Diatom Research, 2014
Vol. 29, No. 2, 105–110, http://dx.doi.org/10.1080/0269249X.2013.804446

Transfer of *Staurosira grunowii* to *Staurosirella*

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The new combination *Staurosirella grunowii* (Pantocsek) E. Morales, Buczkó & Ector comb. nov. is presented based on a detailed analysis of fossil material from Lutila, Slovakia using light and scanning electron microscopy. The species is widely known as *Staurosira harrisonii* var. *amphitetras* Grunow. Striae bearing well-developed vimines delimiting typically long areolae, thick virgae-bearing spines, developed apical pore fields composed of simple round poroids and open girdle bands with valvocopula-bearing fimbriae are some of the features that link this taxon to species currently ascribed to *Staurosirella* D.M. Williams & Round. The taxon is readily distinguished by its tetra-angular shape, which is not seen in any other species within this genus. An analysis of the morphology of this taxon together with its nomenclatural history is presented herein.

Keywords: *araphid diatoms; Bacillariophyta; fossil; Pantocsek collection; Slovakia;* Staurosirella grunowii*; type material*

Introduction

Staurosira grunowii Pantocsek was first described from fossil deposits in Bory, Slovakia (Pantocsek 1892). This taxon, however, is a later synonym of *Staurosira harrisonii* var. *amphitetras* Grunow, which was described from fossil material from Dúbravica, also in Slovakia (Grunow 1882). This rather distinctive diatom is extinct and appears in the fossil record from the Middle Miocene (ca. 15 Ma) until the Late Pleistocene (ca. 100 Ka), more specifically until the end of the Sangamonian glacial time in the Quaternary period (VanLandingham 2004). The long life span of this species (ca. 14.9 Ma) and its characteristic shape attracted the attention of renowned diatomists from around the globe such as Grunow (1882), Kitton (1885), Pantocsek (1892), Hustedt (1930), Řeháková (1980) and Gandhi (1999).

Kitton (1885) referred to the var. *amphitetras* as a 'charming little form' due to its characteristic tetraradiate shape and relatively large size, which made *amphitetras* stand out from the rest of diatoms present in the Dúbravica material examined by Grunow (1882). To date, this taxon has not been examined using scanning electron microscopy (SEM), and although its relationship with taxa currently placed in *Staurosirella* D.M. Williams & Round (Williams & Round 1987) was established based on light microscopy (LM) observations, SEM information was needed to confirm such a placement. The present study includes LM and SEM data, and a detailed description of the morphological features of the var. *amphitetras*. This analysis leads to the conclusion that this taxon is sufficiently different from closely related extinct and extant representatives of *Staurosirella* and thus it should be transferred to the latter genus at the species level.

Materials and methods

The material from Dúbravica analyzed by Grunow (1882) was not available to us, but material from Dúbravica and Lutila (the latter also in Slovakia) from the Pan-to-csek Collection at the Hungarian Natural History Museum (BP) was accessed. All the LM features of *S. harrisonii* var. *amphitetras* were the same in the samples from Dúbravica and Lutila deposits. Because the population in Lutila was well-developed, sediments from this locality were chosen for detailed SEM analysis. Lutila is a small village in the Žiar nad Hronom district of the Banská Bystrica region of central Slovakia (48°36′50″N, 18°50′30″E; 294 m above sea level). The Lutila diatomite is located in the southwest periphery of the Žiar Basin and is part of unnamed sediments dated to 11.6 Ma (Harzhauser & Piller 2007). This diatomite occurred west of the creek Lutilsky potok (Lexa et al. 1998).

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(Received 18 November 2012; accepted 7 May 2013)

Two small vials, nos 92 and 93, from the Pantocsek Collection, were studied. Vial no. 92 is dominated mainly by centric diatoms [*Aulacoseira* spp. and *Ellerbeckia kochii* (Pantocsek) Moisseeva] and diverse cymbelloid forms. Vial no. 93 is characterized by a dominance of *S. harrisonii* var. *amphitetras*. Permanent preparations (slides BP 2199–2206) and SEM stubs were examined for this study. Dúbravica samples nos 52 and 53 were also checked and used for comparison at the LM and SEM levels. However, valves of the var. *amphitetras* in these samples were too rare to allow for detailed SEM analysis.

