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Cymbella schmidtii Grunow transferred to *Cymbopleura schmidtii* (Grunow) Stenger-Kovács nov. comb. - a rare diatom species occurring in Lake Balaton (Hungary)

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NOTE

Cymbella schmidtii Grunow transferred to *Cymbopleura schmidtii* (Grunow) Stenger-Kovács nov. comb. – a rare diatom species occurring in Lake Balaton (Hungary)

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Taxonomic guides to a rare diatom species, *Cymbella schmidtii* Grunow, were reviewed because of a number of misunderstandings and insufficient documentation of this species. Accurate and detailed taxonomic features were described based on morphology (in light microscopy) and fine structure (in scanning electron microscopy), and the species was transferred to another genus, *Cymbopleura* (Krammer) Krammer. Not only were the morphological features clarified, but also the species distribution and occurrence as well. Cells of *Cymbopleura schmidtii* Stenger-Kovács nov. comb. occur as solitary individuals. The species was found in the littoral region of Lake Balaton (Hungary). It is not abundant, but is a characteristic diatom species of the lake, and is not restricted only to recent samples, but occurs also in fossil materials.

Keywords: *diatom,* Cymbopleura, *morphology, lake, Water Framework Directive*

Introduction

Lake Balaton has specific features compared with other Hungarian shallow lakes: not only is its surface area larger than that of others, but it also has a remarkably large number of species and diversity of diatoms, which was already obvious in the nineteenth century (Istvánffy 1897). Although there were some fundamental studies on Lake Balaton diatom flora in the last century by Pantocsek (1902), Szemes (1957), Tamás & Gellért (1958) and Tamás (1963), our knowledge is sporadic, both in space and time. The paleolimnological study of Buczkó et al. (2005) on a collection by Márta Hajós provided a detailed species list for the lake.

After initiation of the Water Framework Directive, diatoms gained special interest as they proved to be potential indicators of environmental changes (e.g., Ács et al. 2005; Stenger-Kovács et al. 2007). This is why the taxonomical identification of species is very important because it is the basis of ecological analyses.

A rare, but characteristic species of Lake Balaton, *Cymbella schmidtii* Grunow, appears in samples from time to time. Although the original illustration by Grunow (Schmidt et al. 1874–1959) and the text description of the species provided by Cleve (1894) are clear, several mistakes can be found in other publications regarding its morphological features, taxonomic status and distribution (Pantocsek 1902, Gallik 1926, 1935). Furthermore, diatom taxonomy has evolved in recent decades.

In 1982, Krammer described a new subgenus under the genus *Cymbella* (Krammer 1982) which belongs to the large genera in the Naviculaceae. Validation of the *Cymbopleura* genus was proposed by Krammer in 1997, but was only validated by Krammer in 1999 (Lange-Bertalot & Genkal, 1999). The genus *Cymbopleura* is a symmetric or slightly asymmetric taxon with dorsally bent apical raphe without stigmata or stigmoids and with terminal pore fields. Therefore, these mostly free-living forms never produce stalks and colonies (Krammer 2003). Diatoms in this genus have only rarely been reported in the literature or found in different databases.

The aims of this article is to: (1) overview and analyse information and data about *Cymbella schmidtii*; (2) re-analyse the morphological parameters of the species based on light microscopy (LM) and scanning electron microscopy (SEM); (3) transfer the species to the right genus according to recent taxonomy; and (4) clarify the distribution of the taxa.

Material and methods

Lake Balaton was formed by tectonic forces and subsequent erosion some 12,000–20,000 years ago. Owing to its shallowness and intense wind, the lake is polymictic with characteristically low transparency. Macrophytes (mostly *Phragmites* sp.) are restricted to the narrow shoreline region, covering only 3% of the lake surface because red sandstones used for shoreline protection prevent the development of thick *Phragmites* stands. The water level is regulated, and the theoretical residence time is 2–7 years.

