraphic units within the Group. Its lithostratigraphy has been redefined according to well preserved fossil leaves, endemic bivalves, gastropods, and ostracods (Kováč et al. 2011).

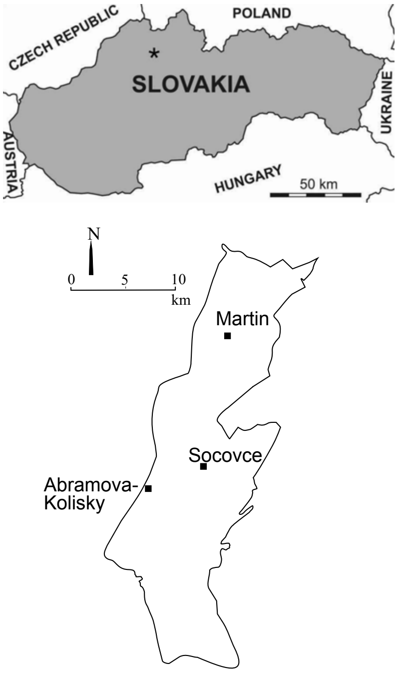

Fig. 1. Schematic map of the Turiec Basin in Slovakia with locations of the three sampling stops: Martin (49°03’52”N; 18°53’42”E), Socovce (48°57’11” N; 18°51’45”E) and Abramová-Kolísky (48° 55’47”N; 18°47’09”E).

A total of 20 samples from the area of Turiec Basin were analyzed for siliceous microfossils: the profiles Martin (49°03’52”N; 18°53’42”E), Socovce (48°57’11”N; 18°51’ 45”E) and Abramová-Kolísky (48°55’47”N; 18°47’09”E) (Fig. 1). Diatom-bearing sediments were determined only in the lowermost part of the profile Abramová-Kolísky on the south-western edge of the Turiec Basin: 6 samples per 0.25 m intervals. The studied sediments belonged to the Abramová Member (Kováč et al. 2011), and the geology of the profile has been accurately described by Pipík (2005).

The samples for diatom analysis were cleaned according to the method described by OGNJANOVA-RUMENOVA (1991). The relative abundance of diatoms was estimated by Schrader's scale (SCHRADER 1973). Light micrographs were taken with a Nikon DS-Fi 1 camera. For scanning electron microscope (SEM) analyses, samples of cleaned material were dried onto aluminium stubs and coated with gold-palladium. SEM micrographs were provided on a Jeol JSM 5510 using accelerating voltages from 5–10 kV. Ecological spectra were composed on the basis of studies of recent diatoms by the method of ABBOTT and VAN LANDINGHAM (1972). The basic environmental factors interpreted in the paleoecological analyses were the active-water reaction (pH), temperature, trophic state, type of habitat and salinity. The percentage ratio of diatom frustules to chrysophycean stomatocysts was applied as an index of trophic status (SMOL 1985).

Results

Analysis of the diatom flora and taxonomical remarks

The fossil diatom flora consists of only 42 species and varieties of 22 genera (Tab. 1). The classification follows ROUND et al. (1990). The flora is almost entirely formed of recent species (85.7%).

The taxonomic diversity is very poor. The studied profile is generally dominated by the centric diatom *Alveolophora jouseana* (Moiss.) Moiss., hence this species was selected for morphological investigation in light and scanning microscope, due to its stratigraphic importance and evolutionary interest.

***Alveolophora jouseana* (Moisseeva) Moisseeva**
Figs. 5 A–K, 6 A–F, 7 A–H, 8 A–C

Melosira jouseana Moisseeva (MOISSEEVA 1971, p. 24, Pl. I, Figs. 1–10)
Aulacoseira jouseana (Moisseeva) Moisseeva; (MOISEEVA 1981, p. 125)
Alveolophora jouseana (Moisseeva) Moisseeva; (MOISSEEVA and NEVREDTINOVA 1990, p. 542, Pl. I, Figs. 1–10)
Miosira jouseana (Moisseeva) Krammer, Lange-Bertalot et Schiller; (KRAMMER et al. 1997, p. 17)
Miosira jouseana (Moisseeva) Krammer, Lange-Bertalot et Schiller; (KOZYRENKO et al. 2008, p. 114)
Miosira jouseana (Moisseeva) Krammer, Lange-Bertalot et Schiller; (KUZMIN et al. 2009, Pl. 107, Figs. 1–6)
Miosira jouseana (Moisseeva) Krammer, Lange-Bertalot et Schiller; (KHURSEVICH and KOCIOLEK 2012, p. 347)
Alveolophora jouseana (Moisseeva) Moisseeva; (USOLTSEVA et al. 2013, p. 114)

Frustules round in valve view, diameter 7–20 µm. Areolae on the valve face often located over the entire surface, scattered or isolated as a ring near the margin (Figs. 5 H–K, 6 A–B, C, E). Frustules – short cylinders, 7–10 µm height, with robust costae (3–5 in 10 µm) on the valve mantle. Separating spines pointed (Fig. 7 B). Areolae on the mantle circular, situated in straight rows, 8–12 in 10 µm. Collar short with small ribs, not high (Figs. 7 A–C). Ringleiste varied from deep to shallow, dependent upon the valve diameter (Figs. 5

Tab. 1. List of diatom taxa from the sediment sequence of the Abramová-Kolísky profile with their relative abundance. Range: Ol – Oligocene; Mi – Miocene; eMi – Early Miocene; IMi – Late Miocene; PI – Pliocene; ePl – Early Pliocene; Plei – Pleistocene; R – recent. Abundance: 2 – rare; 3 – frequent; 4 – common; 5 – abundant; Ecology: habitat: pl – planktonic; ep – periphytic (epiphytic); d – periphytic (deep water form); halobity: hb – halophobous; i – indifferent; hl – halophilous; pH: ac – acidophilic; i – indifferent; alk – alkaliphilic; albnt – alkalibiontic; geographical distribution: n-a – north-alpine; c – cosmopolitan; b – boreal; tr – tropical.

