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The extinct diatom species *Thalassiosira rugulosa* (Hajós) Ognjanova-Rumenova – typification and biostratigraphic significance

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Key words:
Bacillariophyta, Thalassiosira rugulosa comb. nov., fine morphology, typification, biostratigraphy, Fruška Gora, Serbia.

Abstract. *Thalassiosira rugulosa* (Hajós) Ognjanova-Rumenova is described and typified as a new fossil diatom combination belonging to the plicated group of the genus *Thalassiosira* Cl. Until now, these specimens had been identified in a series of biostratigraphic studies conducted in Hungary, Croatia, Serbia, and Romania under the name *Coscinodiscus rugulosus* Hajós. The presence of loculate areolae - open to the outside by foramina and internally occluded by slightly raised cribrum, as well as two types of processes, both rimoportula and fultoportulae, confirms its assignment to the genus *Thalassiosira* Cl.

Кључне речи:
Bacillariophyta, Thalassiosira rugulosa comb. nov., фина морфологија, типизација, биостратиграфија, Фрушка гора, Србија.

Апстракт. *Thalassiosira rugulosa* (Hajós) Ognjanova-Rumenova је описана и типизована као фосилна врста дијатомеја која припада пликативној групи рода *Thalassiosira* Cl. До сада су ови примерци идентификовани у низу биостратиграфских студија спроведених у Мађарској, Хрватској, Србији и Румунији под именом *Coscinodiscus rugulosus* Hajós (nom. nud.). Присуство локулатних ареола - отворених споља фораминама и изнутра затворених благо подигнутим крибрумом, као и две врсте наставка, и римопортула и фултопортула, потврђује њену припадност роду *Thalassiosira* Cl.

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Introduction

One plicated diatom, initially identified as a species of the genus *Coscinodiscus* Ehrenberg (*C. impressus* Hajós), was first mentioned in Hajós & Radósz (1971), appearing briefly in a table and a few illustrations. However, the absence of a formal description rendered this initial introduction invalid. The same name also appeared in another paper in the same volume (Gyarmati & Hajós, 1971).The first valid description, including illustrations, was later provided by Hajós & Řeháková (1974). Hajós (1985) subsequently reported the same taxonomic identification in her summary of Pannonian diatoms from Hungary, though without illustrations. This species was examined in sediments of the Edelény Formation (early Pannonian), Csákvár Formation (middle Pannonian), and Zala Mari Formation (Pannonian).

A new taxonomic name, *Coscinodiscus rugulosus* nov. nom. Hajós (pro *C. impressus* Hajós 1974), along with both light and scanning electron microscope illustrations, was established by Hajós (1986: Plate LVII, figs. 3–8) for material from the Mecsek area, derived from Sarmatian sediments. Since then, this name has been widely adopted in biostratigraphic studies across Romania (Pestrea, 1999), Croatia (Galović & Bajraktarević, 2006; Galović et al., 2017), and Serbia (Rundić et al., 2014).

During our investigation in the Filijala open pit (Fruška Gora Mt., Serbia), for the first time in this area, the sediments with siliceous microfossils – diatoms, silicoflagellates, ebridians and chrysophycean stomatocysts were found. Their finding, identification and biostratigraphical remarks were published previously (Rundić et al., 2014). Within the whole fossil assemblages the representatives of marine-brackish diatom flora (class Coscinodiscophyceae) are dominant. Among them, the index species of *Coscinodiscus rugulosus* Hajós is most abundant and it points the upper part of Sarmatian s.str. (Lower Bessarabian). The primary purpose of this paper is to provide the results of its taxonomic study and typification. For this purpose, observations have been made mainly on diatom specimens from the core B-11, which contains the most abundant representatives of *Coscinodiscus rugulosus* Hajós. Specimens investigated herein have processes, both rimoportula and fultoportulae. These specimens belong to a group characterized by loculate areolae – open to outside by a foramina, internally occludes by slightly raised cribra. The presence of these taxonomic features is a character of the family Thalassiosiraceae, to which the genus *Thalassiosira* Cl. belongs (Hasle, 1973).