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The catchment area (5181 km^2) of this meso-eutrophic lake consists of 51 inflows, and the only outlet is the Sió channel constructed in the 1860s to regulate the water level.

In August 2005, 53 diatom samples were collected from three different substrata in the littoral region of the lake: reed (21 samples), mud (19 samples; largely epipsammon on the southern shoreline and epipelon on the northern) and pier (artificial substrata; 13 samples). After this preliminary study, intensive investigation started in 2006: ten sites of the lake are investigated every second or third week (five on the northern shoreline and five on the southern shoreline). These samples were collected from reeds. The detailed list, in which the *Cymbopleura schmidtii* was found is given in Table 1.

Diatom samples were cleaned with hot hydrogen peroxide (35%) and hydrochloric acid. Cleaned material was mounted in Pleurax. At least 400 valves were counted for each sample and the relative abundance of the species was calculated (Table 1). Diatom species were identified using Zeiss Imager A1 light microscopy, Plan-apochromat 1.4 Oil Dic object-lens with AxioCam Mrc 5 camera. Scanning electron microscopy was performed with a Hitachi S-2600N. The morphological analyses followed the guide of Barber & Haworth (1981).

Water sampling for further laboratory analyses (chemical oxygen demand, P and N amounts) and in situ measurements (dissolved oxygen, conductivity and pH by Consort 535) were carried out simultaneously with diatom sampling. Using international and national standards (Marczenko 1976, Inczédy 1996, Németh 1998), NO_2^-, NO_3^-, NH_4^+, PO_4^{3-} and TP were determined using spectrophotometry. The mean of the measured parameters over the two years was similar (Table 2), and represents the recent general status of the lake.

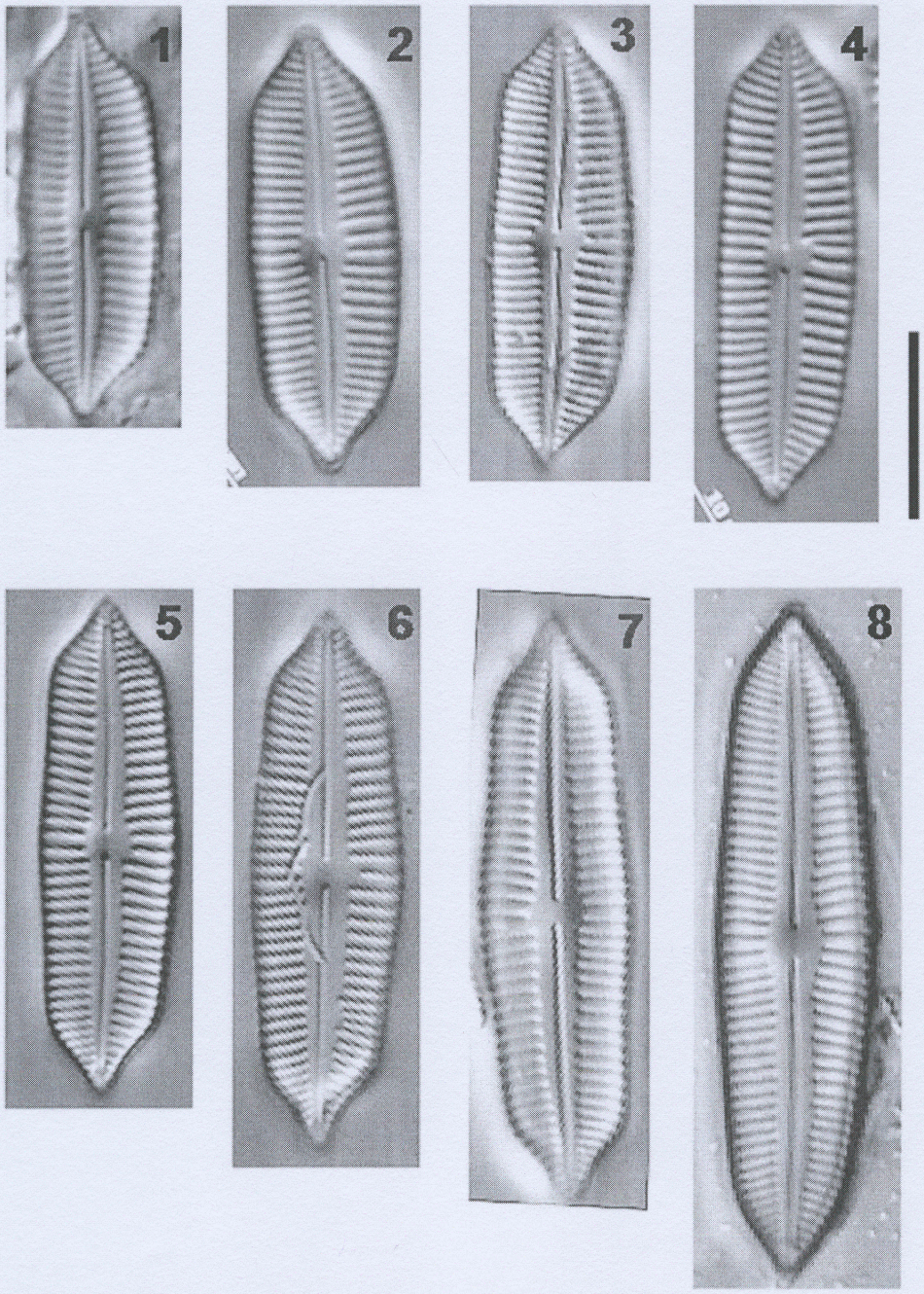
Grunow slide collection 1623 Van Hauck No.159, from Herbarium W of the Natural History Museum,