DIATOMS	RANGE	Abundance						Ecology			
		Bottom	2 – 0.25 m	3 – 0.25 m	4 – 0.25 m	5 – 0.25 m	6 – 0.25 m	Habitat	Halobity	pH	Geographical distribution
***Alveolophora** jouseana* (Moiss.) Moisseeva, 1990	Mi-Pl	5	5	5	5	5	2	pl			
***Melosira** undulata* (Ehr.) Kützing, 1844	Mi-R	3	2	2		2		ep	i	i	tr
***Ellerbeckia** kochii* (Pant.) Moisseeva, 1992	eMi-lPl	3	3	3	2	3					
***Aulacoseira** granulata* (Ehr.) Simonsen, 1979	Ol-R	2	2	3	3			pl	i	alk	c
***Fragilaria** bituminosa* Pantoscek, 1889	lMi-Pl	3	3	3		2	2				
F. ulna (Nitzsch.) Lange-Bertalot, 1980	Ol-R	2		2				pl	i	alk	c
F. heidenii Oestrup, 1910	Pl-R			2				ep	i	alk	n-a
***Pseudostaurosira** brevistriata* (Grun.) Williams & Round, 1987	Ol-R	2						ep	i	alk	c
***Staurosira** construens* Ehrenberg, 1843	Ol-R	3		3				ep	i	alk	c
S. construens var. *binodis* (Ehr.) Hamilton, 1992	Mi-R	2						ep	i	alk	c
S. construens var. *venter* (Ehr.) Hamilton, 1992	Ol-R	2	3	3				ep	i	alk	c
***Staurosirella** grunowii* (Pant.) Morales, Buczkó & Ector, 2013	Mi	2		3		2					
S. leptostauron (Ehr.) Williams & Round, 1987	Ol-R	3	2	3		2		d	hb	alk	b
S. leptostauron var. *dubia* (Grun.) Edlund, 1994	Mi-R	3	3	4				ep	i	i	b
S. martyi (Hérib.) Morales & Manoylov, 2006	lMi-R	3	3	4	2			ep	i	alk	c
S. pinnata (Ehr.)Williams & Round, 1987	Ol-R	3	3	3	2			ep	i	alk	c
Staurosirella sp. 1 *(= Fragilaria magna* Hajós, 1985)	Mi	4	3	4	2	3	2	ep			
Staurosirella sp. 2		2	2	3	2	2					

DIATOMS	RANGE	Abundance						Ecology			
		Bottom	2 – 0.25 m	3 – 0.25 m	4 – 0.25 m	5 – 0.25 m	6 – 0.25 m	Habitat	Halobity	pH	Geographical distribution
Cavinula *scutelloides* (Smith) Lange-Bertalot, 1996	Mi-R	2		2				ep	i	albnt	c
Placoneis *gastrum* (Ehr.) Mereschkowsky, 1903	Mi-R	2						ep	i	i	c
*P. signata (*Hust.) Mayama, 1998	eMi-R		2					d	i	alk	c
Placoneis sp. 1				2							
Caloneis *schumanniana* (Grun.) Cleve, 1894	ePl-R	2	2					ep	i	alk	c
Diploneis *carpathorum* (Pant.) Pantocsek, 1913	lMi-ePl	2		2	2	3					
D. krammeri Lange-Bertalot & Reichardt, 2004	Mi-R	2	2	2				ep	i	alk	c
D. ostracodarum (Pant.) Jovanovska, Nakov & Levkov, 2013	Mi-R	3			2						
Diploneis sp.				2							
Cocconeis *neodiminuta* Krammer, 1991	Pl-R	3	2		2			ep	i	albnt	c
C. neothumensis Krammer, 1991	Plei-R		2	3					hb	alk	
C. placentula var. *euglypta* (Ehr.) Grunow, 1884	Mi-R	2		2				ep	i	alk	c
Planothidium *hauckianum* (Grun.) Round & Bukhtiyarova, 1996	Mi-R			2					hl	albnt	c
Eunotia *faba* Ehrenberg, 1838	eMi-R			2							
E. minor (Kütz.) Grunow, 1881	MI-R			2				ep	hb	ac	c
Encyonema *silesiacum* (Bleisch) Mann, 1990	eMi-R			2				ep	i	i	c
Amphora *buczkoae* Levkov, 2009	Mi	2	2	2	2						
Gomphonema *angustatum* (Kütz.) Rabenhorst, 1864	eMi-R			2				ep	i	alk	b
Gomphonema sp.		2									
Gomphosphenia *grovei* var. *lingulata* (Hust.) Lange-Bertalot, 1995	Mi-R			2							
Epithemia *cistula* (Ehr.) Ralfs in Pritchard, 1861	Mi-R		2								
E. turgida (Ehr.) Kützing, 1844	Mi-R			2				ep	i	albnt	c
Surirella *linearis* W.Smith, 1853	Plei-R				2			d	i	i	c

L, 8 A–C). Rimoportulae not observed in SEM, as frustules were more or less dissolved, but the channels of the rimoportulae was oblique and passed through the Ringleiste visible in LM (Fig. 5 L). Alveolae with a complex structure (3–5 in 10 µm) (Figs. 7 F–H).

The specimens of *Alveolophora jouseana* from the Abramová-Kolísky profile show slight differences in valve dimensions (the range of the height is 7–10 µm) relatively to those given in Moisseeva (1971). Despite these differences we feel confident in assigning all specimens we observed to the same taxon.

According to Usoltseva et al. (2013) the genus *Alveolophora* had a restricted distribution, found only in fossil localities in Asia and the Russian Far East, but in Khursevich and Kociolek (2012) the known stratigraphic range is from Oligocene (Czech – North Bohemia), Late Oligocene – Early Miocene (Sea of Japan), Early to Middle Miocene (Russia – Transbaikal area, Primorye), Middle Miocene (Belarus), Late Miocene (Bulgaria, West Kamchatka, Lake Baikal – bottom sediments).

The accompanying species are from the genus *Fragilaria* Lyngb. *sensu lato* (class Fragilariophyceae). The most interesting taxa are those that now belong to the genus *Staurosirella – S. grunowii* (Pant.) Morales, Buczkó, Ector, *S. leptostauron* (Ehr.) Williams et Round, *S. martyi* (Herib.) Morales et Manoylov. Alongside these are two very unusual forms that can be identified to genus level only (Figs. 9 E–H. 10 A–C). *Staurosirella* sp. 1 has valves with rhomboid to lanceolate shape, with broadly rounded apices. The central sternum is wide with lanceolate form. The valve dimensions are: length 13–45 µm, width 8–20 µm, striae 3–5 in 10 µm, parallel to slightly radial towards the apices. Apical pore fields are present at both apices, consisting of several rows of round poroids. A similar *Fragilaria* complex was determined by Hajós (1985) in Miocene sediments, Hungary, where she described the new species *Fragilaria magna* Hajós – extremely similar to *Staurosirella* sp. 1. *Fragilaria magna* was invalidly published as it lacked any description and was accompanied by only a few illustrations.

Diatom biostratigraphy

The results of diatom analysis have been synthesized in the form of a diagram of the species attaining relative abundance 4–5 according to Schrader's scale in at least one sample (Fig. 2).