A 2 mL aliquot of vial no. 93 was oxidized by the addition of 100 mL of 35% hydrogen peroxide, which was heated by placing the test tube containing the mixture in hot sand for 36 h, reaching a temperature of 210°C for at least 24 h during the process. The preparation was allowed to settle and the peroxide eliminated by vacuum aspiration. One milliliter of 37% hydrochloric acid was then added to the sample and allowed to rest for 2–4 h, after which the sample was rinsed at least three times with distilled water to remove all traces of acid. A few drops of the suspension with the clean frustules were poured onto coverslips and allowed to dry overnight at room temperature. Permanent slides were mounted with the aid of a hot plate and using Naphrax© as the mounting medium.

LM observations (Figs 1–10) and morphometric measurements of 30 valves were performed using a Leica® DMRX bright-field microscope with a 100 × oil immersion objective and LM photographs were taken with a Leica® DC500 camera.

Part of the SEM analysis was done in Budapest (Figs 11–13, 15–16). For this, materials from vials nos 92 and 93 were initially diluted in distilled water and allowed to dry on stubs. Coating with gold–palladium was accomplished using a XC7620 Mini Sputter Coater for 120 s at 16 mA. A Hitachi S-2600 N scanning electron microscope operated at 20 kV and 5–8 mm distance was used.

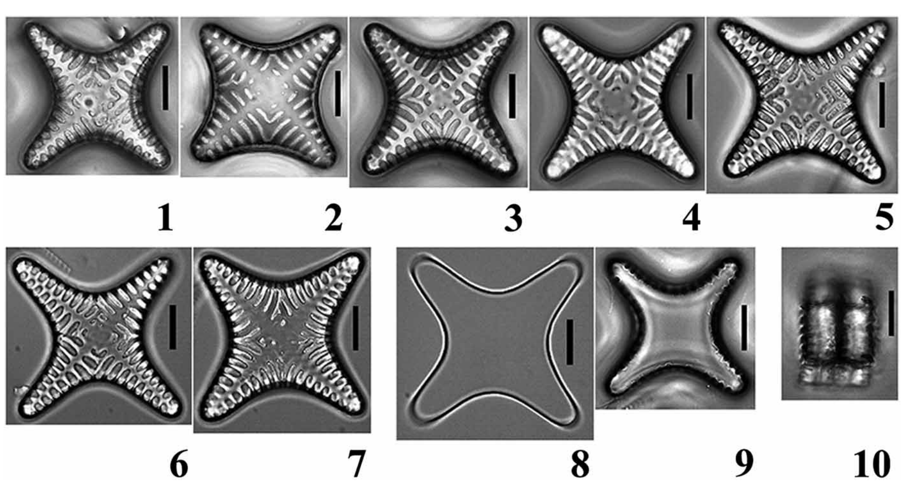
For SEM analysis in Luxembourg (Figs 14, 17–18), a small aliquot of material digested for LM preparations was filtered through a glass fiber filter with a pore diameter of 3 μm and mounted on a stub using double-sided carbon tape. Coating with platinum was accomplished using a BAL-TEC MED 020 Modular High Vacuum Coating System for 30 s at 100 mA. A Hitachi SU-70 electron microscope operated at 5 kV and 10 mm was used.

Micrographs were digitally manipulated and plates containing LM and SEM pictures were mounted using Adobe Photoshop CS3. Terminology follows Anonymous (1975), Cox & Ross (1981) and Williams & Round (1987).