Table 1. Relative abundance (%) of *Cymbopleura schmidtii*, sampling sites and their coordinates, substrate type, sampling date and the archive code of slides and cleaned materials.

Code	Relative abundance (%)	Date	Substrate type	GPS coordinates	Site
LIM_IX/612	0.7	29.08.2005	Mud	46°57′51″	2b Siófok
LIM_IX/613	0.2		Pier	18°02′20″	2c Siófok
LIM_IX/616	0.2	29.08.2005	Reed	46°50′74″	4a Balatonaliga
LIM_IX/617	**3.5**		**Mud**	18°09′74″	4b Balatonaliga
LIM_IX/618	1		Boat		4c Balatonaliga
LIM_XVII/779	0.2	18.03.2006	Reed	46°57′51″	BD2 Zamárdi
LIM_XII/799	0.7	17.04.2006		18°02′20″	
LIM_XV/897	0.5	10.10.2006			
LIM_XV/908	0.3	02.11.2006			
LIM_XVI/938	0.2	08.01.2007			
LIM_XVII/976	0.2	12.03.2007	Stone		
LIM_XIV/856	0.2	15.07.2006	Reed	47°02′24″ 18°04′99″	BD1 Balatonkenese
LIM_XVII/787	0.2	18.03.2006	Reed	46°57′96″ 17°55′68″	BÉ5 Csopak
LIM_XV/909	0.2	02.11.2006	Reed	46°52′72″	BD3 Szántód
LIM_XVII/973	0.2	12.03.2007		17°54′14″	
LIM_XVII/989	0.2	02.04.2007			

Table 2. The annual values of physical and chemical parameters (BDL: below detection limit) in the type locality of the species (Lake Balaton, Siófok basin).