One assemblage was distinguished in the development of the diatom flora in the investigated profile. In the lowermost part of the microlaminated sequence (bottom-sample 3) the diatom flora was rich and variable. This was the association of *Alveolophora jouseana, Aulacoseira granulata* and *Ellerbeckia kochii.* More of the frustules were joined into short chains. The class Coscinodiscohyceae was represented also by *Melosira undulata* as subdominant species. The lower diversity and abundance of the assemblage was observed above this interval (samples 4–6).

Several extinct species of stratigraphic interest were detected: *Alveolophora jouseana* (Moiss.) Moiss., *Fragilaria bituminosa* Pant., *Staurosirella grunowii* (Pant.) Morales, Buczkó & Ector, *Staurosirella* sp. 1 (= *Fragilaria magna* Hajós), *Diploneis carpathorum* (Pant.) Pant., and *Amphora buczkoae* Levkov. They can be considered as biostratigraphic markers for the beginning of the Late Miocene age (Late Pannonian s. str.) (Hajós 1985).

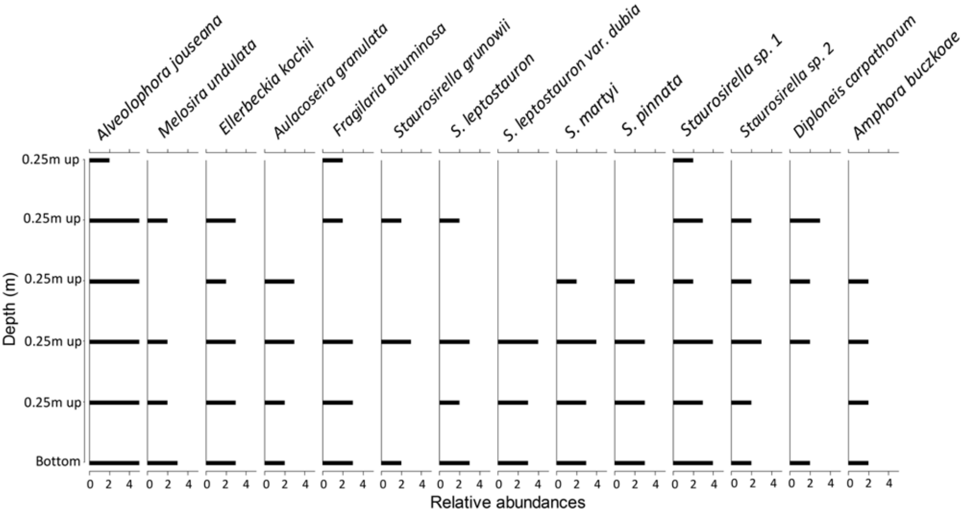

Fig. 2. Diatom diagram from a profile near the village of Abramová-Kolísky, showing the succession of the most common taxa.

Ecological analysis of the diatom flora

Ecological spectra were established for 28 taxa (66.7% of the determined diatom taxa). The results of ecological analysis are presented in the histograms (Fig. 3).

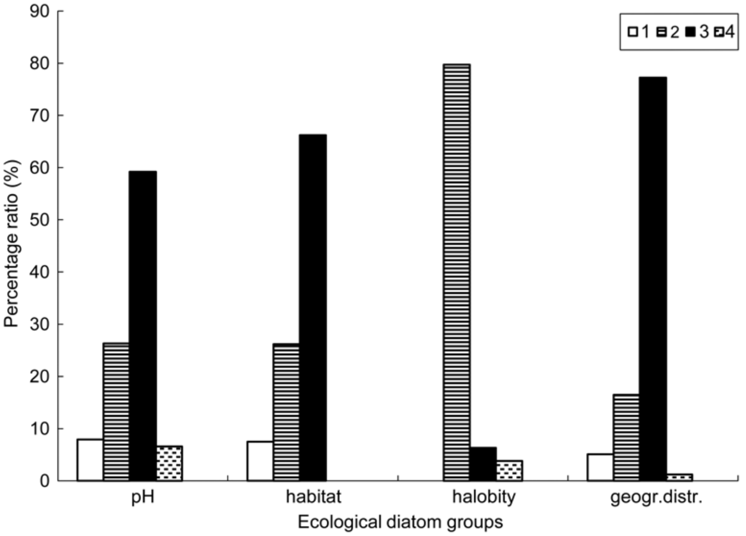

Fig. 3. Percentage ratio of the ecological groups diatoms. pH spectrum: 1 – acidophilic, 2 – indifferent, 3 – alkaliphilic, 4 – alkalibiontic; »Habitat« spectrum: 1 – planktonic, 2 – periphytic (deep water forms), 3 – periphytic (epiphytic); Halobion spectrum: 1 – halophobous, 2 – indifferent, 3 – halophilous; Geographical distribution: 1 – tropical forms; 2 – boreal forms, 3 – cosmopolitans, 4 – north-alpine forms.

Planktonic species formed 15.4–50% of the assemblage, especially in the uppermost part of the profile, where *Alveolophora jouseana* showed a massive appearance. Periphytic forms predominated, with epiphytic ones ranging from 50 to 78.9%, and benthic deep water forms ranging from 5.3 to 25%.

With respect to salinity, the oligohalobous indifferent species prevailed in the assemblage, ranging from 50 to 100%, with halophobous taxa accounting for 5.9 to 50%, while halophilous taxa (5.3%) were less abundant. *Staurosirella leptostauron* was a transient subdominant species of the halophobous group.

In relation to pH of the water, the content of alkaliphilic species ranged between 50 and 70.6%, and of indifferent ones between 15.8 and 50%. These two groups strongly dominated in the diatom flora. The content of acidobiontic forms ranged from 0–5.2%, and of alkalibiontic forms from 0–20%. Only one acidophilic species was present: *Eunotia minor.*

In biogeographical distribution, the abundance of cosmopolitan taxa predominated in the assemblage (72.2 to 100%), followed by boreal (11.8 to 50%), tropical (5.6 to 50%), and north-alpine (only 5.6%).

Relative proportions of diatom frustules and chrysophycean stomatocysts

Tracing the ratio of diatom frustules/chrysophycean stomatocysts only one peak in the development of the latter was determined (Fig. 4). Chrysophycean stomatocysts were most abundant at 1.00 m (22%); at the top of the profile there were only a few diatom frustules and the chrysophycean stomatocysts disappeared.