The aim of this study was to reexamine the morphology and ultrastructure of *Coscinodiscus rugulosus* Hajós and to represent a new typification of this important component of the Miocene marine-brackish diatom flora within the Central Paratethys Sea.

Material and Methods

The northern field of the Filijala open pit (northern slope of Fruška Gora Mt., Serbia) contains only the Pannonian caspibrackish deposits. However, the area in which Sarmatian sediments were drilled is situated in the so-called southern field of the pit. Two exploration boreholes, B-11 and B-13, were drilled (Rundić et al., 2014). In borehole B-11, with a total depth of 53 m, Sarmatian deposits occur from a depth of about 20 m down to the end of the borehole at 53 m. These deposits are represented by gray-dark, laminated marls with interbeds of marly sandstones. Above them, typical light-gray, poorly bedded "Beočin marls," containing numerous ostracods and mollusks, were found. In borehole B-13, with a total depth of 19 m, below the Quaternary anthropogenic deposits consisting of remnants of former landfills, with a total thickness of 4 m, overlie similar poorly bedded Pannonian marls drilled to a depth of 7.6 m. Below these, in the lower part of the borehole down to 19 m depth, various Sarmatian sediments represented by striped dark-gray laminated marls, sandy marls, and diatomites were found.

Five samples from borehole B-13 (depth 11.03–12.55 m) and one-from borehole B-11 (depth 21.00 m) were analyzed. Diatom analysis was carried out by standard techniques (Ognjanova-Rumenova, 1991), which combined the methods of Schrader (1973) and Hasle & Fryxell (1970). Permanent microscope diatom slides were prepared with NAPHRAX® as a mountant and analyzed under oil immersion at

x1000 magnification with a Nikon Eclipse 80i light microscope with phase contrast (DIC) equipped with a the Nikon DS-Fi 1 camera. A total of 100 valves were measured from different samples in the sediment sequence. For scanning electron microscope (SEM) analyses, samples of cleaned material were dried onto aluminum stubs and coated with gold–palladium. SEM micrographs were produced on a JEOL JSM 5510 using accelerating voltages from 5–10 kV. Relative abundance of diatoms was defined according to Schrader's scale (Schrader, 1973).

The terminology used in the paper followed Anonymous (1975), Ross et al. (1979), Round et al. (1990), with a few additions from recent proposals Tanimura (1996), Julius & Tanimura (2001) and Stachura-Suchoples & Williams (2009).

Result

***Thalassiosira rugulosa* (Hajós) Ognjanova-Rumenova comb. nov.**

Figs. 1(a–j), 2 (a–h).

Basionym: *Coscinodiscus rugulosus* Hajós 1986, p. 117, pl. 57, figs 3–8 ≡ *Coscinodiscus impressus* Hajós in Hajós & Rehákova 1974: 551, pl. 1, fig. 18 non *Coscinodiscus impressus* Grunow in Van Heurck 1883: pl. 132, fig. 5.

Holotype: BP 685/9 (= "taf. 1, fig. 18, Süd-Ungarn, Mecsekgebirge, Hosszúhetény, Böhrung No. XII, 24,00-24,50 m.")

Synonyms: *Coscinodiscus impressus* Hajós in Hajós & Radócz 1971 ('1969'): 275, pl. 4, figs 4–8, *nom. nud.*; Hajós in Gyarmati & Hajós 1971 ('1969'): 462, *nom. nud.*

Additional material examined: Serbia, The southern field of the Filijala open pit (Fruška Gora Mt.), Diatomite, borehole B-13, Praep. B-13/ depth 11.03 m, – in Collection Nadja Ognjanova-Rumenova, Institute of Geology, Bulgarian Academy of Sciences.

Dimensions: 13–28 μm in long axis and 9–25 μm in short axis. Areolae arranged primarily in radial rows – 10–15 in 10 μm.