	PO_4^{3-}-P ($\mu g\,L^{-1}$)	TP ($\mu g\,L^{-1}$)	NO_3^--N ($mg\,L^{-1}$)	NO_2^--N ($mg\,L^{-1}$)	NH_4^+-N ($mg\,L^{-1}$)	COD ($mg\,L^{-1}$)	pH	Conductivity ($\mu S\,cm^{-1}$)	dissolved O_2 ($mg\,L^{-1}$)
2006									
Mean	7.5	83.4	0.5	0.1	0.1	7.6	7.8	520	14.7
SD	6.4	78.4	0.2	0.0	<BDL	0.9	0.4	136	3.0
Min	<BDL	<BDL	0.2	0.1	<BDL	5.7	6.5	230	6.8
Max	34.8	460.7	1.0	0.3	0.2	11.1	8.8	770	16.4
2007									
Mean	9.8	97.7	0.6	0.1	0.2	14.7	8.1	614	11.3
SD	4.7	96.8	0.3	0.1	0.1	4.2	0.3	88	2.1
Min	<BDL	5.4	<BDL	<BDL	<BDL	<BDL	7.1	350	7.6
Max	25.9	1371.4	2.5	0.6	0.5	53.6	8.7	850	15.3



Figs 1–8. *Cymbopleura schmidtii* in Lake Balaton, LM. Scale bar = 10 μm.

Vienna, Austria and the following slides from the diatom collection of the Department of Limnology, University of Pannonia, were studied: LIM_IX/612, LIM_IX/613, LIM_IX/616, LIM_IX/617, LIM_IX/618, LIM_XII/779, LIM_XIV/856, LIM_XV/897, LIM_XV/909, LIM_XV/908, LIM_XVI/938, LIM_XVII/779, LIM_XVII/787, LIM_XVII/976, LIM_XVIII/973.

Observations

According to Cleve (1894), the valve of *Cymbella schmidtii* is 'almost symmetrical, broadly linear, with triundulate margins and cuneate ends. Length: 0.026; Breadth: 0.009 mm. Median line almost central, slightly flexuose. Axial and central area indistinct. Striae about 14 in 0.01 mm slightly radiate'. Nevertheless, the structure and morphological features agree with the typical *Cymbopleura* structure (raphe similar to *Cymbella* spp., stigmata and pore fields always absent, valves having usually more naviculoid outline than dorsiventral), as described in Krammer (2003). Therefore, for this reason the species was transferred to the *Cymbopleura* and its detailed description was added.

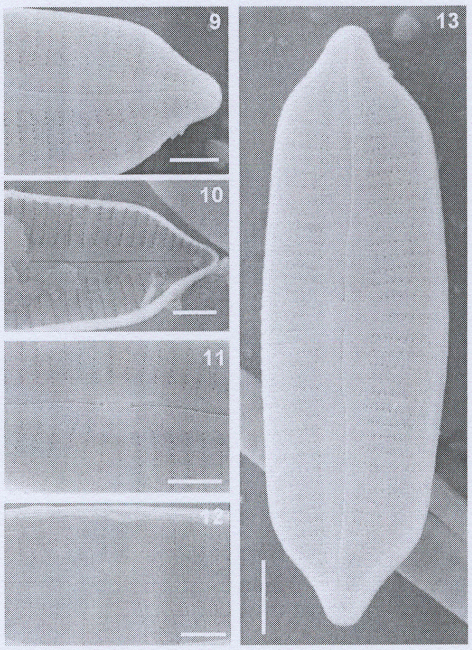
Cymbopleura schmidtii (Grunow) Stenger-Kovács nov. comb. (Figs 1–13, 21)

Basionym: Cymbella schmidtii Grunow 1875 sp. nov. fig. 22. in Schmidt et al. 1874–1959, fig. 9: 48

Symonyms: Cymbella schmidtii Grunow, fig. 14 in Pantocsek, 1902; *Cymbella reducta* Pantocsek, fig. 15 in Pantocsek, 1902; *Cymbella reducta* var. *tumida* Pantocsek fig. 16 in Pantocsek, 1902; *Cymbella schmidtii* Grunow fig. 21 in Hajós photo collection; *Navicula integra* (W. Smith) Ralfs, fig. 23 in Gallik, 1935.

The solitary cells lie in valve view. Benthic, unattached, free-living freshwater diatom species.