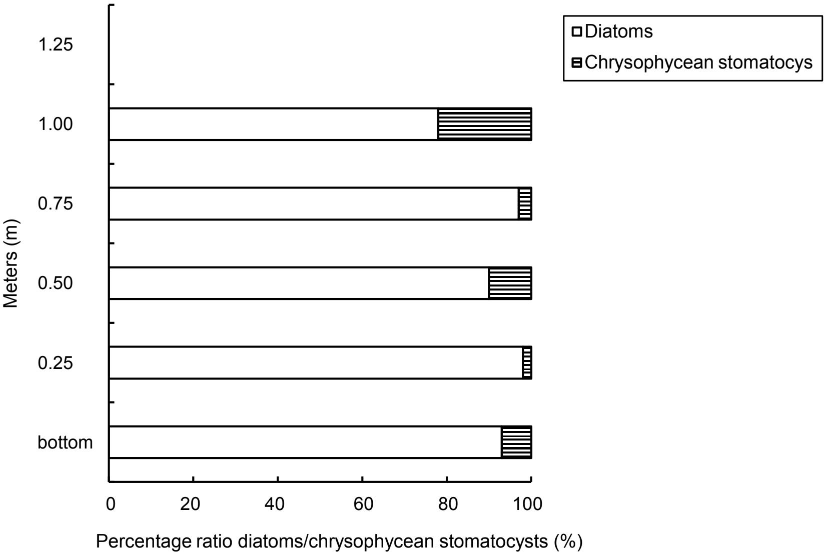

Fig. 4. Percentage ratio of the diatom frustules/chrysophycean stomatocysts.

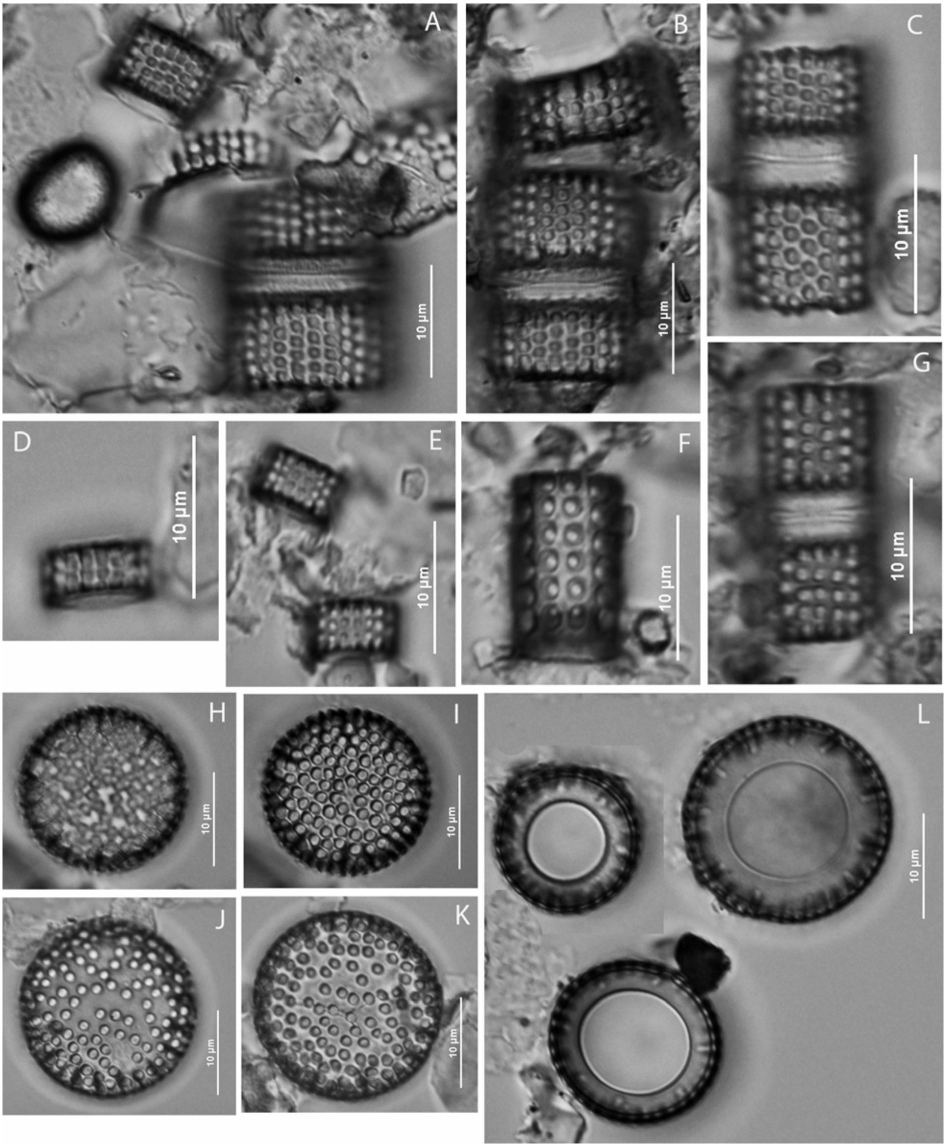

Fig. 5. *Alveolophora jouseana* (Moiss.) Moiss., light microscope images (A–L): external view of mantle (A–G), external view of valve face showing areolae position (H–K), external view of valve from the Ringleiste with channels of rimoportulae (L).

Discussion

This study integrates our work on diatom biostratigraphy. The dominant complex from the sediments of Turiec Basin is comprised of variable roughly silicified frustules of *Alveolophora jouseana*. During recent decades this species has been placed in various genera: *Melosira* Ag., *Alveolophora* Moiss. et Nevretd., *Miosira* Krammer, Lange-Bertalot et