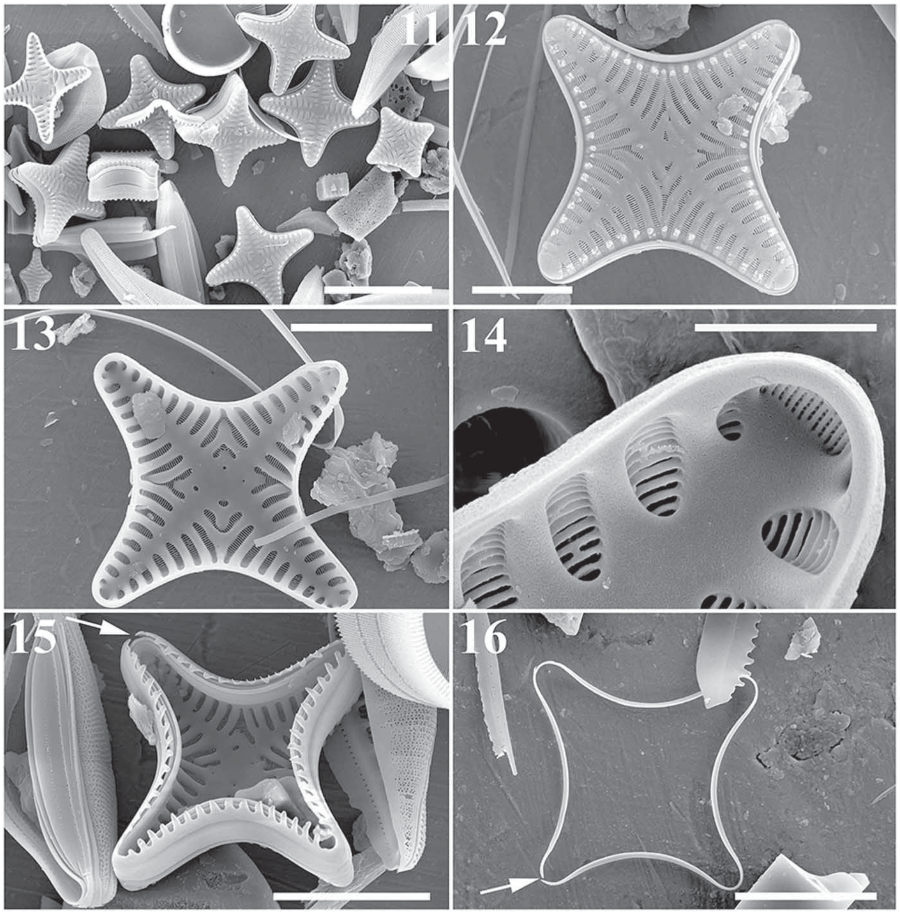
Results and discussion

Despite the age of the Lutila material, diatom valves and frustules are well preserved allowing for clear observations under LM (Figs 1–10) and SEM (Figs 11–18). Even delicate structures such as girdle bands (Figs 8–9) and volae (Fig. 17) are well preserved. Good preservation is not restricted to the var. *amphitetras*, but also other diatoms present in the material show this feature, allowing for detailed taxonomic studies.

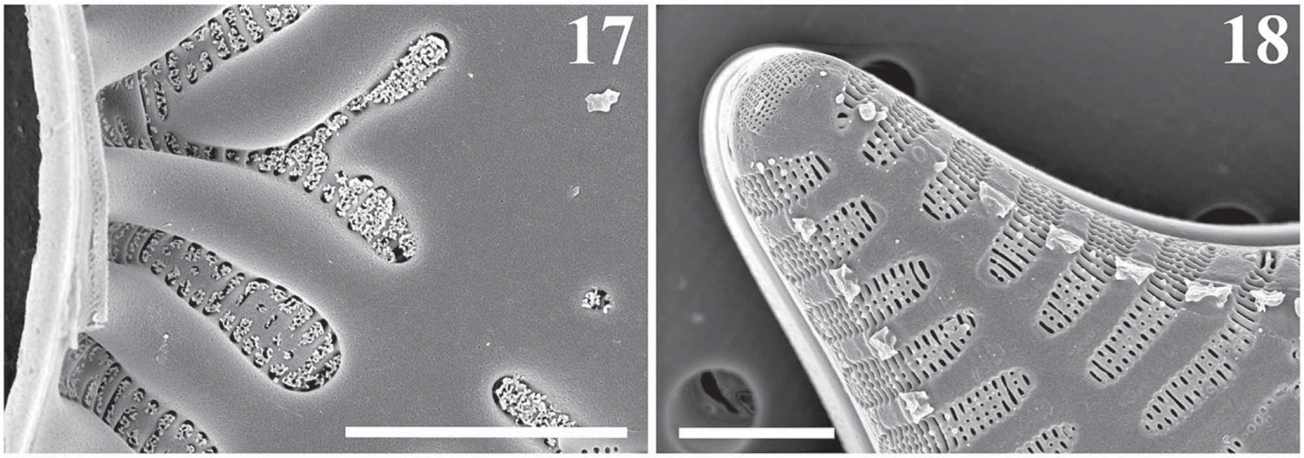
Characteristics based on LM and SEM. The frustules are irregular in girdle view and form ribbon-like colonies with the aid of linking spines (Figs 10, 18). The valves are tetra-angular with more or less protruding, broadly rounded ends (Figs 1–7). The valves vary from 28 to 51 μm (median 48 μm) in length and from 18 to 24 μm (median 22 μm) in width (i.e., the distance between two opposing vertices at the valve middle), with 4–5 (median 4) striae in 10 μm. The valve face is undulate due to the raised virgae (Figs 12, 18). The central area varies from square to rhomboid and