Description: Valvae usually with elliptical outline, some smaller specimens, however have circular to oval outline. The valve face with strong tangentially undulation. Areolae are small, circular in shape, organized into radial rows of striae, but in central plicated area appear slightly disorganized. Areolae loculate with crucial almost imperceptible foramina external and slightly raised cribra internal. Regularly spaced fultoportulae making a ring on the valve mantle, ~6 in 10 μm. Each fultoportula having an internal tube with four satellite pores and a circular external pore on a slight elevation. One rimoportula located on valve mantle closer to one fultoportula than to other. It is internally with a thin lipped flattened stalk, oriented parallel to the valve plain. Its external pore is on slight elevation. One to three central fultoportulae with four satellite pores located on both the externally raised part of the valve face. An irregular, and partial, ring of small coarse bumps are positioned on the boundary of the valve face and mantle. The girdle band is smooth composed of several copulae.

Known geologic range: Middle/Upper Miocene.

Habitat: Marine-brackish water.

Differential diagnosis: *Thalassiosira rugulosa* is characterized by the following distinct morphological features that clearly separate it from similar plicated taxa: smaller size dimensions; strong tangentially undulation of the valve face; finer areolae density; structure and position of the rimoportula; number and position of the subcentral fultoportulae.

Thalassiosira rugulosa can be associated with *Thalassiosira brunii* Akiba & Yanagisawa (Tanimura, 1996). However both species can be distinguished by several morphological structures – and in *Thalassiosira brunii* these characters are: presence of a marginal hyaline area, which is diagnostic for this species, as well as – one prominent rimoportula tube and regularly spaced fultoportula tubes on the externally raised size of valve mantle. *Thalassiosira temperei* (Brun) Akiba & Yanagisawa is much larger than *T. rugulosa* (63–99 μm in long axis and 25–30 μm in short axis vs. 13–28 μm in long axis and 9–25 μm in short axis), with moderate undulation of the valve face, the areolae density is rougher – 4–7 radial rows in 10 μm, the rimoportula is with a thick lipped internal aperture and a long external tube.