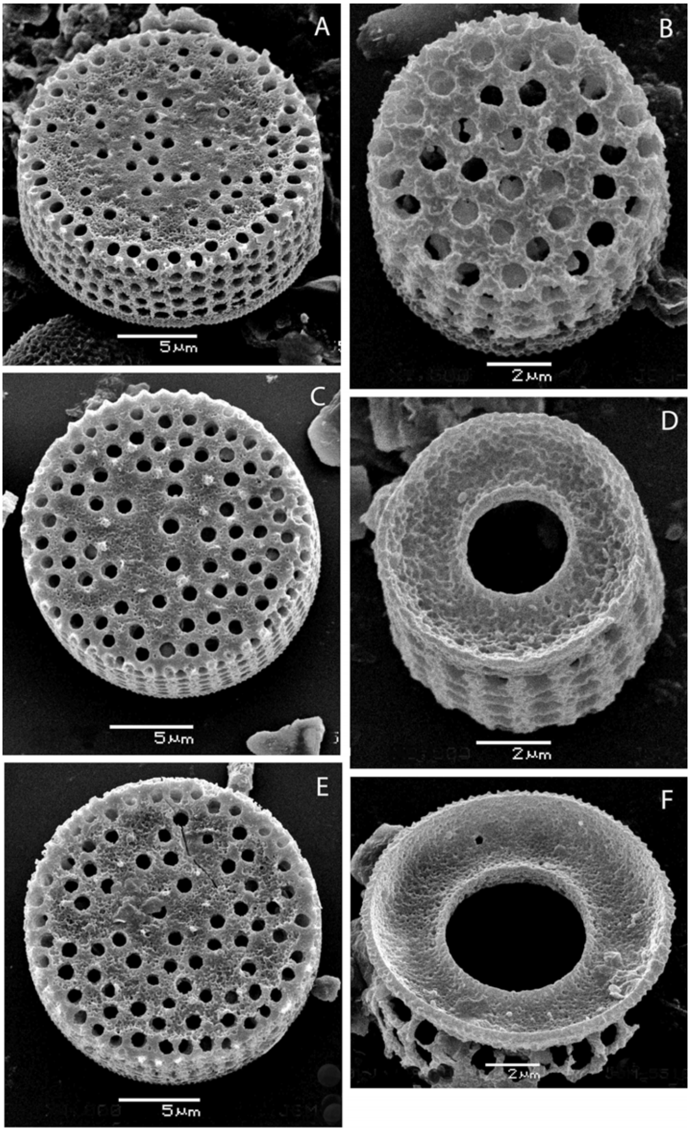

Fig. 6. *Alveolophora jouseana* (Moiss.) Moiss., scanning electron microscope images (A–F): external valvae face view (A–B, C, E), internal view of valve showing the Ringleiste (D, F).

Schiller and again *Alveolophora*. Pertinent taxonomic and morphological data for this taxon, the dominant diatom species, are reviewed and discussed.

Melosira jouseana Moisseeva was described from non-marine Miocene sediments from the Russian Far East (Moisseeva 1971). It was subsequently transferred by Moisseeva to the genus *Aulacoseira* Thwaites (Davidova and Moisseeva 1988) and then to a newly described genus – *Alveolophora* Moisseeva et Nevredtinova, which was introduced to a new family Aulacoseiraceae (Moisseeva and Nevredtinova 1990).

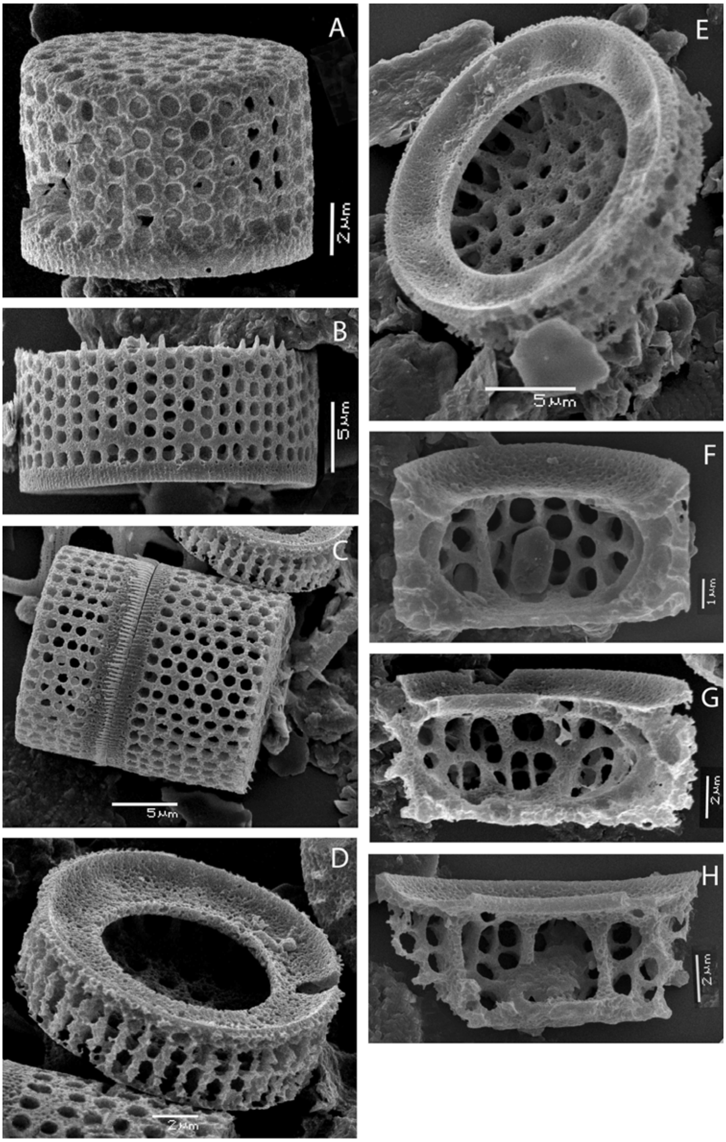

Fig. 7. *Alveolophora jouseana* (Moiss.) Moiss., scanning electron microscope images (A–H): external view of mantle (A, C), external view of mantle showing separating spines (B), internal view of valvae showing the Ringleiste (E), internal view showing valve with costae (F–H).

In 1997, KRAMMER et al. described the new genus *Miosira* Krammer, Lange-Bertalot et Schiller from non-marine diatomaceous sediments of Miocene age from Rüdenschwinden – a village of the eastern slope of the Hohe Rhön (Central Germany). In this study *Alveolophora jouseana* was transferred to *Miosira jouseana* (Moiss.) Krammer, Lange-Bertalot et Schiller. This new name has been cited in several publications without any further descriptions (KOZYRENKO et al. 2008, KUZMIN et al. 2009, KHURSEVICH and KOCIOLEK 2012).

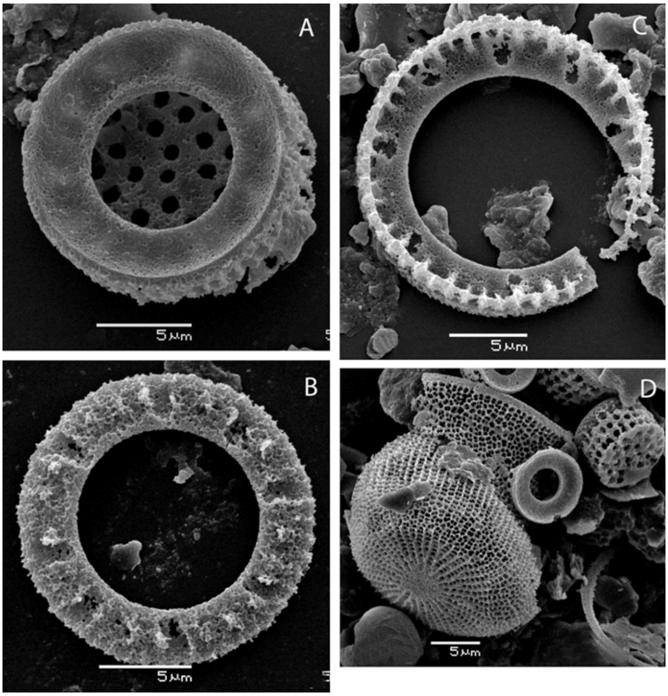

Fig. 8. Scanning electron microscope images (A–D): *Alveolophora jouseana* (Moiss.) Moiss., internal valve view showing different stages of dissoluted Ringleiste (A–C), *Melosira undulata* (Ehr.) Kütz., external valve view (D).