Description in LM and SEM. Medium-sized valves with elliptical–lanceolate outline. Poles apiculate. Length 22–36 μm, breadth 7–9 μm ($n = 32$). Maximum length/breadth ratio 4.2. Axial area lanceolate and slightly widening to central area (Figs 1–8; 13). Central area small, smaller than 1/5 the valve breadth and round sometimes somewhat asymmetrical. Raphe slightly lateral, bent a bit to the dorsal side (Figs 1–8). Proximal raphe endings with only weakly expanded pores, sometimes ventrally tipped (Figs 11, 13). Externally, terminal raphe endings (a terminal fissures) dorsally deflected (Figs 9, 12). Internally, proximal raphe endings are simple, terminating in a slightly raised central nodule (Fig. 12); an intermission is present. Striae slightly curved around the central area and slightly radiate throughout (Figs 1–13). Striae uniseriate; puncta visible only in the SEM (Figs 9–13). Striae 13-17/10 μm, puncta 40/10 μm (Figs 1–13).



Figs 9–13. SEM *Cymbopleura schmidtii*. **Fig. 9.** External view of the apex. **Fig. 10.** Internal view of the apex. **Fig. 11.** External view of the central area. **Fig. 12.** Internal view of the central area. **Fig. 12.** External view of the species. Scale bars = 2.5 μm (Figs 9–11); 5 μm (Fig. 12).

Distribution: Lake Balaton, Hungary.

Lectotype: Grunow slide collection 1623 Van Hauck No.159 (Fig. 24), Herbarium W, Natural History Museum, Vienna; the valve as Fig. 25.

Locus typicus: Lake Balaton, Hungary.

Distribution and ecology

The *Cymbopleura* species published by Krammer (2003) were found mostly in oligotrophic or oligo-mesotrophic waters with low or moderate electrolyte content from the Alps to the plains in Nordic and subarctic regions. Most were reported from stones or fossil materials. A number of *Cymbopleura* taxa are known only from the type locality, where the species is abundant (Krammer 2003). *Cymbopleura schmidtii* appeared in a meso-eutrophic, freshwater lake (Table 2) and the species was found to be the most abundant in sandy lake sediments (Table 1). Therefore, the species is considered epipsammic. In this sense, the eastern part of Lake Balaton (Siófok basin) provides a particularly appropriate habitat for the species, because it is

characterized as lower in organic material and carbonate content than other parts of the lake and the water is mesotrophic (Csermák & Máté 2004). The lake's oxidized sediment exhibits oligotrophic characters although the water is characterized as meso-eutrophic.

Discussion

Cymbella schmidtii *and its taxonomic problems*

An illustration of *Cymbella schmidtii* (Fig. 22) was firstly published by Grunow (Schmidt et al. 1874–1959). The basic characteristics of the species were described in Cleve (1894), in which only length (26 μm) and width (9 μm) were given and the estimated striae number (~14) (Table 3). However, the indicated type locality (Lake Fertő – Neusiedler See, inland saline lake) was not supported by later researchers, because none of them (Buczkó & Padisák 1988, Buczkó 1989, Ács et al. 1991, Buczkó & Ács 1997) have ever found this species in this saline shallow lake. To clarify the type locality, the Grunow collection of diatom slides were checked, and one slide (Fig. 24) with two individuals of the species was found (Fig. 25, 26) from Lake Balaton. The morphological parameters of these valves match our findings (length: 22 and 25 μm; width: 8–9 μm; stria number: 14/10 μm).

A description and drawings of the species (Fig. 14) were published in Pantocsek's (1902) monograph on diatom flora of Lake Balaton. Two other species of similar appearance (apiculate apices, width of the axial area) and dimensions (Table 3) were given: *Cymbella reducta* (Fig. 15), *C. reducta* var. *tumida* (Fig. 16). These three species were found in the mud close to Siófok and Szántód on the southern shores of the lake, similar to our findings. Pantocsek's slides (31 samples) and cleaned materials (eight samples), stored in the Hungarian National History Museum, were studied intensively using both light and electron microscopy, but, unfortunately, none were found. Nevertheless, taking the drawings (Fig. 14–16) and descriptions into account, these species clearly differ from Figs 1–13 and from the first drawing (Fig. 22) which can be found in Schmidt Atlas (Schmidt et al. 1874–1959, fig. 9: 48.), since their striae are parallel and the valves have a very small central area unlike those of *Cymbella/Cymbopleura schmidtii*.