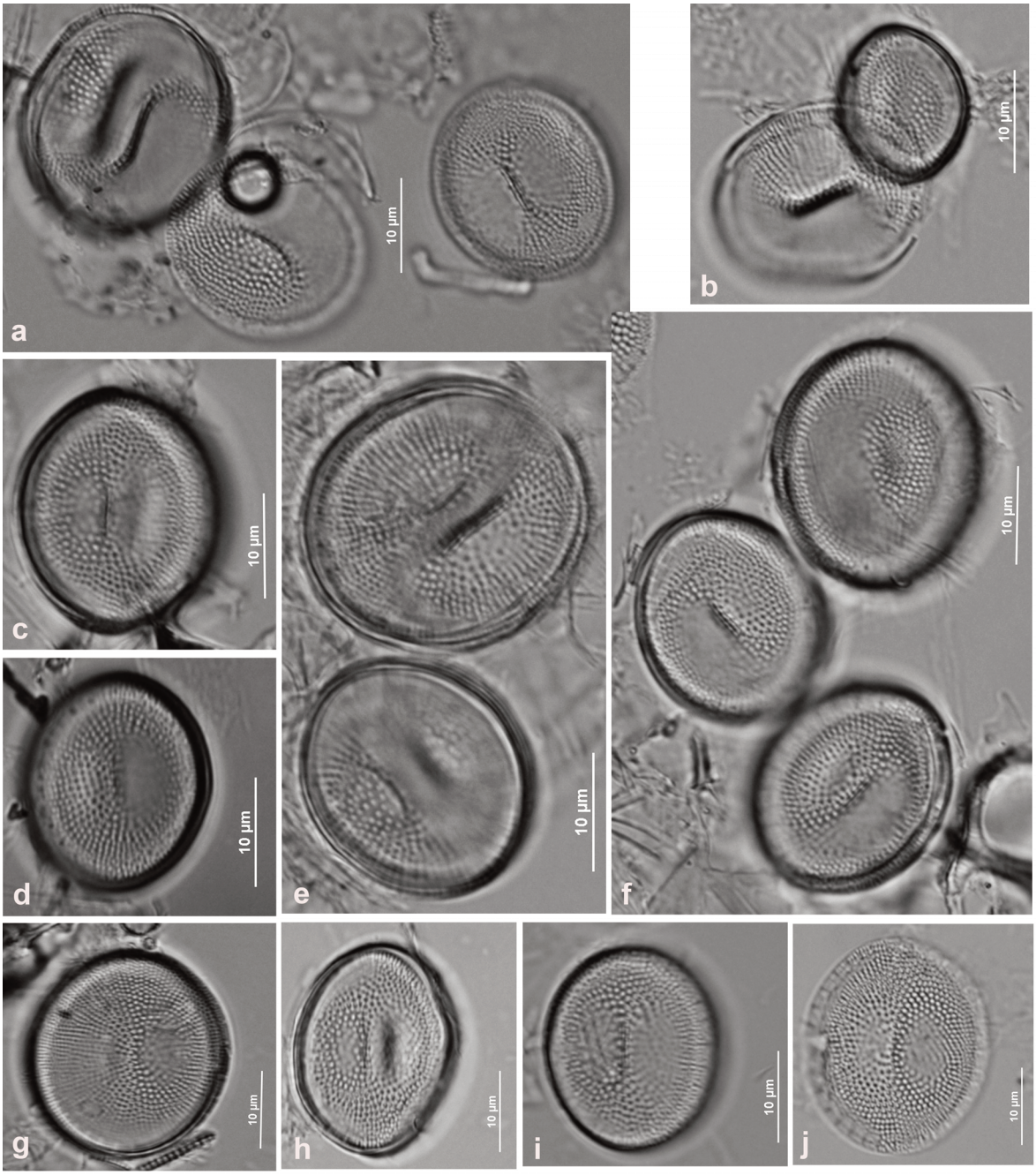

Fig. 1. *Thalassiosira rugulosa (Hajós) Ognjanova-Rumenova* comb. nov. *All LM (light microscope).* ***a–c; e–j)*** *Specimens from the type population, Fruška Gora, Serbia, Core B-13, depth 11.03 m; Scale bars a–j = 10 µm.*

Discussion

According to Makarova (1988) and Glezer et al. (1988) four sections were delineated within the genus *Thalassiosira* Cleve, primarily on the basis of areolation pattern: Tangentales (type species: *Thalassiosira eccentrica* (Ehrenberg) Cleve), Fasciculigera (type species: *T. baltica* (Grunow in Cleve & Grunow) Ostenfeld), *Thalassiosira* (type species: *T. nordenskioeldii* Cleve), and Inconspicuae (type species: *T. condensata* Cleve). A total of 25 species were assigned to the section Tangentales, characterized by the following features: areoles arranged in straight or tangentially curved rows; a single ring of marginal fultoportulae; typically one valve-face fultoportula (rarely more), scattered across the central area; and one (occasionally two or more) rimoportula, usually positioned at the valve face–mantle junction.