KRAMMER et al. (1997) showed that *Miosira* lacked rimoportulae and the type species possesses triangulate forms, features that make it different from all other species in *Alveolophora*. Similar triangulate forms were also established in abundant quantities from the Miocene sediments of Bes Konak Basin, Turkey (SERVANT-VILDARY et al. 1986). EDGAR and THERIOT (2004) suggested that the phylogeny of *Aulacoseira* may include *Miosira*, they noted that *Aulacoseira* sensu lato was a monophyletic group, then that *Miosira* must be included in *Aulacoseira*, and they provided some evidence to support this systematic placement. Recently three new species of genus *Alveolophora* were described from North America (USOLTSEVA et al. 2013). Comparison of the frustules morphology with the known members of the genera *Melosira/Alveolophora/Miosira* supported our decision to name the most abundant centric form from the investigated profile in Turiec Basin *Alveolophora jouseana* (Moiss.) Moiss.: these specimens possess the channels of the rimoportulae (Fig. 5 L), as well as complex alveolar structure on the internal surface of the valve mantle (Figs. 7 F–H). Our observations suggest that there may be several fossil species of the genus *Miosira/Alveolophora* but their taxonomy is far from being clear.

Several extinct species of stratigraphic interest are detected in the established diatom thanatocoenosis: *Alveolophora jouseana* (Moiss.) Moiss., *Fragilaria bituminosa* Pant., *Staurosirella grunowii* (Pant.) Morales, Buczkó & Ector, *Staurosirella* sp. 1 (= *Fragilaria magna* Hajós), *Diploneis carpathorum* (Pant.) Pant., and *Amphora buczkoae* Levkov. They can be considered as biostratigraphic markers for the beginning of the Late Miocene (Late

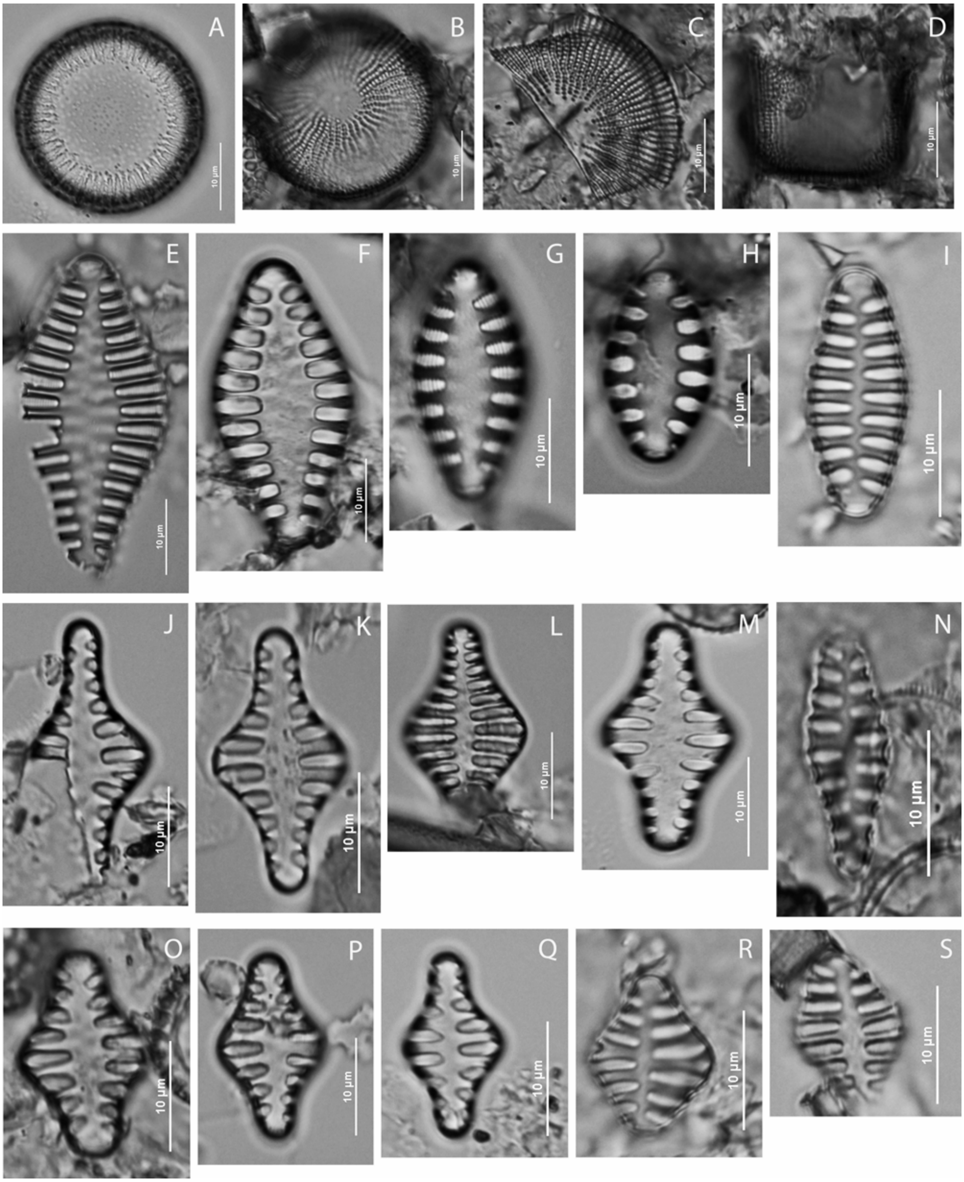

Fig. 9. Light microscope images (A–S): *Ellerbeckia kochii* (Pant.) Moiss. (A), *Melosira undulata* (Ehr.) Kütz. (B–D), *Staurosirella* sp. 1 (E–H), *Staurosirella leptostauron* var. *dubia* (Grun.) Edlund (I), *Staurosirella leptostauron* (Ehr.) Williams et Round (J–M, O–S), *Staurosirella martyi* (Hérib.) Morales et Manoylov (N).