Figs 1–10. *Staurosira harrisonii* var. *amphitetras* Grunow [= *Staurosirella grunowii* (Pantocsek) E. Morales, Buczkó & Ector comb. nov.] from the Lutila material, vial no. 93 from the Pantocsek Collection (BP). **Figs 1–7.** Valve views showing details of valve outline, sternum and striae. **Fig. 8.** Copula. **Fig. 9.** Valvocopula with fimbriae. **Fig. 10.** Two neighboring cells forming a reduced chain. Scale bars = 10 μm.



Figs 11–16. *Staurosira harrisonii* var. *amphitetras* Grunow [= *Staurosirella grunowii* (Pantocsek) E. Morales, Buczkó & Ector comb. nov.] from the Lutila material, vial no. 93 from the Pantocsek Collection (BP), SEM. **Fig. 11.** Portion of the stub showing a well-developed population in the examined material. **Fig. 12.** External view of valve showing features of valve outline, sternum, striae and spines. **Fig. 13.** Internal view of valve showing details of sternum and striae. **Fig. 14.** Close up of one of the arms showing internal details of the apical pore field and absence of rimoportula in that arm. **Fig. 15.** Internal view of valve with valvocopula of opposite valve resting on top of it. Notice developed fimbriae and opened girdle element (arrow). **Fig. 16.** Smooth and open (arrow) copula. Scale bars = 50 μm (Fig. 11); 25 μm (Fig. 15); 20 μm (Figs 12–14, 16).



Figs 17–18. *Staurosira harrisonii* var. *amphitetras* Grunow [= *Staurosirella grunowii* (Pantocsek) E. Morales, Buczkó & Ector comb. nov.] from the Lutila material, vial no. 93 from the Pantocsek Collection (BP), SEM. **Fig. 17.** Close up of valve interior showing detail of the areolae occluded by fine volae. **Fig. 18.** Close up of the exterior of an arm showing details of striae, spines and apical pore field. Notice the coalescence of cross-bars between neighboring vimines reducing the extension of the areolae. Scale bars = 5 μm.

is generally devoid of ornamentation and surrounded by V-shaped striae (Figs 12–13). The central sternum is tetraradiate, with linear to V-shaped branches opening at the central area (Figs 12–13). The striae are alternate, varying from radiate at the valve center to parallel toward the ends, and running continuously from near the sternum to midway into the valve mantle (Figs 12–13, 17–18). In internal view, the striae lie on deep depressions (Figs 13, 17). The areolae are long, sometimes becoming shortened by the production of cross-bars between neighboring vimines, and bearing profusely, dichotomously branched volae (Figs 13, 17–18). The virgae are wide, thickened on the valve exterior and interior, and bear spines toward the valve face–mantle junction (Figs 12, 17–18). The spines are spatulate, originating from the virgae (Figs 12, 18). The apical pore fields are of the ocellulimbus type, they are well-developed at the four valve ends and bear several rows of round poroids positioned on the transition between valve face and mantle (Figs 12, 18). In internal view, the apical pore fields lie within a circular depression (Figs 13–14). There were no rimoportula present (Figs 13–14), and no blisters observed on the valve mantle abvalvar edge. The girdle bands are open, without perforations and lacking ligulae (Figs 8–9, 15–16). The valvocopula are fimbriate, larger than the rest of the girdle elements and recessed, clearly delimiting a pars interior and a pars exterior (Figs 9, 15). The plastids are unknown.
Staurosira harrisonii var. *amphitetras* has all the features that relate it to other species currently ascribed to the genus *Staurosirella*. The characteristics of the striae composed of areolae delimited by well-developed vimines, the thick virgae-bearing spines, the apical pore fields composed of simple round poroids, the girdle bands with distinguishable pars interior and exterior, and valvocopula bearing fimbriae are among these features. The character that defines *S. harrisonii* var. *amphitetras* is the tetra-angular shape of its frustules, which is nicely maintained in the population found in the Lutila material, even at small frustule sizes. This tetra-angular shape has not been observed in any other staurosirelloid species.