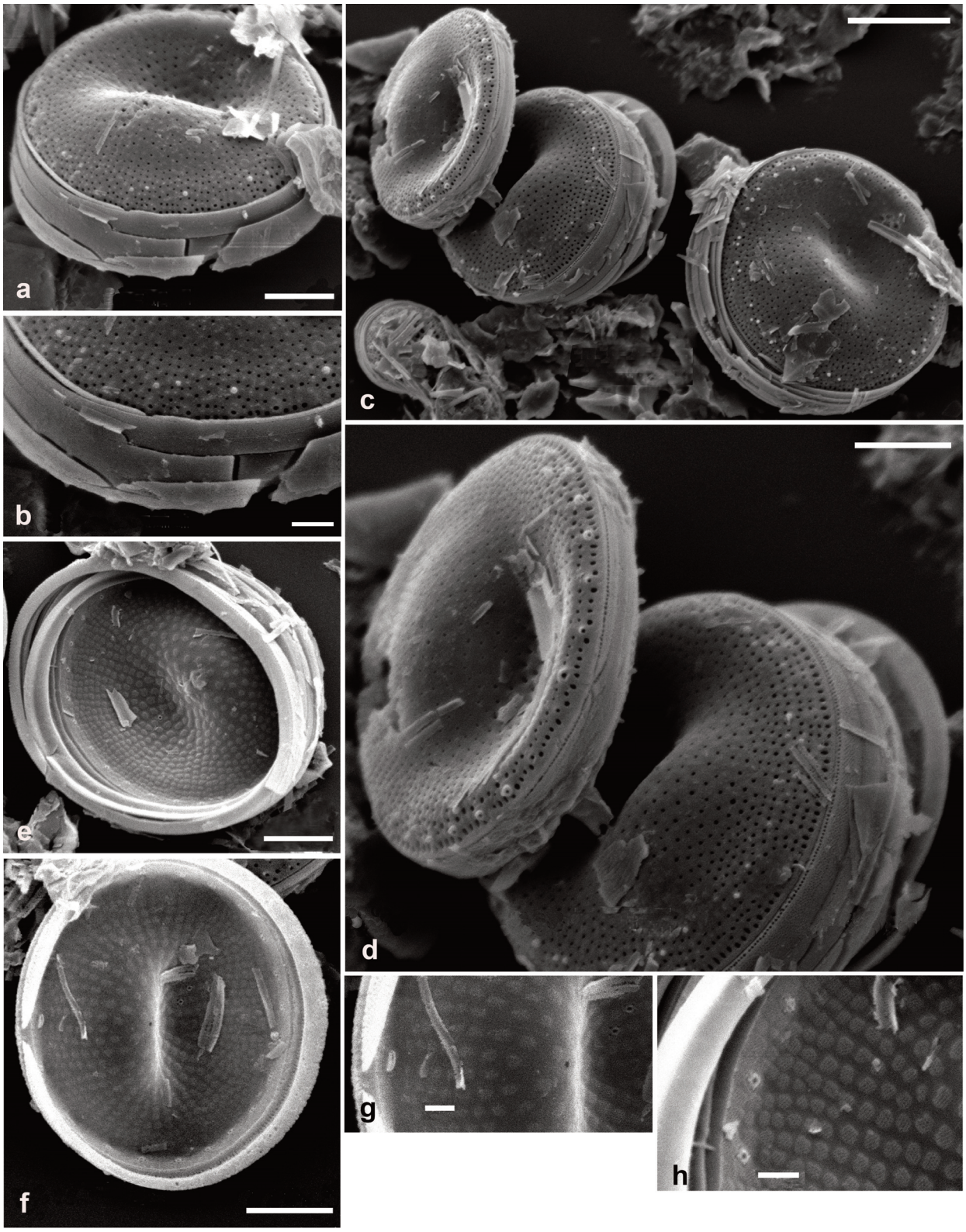

Fig. 2. *Thalassiosira rugulosa (Hajós) Ognjanova-Rumenova* comb. nov. *All SEM (scanning electron microscope);* ***a, c, d)*** *Outside view of the whole valve;* ***d)*** *Valve margin with external openings of the marginal fultoportulae and external opening of the rimoportula; Scale bars: a, d = 5 µm; c = 10 µm;* ***b)*** *Detail showing marginal area with external openings of the fultoportulae, the bamps on the boundary of the valve face and mantle, the girdle band composed of several copulae; Scale bar = 2 µm;* ***e, f)*** *Inside view of whole valve; Scale bars: = 5 µm;* ***g)*** *Detail showing a thin lipped flattened stalk, oriented parallel to the valve plane; Scale bar = 1 µm;* ***h)*** *Detail showing the ring with the marginal fultoportulae having an internal tube with four satellite pores; Scale bar = 1 µm.*

Among the representatives of section Tangentales, none of the 25 species examined exhibits a tangential undulation as pronounced as that observed in *Thalassiosira rugulosa*.