Despite all our efforts (detailed above), the species was not found, nor in any other slides or materials, therefore, the species (Fig. 25) from the original Grunow slide (Fig. 24) was chosen as the lectotype of the species and Lake Balaton as the type locality.

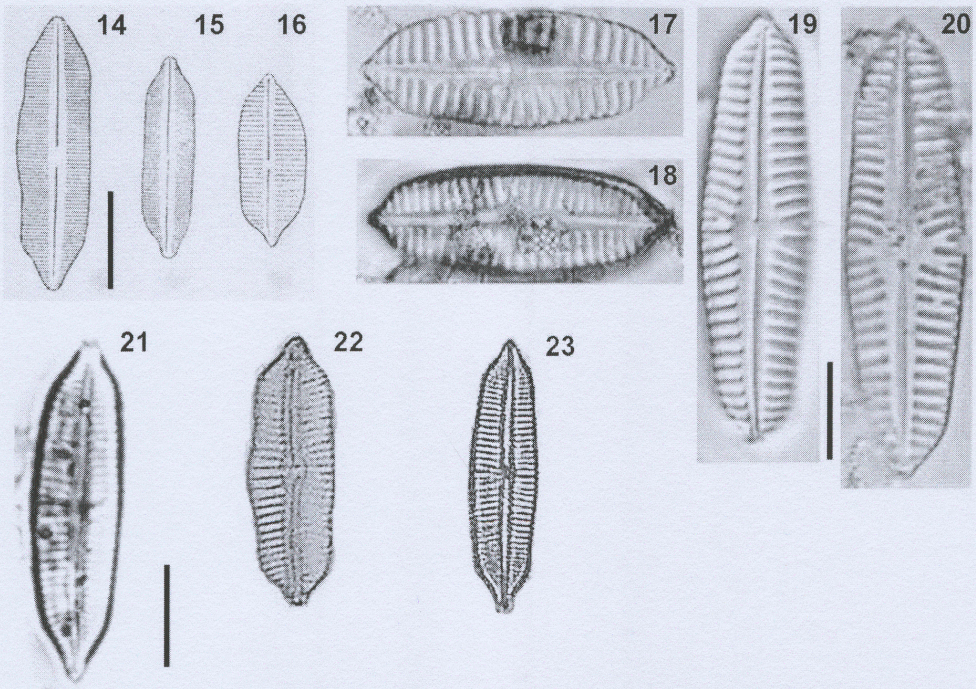
In 1926, Gallik criticized Pantocsek's work about these species, arguing that:

1. The drawing and the description of *C. schmidtii* are not harmonized and the striae were drawn as perpendicular lines to the longitudinal axis. According

Table 3. Morphological characters of some similar species.

Taxon name	Length	Breadth	Striae	Puncta	References
Cymbopleura schmidtii	22–36	7–9	13–17 in 10 μm	40 in 10 μm	This study
Cymbella schmidtii Grunow	22; 25	8; 9	14 in 10 μm	No data	Grunow collection, slide 1623
	28–29	7–7.5	15 in 10 μm	No data	Pantocsek 1902
	26	9	~14 in 10 μm	No data	Cleve 1894
Cymbella reducta Pantocsek	27–28	6.5–7	16–17 in 10 μm	No data	Pantocsek 1902
Cymbella reducta var. *tumida* Pantocsek	24	6.5	14 in 10 μm	No data	Pantocsek 1902
Navicula integra (W. Smith) Ralfs	29.5	7.9	No data	No data	Gallik 1935
	25–45	8–10	17–23 in 10 μm	No data	Krammer & Lange-Bertalot 1999
Navicula integra (W. Smith) Ralfs var. *gibba* Pantocsek	20.7	8	16 in 10 μm	No data	Pantocsek 1902
Navicula turris Hustedt	29–46	11–12	No data	No data	Simonsen 1987
Cymbopleura hybrida (Grunow) Krammer	30–62	9–11	9–13 in 10 μm	29–31 in 10 μm	Krammer 2003
Cymbopleura hybrida var. *capitata* (Fontell) Krammer	42–52	10.7–11.4	10–11	30–35	Krammer 2003
Cymbopleura fluminea (Patrick & Freese) Lange-Bertalot & Krammer	34–40	7–8.5	10–13	27–30	Krammer 2003
Cymbopleura elliptica Krammer	30–44	8–11.5	10–13	30–32	Krammer 2003