The net-like appearance of some of the striae (Figs 17–18) is also present in other *Staurosirella* species (see discussion in Morales 2005). This capability of producing cross-bars between neighboring vimines is shared with species in *Punctastriata* D.M. Williams & Round, but in the latter, the production of multiareolated striae is a fixed character. In the Lutila population, although some striae of some valves had this net-like structure, others did not show this feature (Fig. 11).

An interesting observation seen in LM was that the girdle bands seem to be closed (Figs 8–9). However in SEM, these structures revealed their open nature (Figs 15–16). It is possible that because of the highly undulated character, the open ends remain in close contact and their separation is hard to distinguish in LM.

Nomenclatural history of Staurosira harrisonii *var.* amphitetras.

Staurosira harrisonii var. *amphitetras* Grunow 1882, p. 139, pl. 29, fig. 18.

Heterotypic synonyms:

= *Staurosira grunowii* Pantocsek 1892, pl. 4, fig. 66, 1905, p. 95.

= *Fragilaria harrisonii* var. *major* Héribaud 1903, p. 25, pl. 10, fig. 12.

= *Staurosira grunowii* var. *minor* Héribaud 1908, p. 17, pl. 14, fig. 13.

= *Staurosira grunowii* var. *major* Héribaud 1908, p. 18, pl. 14, fig. 14.

= *Staurosira grunowii* var. *triangulata* Héribaud 1908, p. 18, pl. 14, fig. 15.

Homotypic synonyms:

≡ *Fragilaria harrisonii* var. *amphitetras* (Grunow) Hustedt in Schmidt 1913, pl. 296, figs 1–5, *comb. illeg*.

≡ *Fragilaria harrisonii* var. *amphitetras* (Grunow) Hustedt 1930, p. 140, *comb. illeg*.

≡ *Fragilaria leptostauron* var. *amphitetras* (Grunow) Řeháková 1980, p. 120, pl. 12, fig. 14, *comb. illeg*.

≡ *Fragilaria leptostauron* var. *amphitetras* (Grunow) Gandhi 1999, p. 301, pl. 4, figs 28–35, *comb. illeg*.

Biogeography of Staurosira harrisonii *var.* amphitetras

This diatom appears to have been fairly widespread because it has been recorded from the following quite disparate localities (Fig. 19):

- Bulgaria: Oranovo–Simitli Basin (N. Ognjanova-Rumenova, pers. obs.);
- France: Joursac (Héribaud 1903) and Lugarde deposits (Héribaud 1908, Lauby 1910, Tempère & Peragallo 1913) in Cantal, Auvergne region;
- Germany: Willershausen (Kalefeld in Landkreis Northeim) (Krasske 1932, Jousé 1952, 1966);
- Greece: Serres Basin (Ognjanova-Rumenova 2006);
- India: Baltal, Karewa Beds of Kashmir (Gandhi et al. 1983a, b, Gandhi 1999);
- Mexico: Hueyatlaco archeological site in Valsequillo (VanLandingham 2000, 2004);
- Romania: Kopacsel (Copăcel) (Pantocsek 1905, Semaka & Givulescu 1965, Řeháková 1980), Baraolt (Bibarcfalva) (K. Buczkó, pers. obs.);
- Slovakia: Bory (Tempère & Peragallo 1889–1895, 1911, Pantocsek 1892, 1905, Řeháková 1980), Buča (Řeháková 1980), Dúbravica (Grunow 1882, Kitton 1885, Pantocsek 1905, Schmidt 1913, Hustedt 1930, Řeháková 1971, 1980, Pastor 1991), Lutila (Pantocsek 1913, Řeháková 1980);
- Switzerland: Lake Hallwil (Hallwilersee) (Brutschy 1925);