Almost contemporaneously with this taxonomic framework for species delimitation within the genus *Thalassiosira*, Hasle & Lange (1989) proposed a new approach based on two key morphological characters: valve face undulation and cribrum structure. This concept was further developed by Tanimura (1996) and Julius & Tanimura (2001), who classified species into plicated and non-plicated forms, and additionally recognized ecological groupings corresponding to marine versus brackish and freshwater environments.

The Miocene represents a critical interval in the phylogenetic development of marine plicated *Thalassiosira* species (Tanimura, 1996; Julius & Tanimura, 2001). The relatively narrow stratigraphic ranges and distinctive morphological features of fossil plicated *Thalassiosira* taxa render them particularly valuable as biostratigraphic indicators in Neogene marine sequences. Tanimura (1996) compiled comprehensive data on the fossil record and phylogeny of marine, plicated *Thalassiosira* species. He proposed that several morphological features consistently characterize these taxa, including distinctly plicated valve faces, a single prominent marginal rimoportula, scattered fultoportulae on the valve face, and a single ring of marginal fultoportulae. All species examined by Tanimura (1996), both extinct and extant, possess individual cribra. With the exception of *Thalassiosira temperei* (Brun) Akiba & Yanagisawa (Miocene–Pliocene) and *T. sancettae* Akiba (Miocene–Pleistocene), extinct species are largely confined to the Miocene. The taxa investigated by Tanimura (1996) collectively span a stratigraphic range from approximately 17 to 0 Ma.

The phylogenetic study by Julius & Tanimura (2001) analyzed 19 *Thalassiosira* species (the so-called 'plicated *Thalassiosira*') using cladistic methods, covering a time span from 17 million years ago to the present. Two most-parsimonious evolutionary trees were identified, both largely consistent with the fossil record. The results support the validity of all examined species under the phylogenetic species concept and highlight key diagnostic traits. The group appears to form a natural lineage with at least two major clades corresponding to previously proposed morphological subgroups, suggesting that the plicated *Thalassiosira* could potentially be reclassified into one or two separate genera. Several previously described species are confirmed as distinct evolutionary units, and the evidence indicates that additional, as-yet-undiscovered species likely exist in the fossil record. These findings underscore the need for further studies of the established fossil diatom flora, not only for biostratigraphic and paleoecological purposes. Much of the rich species diversity recorded in the Neogene marine-brackish sediments of Central and Eastern Europe remains unrevised or is held in collections that are poorly curated.

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Резиме

Изумрла врста дијатомеја *Thalassiosira rugulosa* (Hajós) Ognjanova-Rumenova – типизација и биостратиграфски значај

Пликативна дијатомеја, првобитно описана као *Coscinodiscus impressus* Hajós (1974), касније је преименована у *Coscinodiscus rugulosus* nov. nom. Hajós (1986) на основу светлосне и скенирајуће електронске микроскопске анализе седимената сарматске старости из подручја Мечек у Мађарској. Иако је ово име касније наведено у више биостратиграфских студија у Румунији, Хрватској и Србији, оно је неважеће, јер је уведено без довољно илустрација, формалних описа или ознаке типског примерка.

У овом раду, *Thalassiosira rugulosa* (Hajós) Ognjanova-Rumenova comb. nov је формално описана и типизована као врста фосилних дијатомеја унутар пликативне групе рода *Thalassiosira* Cl. Примерци који су раније били додељени нева-

жећем таксону *Coscinodiscus rugulosus* Hajós (nom. nud.) и коришћени широм Мађарске, Хрватске, Србије и Румуније сада су признати под овим валидним таксоном. Врсту карактеришу локулатне ареоле - споља отворене кроз форамине и изнутра затворене благо подигнутим крибрумом - заједно са две врсте наставака, римопортуле и фултопортуле, што потврђује њено сврставање унутар рода *Thalassiosira* Cl.

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