Pannonian s. str.) age. The diatom assemblage studied from the Turiec Basin bears a strong resemblance to assemblages from the non-marine diatomaceous sediment of Miocene age from Rüdenschwinden, a village of the eastern slope of the Hohe Rhön (Central Germany) (Schiller 1994), non-marine sediments of early Late Miocene from the village of Szilagy

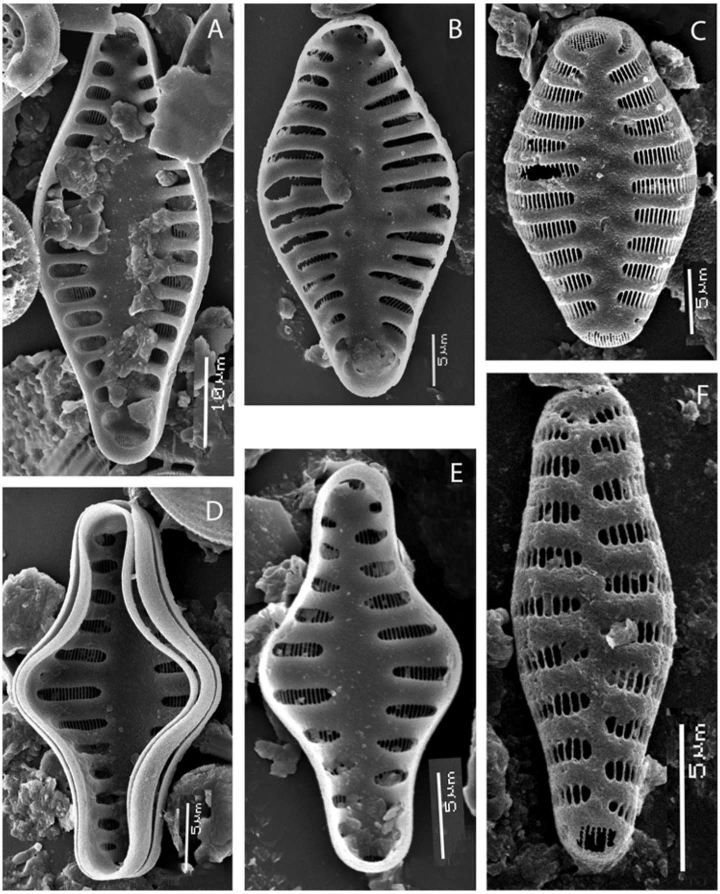

Fig. 10. Scanning electron microscope images (A–F): *Staurosirella* sp. 1, internal valve view (A–B), *Staurosirella* sp. 1, external valve view (C), *Staurosirella leptostauron* (Ehr.) Williams et Round, internal valve view (D–E), *Staurosirella martyi* (Hérib.) Morales et Manoylov (F).

(South Hungary) (HAJÓS 1985), as well as from Bes Konak Basin, Turkey (SERVANT-VILDARY et al. 1986). The above diatom assemblage shows strong differences to the Neogene diatom assemblages from the Balkan Peninsula (OGNJANOVA-RUMENOVA 2000, 2006).

The long-lived Turiec Basin was a large lake system with local development of alluvial fans, swamps and deep water areas (PIPÍK et al. 2012). According to the siliceous microfossils (diatoms and chrysophycean stomatocysts) the lake was large and the periphytic subdominants confirmed the development of a shallow littoral zone. The salt content ranged between 0.2–0.3‰. The active water reaction was neutral to slightly alkaline which corresponds to the results from geochemistry of the sediments. The temperature of the lake water was similar to those from the subtropical areas; a few tropical elements were presented. Further data could be derived from chrysophycean stomatocysts, which were common in the uppermost level of the sedimentary sequence, forming 22% of the total diatom-cyst assemblage. These organisms have been most abundant in low productivity lakes with circum-neutral pH, low alkalinity and low phosphorus (Ognjanova-Rumenova 2005). The ratios thus document a period of oligotrophic conditions.

Conclusions

This paper presents the first biostratigraphic data of siliceous microfossils from Turiec Basin, Slovakia. The fossil diatom flora consists of 42 species and varieties, belonging to 22 genera. The investigated profile is generally dominated by *Alveolophora jouseana*, and the subdominants belong to the genus *Staurosirella*. The established biostratigraphic diatom marker species suggest the beginning of the Late Miocene.

The results of the diatom analysis imply the existence of a large, alkaline shallow lake in Turiec Basin, which belonged to the subtropical climate area at the beginning of the early Late Miocene.

Acknowledgments

The manuscript was prepared with the help of bilateral agreements between the Bulgarian and Slovak Academies of Science: Joint Research project: BAS-SAS (2012–2014) »Ostracod-Diatomaceae paleoecologic and isotopic inference model for the Neogene freshwater and brackish lakes«. We also thank the Synthesys project HU–TAF–3690. Project FP 6 (Structuring the European Research Area Programme, http://www.synthesys.info/), Natural History Museum, Budapest, Hungary.

References

Abbott, W., H., Van Landingham, S., 1972: Micropaleontology and paleoecology of Miocene non-marine diatoms from Harper District, Malheur Country, Oregon. Nova Hedwigia 23, 847–90.

Davidova, N., Moisseeva, A., 1992: Genus *Aulacoseira* Thw. In: Gleser, S., Makarova, I., Moisseeva, A., Nikolaev, V. (eds.), Diatoms of the USSR – fossil and recent, 76–85. Nauka, St Petersburg.

Edgar, S., Theriot, E., 2004: Phylogeny of *Aulacoseira* (Bacillariophyta) based on molecules and morphology. Journal of Phycology 40, 772–788.

Ehrenberg, C., 1854: Mikrogeologie. Das Erden and Felsen schaffende Wirken des unsichtbar kleinen selbständingen Lebens auf der Erde. Leopold Voss, Leipzig.

Grunow, A., 1882: Beitrage zur Kenntniss der fossilen Diatomeen Osterreich-Ungarns. In: von Mojsisovics, E., Neumayr, N. (eds.), Beitrage zur Palaontologie Osterreich-Ungarns und des Orients 2, 136–159. Alfred Holder, Wien.

Hajós, M., 1985: Diatomeen des Pannonian in Ungarn. In: Papp, A. (ed.), Chronostratigraphie und Neostratotypen, Bd. VII: Miozan der Zentralen Paratethys, 534–585. Budapest.

Harzhauser, M., Mandic, O., 2008: Neogene lake systems of Central and South-Eastern Europe: Faunal diversity, gradients and interrelations. Palaeogeography, Palaeoclimatology, Palaeoecology 260, 417–434.