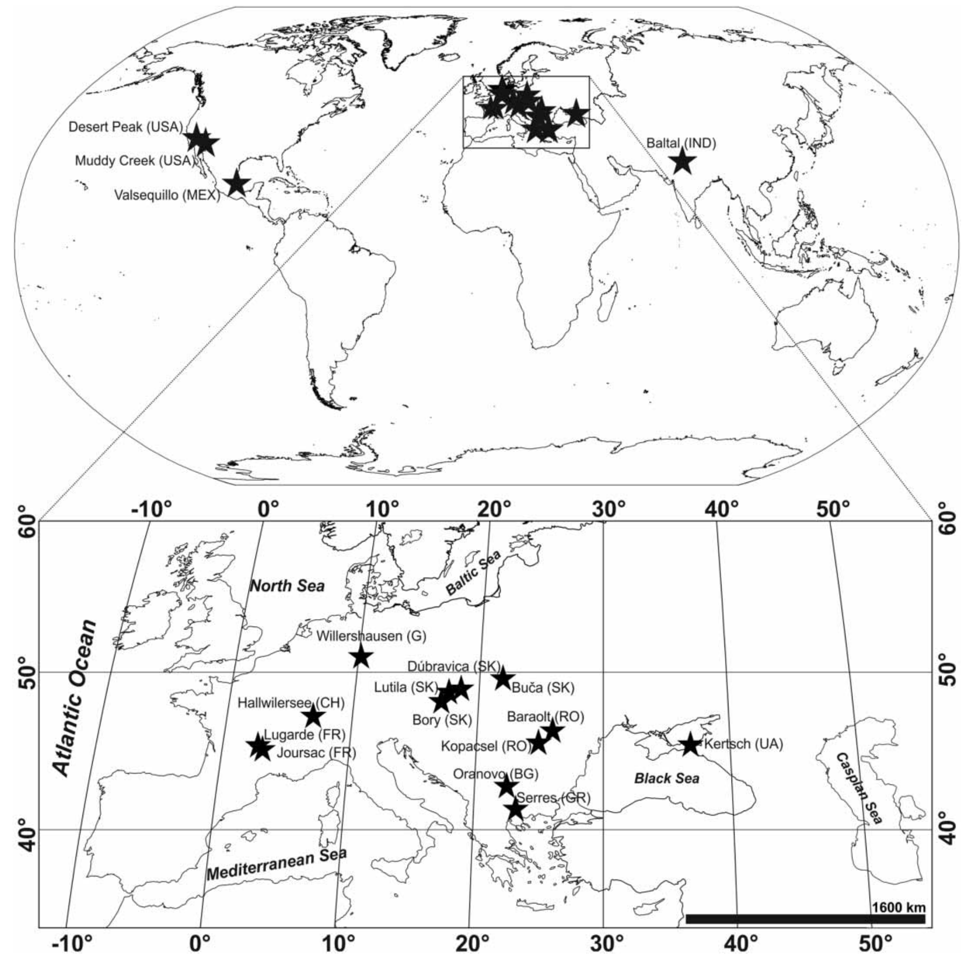


Fig. 19. Geographical distribution of *S. harrisonii* var. *amphitetras* based on literature records of fossil material. Each black star depicts a locality from which the taxon was reported.

- Ukraine: Kerch (Kertsch) in Crimea (brackish fossil deposit, Tempère & Peragallo 1913);
- USA: Lincoln County, Nevada, from Panaca = Muddy Creek Formation [VanLandingham sample 1449 (slide 2831), California Academy of Sciences]; Churchill County, Nevada, probably from Desert Peak Formation [VanLandingham sample 1510 (slide 3066), California Academy of Sciences] (S.L. VanLandingham, pers. comm.).

Conclusion

A close examination of the morphology of *S. harrisonii* var. *amphitetras* associates this taxon with the genus *Staurosirella*; therefore, its transfer to this latter genus is justified. Because the features of the var. *amphitetras* are distinctive and a full range of frustule sizes can be seen in the studied material, the transfer to *Staurosirella* is made at the species level. Following ICN article 11.2 (McNeill et al. 2012), the earliest synonym available at the species level must be chosen for the new combination in *Staurosirella*. This earliest synonym is *S. grunowii*. Therefore, the epithet *grunowii* is chosen as basis for the following transfer:

Staurosirella grunowii (Pantocsek) E. Morales, Buczkó & Ector comb. nov.

Basionym. *Staurosira grunowii* Pantocsek 1892, p. 95, pl. 4, fig. 66. Beiträge zur Kenntnis der Fossilen Bacillarien Ungarns. III. Theil: Süsswasser Bacillarien. Anhang: Analysen 15 neuer Depôts von Bulgarien, Japan, Mähern, Russland und Ungarn. Buchdruckerei von Julius Platzko, Nagy-Tapolcsány.

Acknowledgements

We gratefully acknowledge Delphine Collard (Public Research Centre – Gabriel Lippmann, Department of Environment and Agro-biotechnologies, Belvaux, Luxembourg) for technical assistance in sample treatment and preparation. We thank Saúl Blanco (University of Leon, Spain) for help with taxonomic/nomenclatural issues and the late Sam L. VanLandingham for helping with some literature references. This work is dedicated to Sam for his indefatigable work on diatoms.

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