Notes: length (μm); breadth (μm); number of striae in 10 μm; number of puncta in 10 μm.



Figs 14–23. Figs 14–16. Drawings of József Pantocsek (1902) of *Cymbella schmidtii* Grunow (Fig. 14), *Cymbella reducta* Pantocsek n.s. (Fig. 15) and *C. reducta* var. *tumida* Pantocsek n.v. (Fig. 16). **Figs 17–20.** *Navicula turris* Hustedt. **Fig. 21.** Photo of *C. schmidtii* by Márta Hajós in fossil samples. **Fig. 22.** Drawing of Grunow (1875) about *Cymbella schmidtii*. **Fig. 23.** Drawing of Gallik (1935) of *Navicula integra* (W. Smith) Ralfs. Scale bars = 10 μm.

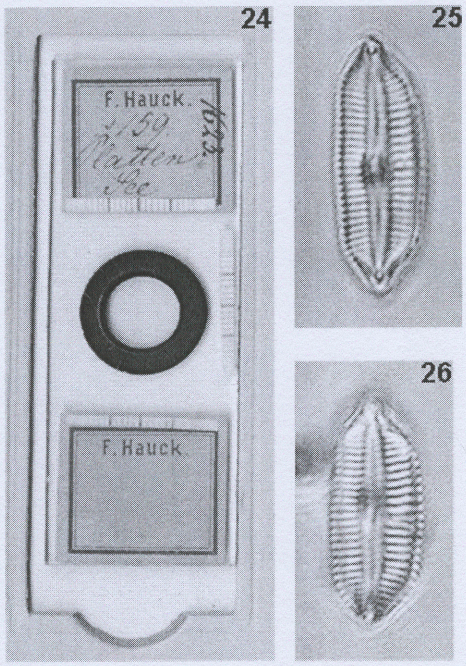
to Gallik (1926) observations, the biggest size of the species 36 μm (length) and 9 μm (width), perfectly agrees with our results (Table 3). The species was not only found in Lake Balaton but also in neither the Kis-Balaton reservoir system nor the Hévíz-stream.

2. *Cymbella reducta* (Figs 15–16) do not differ from *C. schmidtii*, but are only a variation of the taxa caused by size reduction process (Gallik 1926), therefore, it cannot be considered a distinct species (Gallik 1926).

Navicula integra (W. Smith) Ralfs and *N. integra* var. *gibba* Pantocsek (Table 3) also have comparable shapes and features with *C. schmidtii*. The middle part of their valves has a rounder shape, the striae are steeper and denser and they are completely symmetric taxa. *Navicula integra* var. *gibba* with linear striae has a larger, well-developed central area than was recognized in *C. schmidtii*. According to Gallik (1926), *N. integra* can be found also in the Balaton.

However, Pantocsek's study (1902) about the species is questionable, and Gallik's articles (1926, 1935) are also problematic. Namely, Gallik's findings in 1926 contradict those in 1935. The Gallik article (1935) contains a drawing of *C. schmidtii*, but under the name *N. integra* (Gallik 1935, Fig. 8, here reproduced as Fig. 23) with 29.5 μm length and 7.9 μm width (Table 3). The drawing and features of *N. integra* (Fig. 23) differ completely from those that appear in the recent taxonomy guide (Krammer & Lange-Bertalot 1999). Furthermore, *N. integra* was mentioned as halophilous; it appears only rarely in Lake Balaton and can be found in reed bed, mudhole in the littoral part of the lake and in Lake Hévíz (Gallik 1935). Therefore, *C. schmidtii* occurrences are very questionable, but the Grunow collection and recent studies report that *C. schmidtii* is only in Lake Balaton.