Khursevich, G., Kociolek, J. P., 2012: A preliminary, worldwide inventory of the extinct, freshwater fossil diatoms from the orders Thalassiosirales, Stephanodiscales, Paraliales, Aulacoseirales, Melosirales, Coscinodiscales, and Biddulphiales. Nova Hedwigia 141, 315–364.

Kováč, M., Hók, J., Minár, J., Vojtko, R., Bielik, M., Pipík, R., Rakús, M., Král, J., Šujan, M., Králiková, S., 2011: Neogene and Quaternary development of the Turiec Basin and landscape in its catchment: a tentative mass balance model. Geologica Carpathica 62, 4, 361–379.

Kozyrenko, T., Strelnikova, N., Khursevich, G., Tsoy, I., Yakovschikova, T., Mukhina, V., Olshtynskaja, A., Semina, G., 2008: The diatoms of Russia and adjacent countries. Fossil and recent. II, 5, Strelnikova, N., Tsoy, I. (eds), St. Petersburg University Press, St. Petersburg, Russia (in Russian).

Krammer, K., Lange-Bertalot. H., Schiller, W., 1997: *Miosira rhoenana* n. gen. n. sp. (Bacillariophyceae) aus miozänen limnischen Sedimenten der Rhön im Vergleich mit anderen zentrischen Diatomeen. Paläontologische Zeitschrift 71, 5–18.

Kuzmin, M., Khursevich, G., Prokopenko, A., Fedenya, S., Karanov, E., 2009: Centric diatoms in Late Cenozoic: morphology, systematics, stratigraphy and stages of development (based on deep cores of the Baikal drilling project). Academic Publishing House. Novosibirsk.

Moisseeva, A. 1971: Atlas of the neogene diatoms from the Primorsky Region. Nedra Press. Leningrad (in Russian).

Moisseeva, A. 1981: Revision of the freshwater diatom species, belonged to genus *Melosira* Ag. (Bacillariophyta). Workshop Proceeding: Taxonomy, evolution and ecology of algae and their importance in geological investigation, Kiev, 12–126. (in Russian).

Moisseeva, A., Nevredtinova, T., 1990: New family and new genus of non-marine diatoms (Bacillariophyta). Botanical Journal 75, 539–544 (in Russian).

Ognjanova-Rumenova, N., 1991: Neogene diatoms from sediments of Sofia Valley and their stratigraphic significance. Ph. D. Thesis, Geological Institute, Bulgarian Academy of Sciences (in Bulgarian).

Ognjanova-Rumenova, N., 2000: Lacustrine diatom flora from Neogene basins on the Balkan Peninsula: Preliminary Biostratigraphical data. In: Witkowski, A., Sieminska, J. (eds.), The origin and early evolution of diatoms: fossil, molecular and biostratigraphical approaches, 137–143. Krakow, Poland.

Ognjanova-Rumenova, N. 2005: Upper Neogene siliceous microfossils from the Pelagonia Basin, Balkan Peninsula. Geologica Carpathica 56, 347–358.

Ognjanova-Rumenova, N., 2006: Some aspects and problems concerning diatom biochronology for the Neogene in the region of the Balkan Peninsula. In: Witkowski, A. (ed.), Proceedings of the 18th International Diatom Symposium, Miedzyzdroje, Poland, 337–345. Biopress Limited, Bristol.

Ognjanova-Rumenova, N., Crawford, R., 2012: Morphology and ultrastructure of the fossil freshwater diatom *Aulacoseira temperei*. Diatom Research 27, 107–119.

Pantocsek, J., 1892: Beitrage zur Kenntnis der fossilen Bacillarien Ungarns. Teil 3. Susswasser Bacillarien. Anhang: Analysen 15 neuer Depots von Bulgarien, Japan, Mahren, Russlands und Ungarn. Buchdruckerei von Julius Platzko, Nagy-Tapolcsany.

PANTOCSEK, J., 1905: Beschreibung neuer Bacillarien, welche in der Parts III der 'Beitrage zur Kenntnis der fossilenBacillarien Ungarns' abgebildet wurden. Buchdruckerei C. F. Wigand, Pozsony.

PIPÍK, R., 2005: Upper Miocene freshwater ostracods (Ostracoda) of the littoral deposits of the Turiec Formation. Mineralia Slovaca 37, 27–40 (in Slovak).

PIPÍK, R., BODERGAT, A.-M., BRIOT, D., KOVÁČ, M., KRÁL, J., ZIELINSKI, G., 2012: Physical and biological properties of the late Miocene, long-lived Turiec Basin, Western Carpathians (Slovakia) and its paleobiotopes. Journal of Paleolimnology 47, 233–249.

ŘEHÁKOVÁ, Z., 1971: Changements qualitatifs des associations de diatomees dans les sediments tertiaires et quaternaires de Tchecoslovaquie. Bulletin de l'Association Francaise pour l'etude du Quaternaire, Supplement 4, 275–311.

ŘEHÁKOVÁ, Z., 1980: Süsswasserdiatomeenflora des oberen Miozäns in der Tchechoslowakei. Sbornik Geologickychved 23, 83–184.

ROUND, F., CRAWFORD, R., MANN, D., 1990**:** The Diatoms. Biology and morphology of the genera. Cambridge Univ. Press, Cambridge.

SCHILLER, W., 1994: Miozäne Diatomeen von der Guckas bei Rüdenschwinden/Rhön. Beiträge zur Naturkunde in Osthessen 29, 35–47.

SCHRADER, H-J., 1973: Proposal for a standardized method of cleaning diatom-bearing deep sea and land-exposed marine sediments. Nova Hedwigia 45, 403–409.

SERVANT-VILDARY, S., PAICHELER, J., C., SEMELIN, B., 1986: Miocene lacustrine diatoms from Turkey. Proceedings of the 9th International Diatom Symposium, 165–180.

SMOL, J., 1985: The ratio of diatom frustules to chrysophycean statospores: A useful paleolimnological index. Hydrobiologia 123, 199–204.

STACHURA-SUCHOPLES, K., WILLIAMS, D., 2009: Description of *Conticribra tricircularis*, a new genus and species of Thalassiosirales, with a discussion on its relationship to other continuous cribra species of *Thalassiosira* Cleve (Bacillariophyta) and its freshwater origin. European Journal of Phycology 44, 477–486.

USOLTSEVA, M., KOCIOLEK, J. P., KHURSEVICH, G., 2013: Three new species Alveolophora (Aulacoseiraceae, Bacillariophyceae) from Miocene deposits in western North America. Phycologia 52, 109–117.

WILLIAMS, D., KOCIOLEK, J. P., 2010: Classifications of convenience: the meaning of names. Diatom Research 25, 213–216.