Navicula turris Hustedt (Fig. 18–20) has a similar outline to *C. schmidtii*. The two species can easily be discriminated by the valve width (*N. turris* 11–12 μm, *C. schmidtii* 7–9 μm) and the number of striae (*N. turris* 8 in 10 μm, *C. schmidtii* 13–17 in 10 μm). Moreover, the



Figs 24–26. Photos of the Grunow diatom collection in Vienna. **Fig. 24.** The original diatom slide. **Figs 25–26.** LM photos of the two individuals of *Cymbopleura schmidtii* found on the original slide.

striae of *N. turris* are more sharply curved in the central area (mostly in bigger forms) and become convergent at the ends (Simonsen 1987).

Differential diagnosis from other Cymbopleura *species*

Similar species belong to the *Cymbopleura hybrida* group (Krammer (2003) (Table 3). The striae in this group are analogous to *C. schmidtii*. The *C. hybrida* group differs from *C. schmidtii* in the shape of the ends and the central area. The subcapitate to capitate apices of *C. hybrida* var. *capitata*, *C. fluminea* and *C. elliptica* are clearly different from the apiculate apices of *C. schmidtii*. Nevertheless, *C. hybrida* var. *hybrida* may also have apiculate ends and there is overlap in the size and striae number. However, *C. hybrida* is usually large (length: 30–62 μm, breadth: 9–11 μm) and has few striae (9–13 in 10 μm) and puncta (29–31 in 10 μm) compared with *C. schmidtii* (length 22–36 μm, breadth 7–9 μm, striae 13–17 in 10 μm, and puncta 40 in 10 μm). The other remarkable dissimilarity is the large, well-developed central area of *C. hybrida*, which is 1/3 to 1/2 of the valve breadth, in contrast to *C. schmidtii*, where it is small, only 1/5 valve breadth.

Márta Hajós's deposited material in the Hungarian Natural History Museum was searched for Holocene mud from Lake Balaton and a floristical survey of listed fossil diatoms was conducted (Buczkó et al. 2005). One photo from this species (here depicted as Fig. 21) was found but without name and comments from the Tó-4 boreholes. Nevertheless, these fossil forms support the long existence and endemic character of the species in the lake.

Since the genus *Cymbopleura* was introduced (Krammer 1982), two *Cymbopleura* species have been described by Metzeltin & Krammer in Metzeltin & Lange-Bertalot (1998). At the same time, Moser et al. (1998) published more species belonging to this genus. In 1999, thirteen species were recorded with the formal validation of the genus by Krammer in Lange-Bertalot & Genkal (1999). In 2003, Krammer made a detailed analysis of the genus and a further 109 taxa was classified in the genus of which 42 were nov. spec. Whereas in 2007, four new *Cymbopleura* species were described by Levkov et al. (2007) and eleven by Metzeltin & Lange-Bertalot (2007).

Besides the latest identification guides (e.g., Metzeltin et al. 2005, Levkov et al. 2007, Antoniades et al. 2008), few papers (e.g., Le Cohu 1996, Rimet et al. 2007) have mentioned *Cymbopleura* species. This may be due to frequent changes in taxonomy, but the species' rarity and strong habitat specificity (Lowe et al. 2007) certainly play a major role.

There is an urgent need to investigate the phytobenthos of Lake Balaton and similar unknown lakes with special emphasis on diatoms to assess their ecological status and evaluate their reference conditions. Because of these studies and the exceptionally high diatom diversity in the lake, it is most likely that more new species will be added to the Hungarian diatom flora or science and their taxonomic status will be needed for clarification.

Acknowledgements

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