Gomphonema beaugerianum, a new *Gomphonema* species (Bacillariophyta) found in a historic Williams Smith sample from the Auvergne (France)

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Abstract

A large, unknown *Gomphonema* taxon belonging to the *G. truncatum* group was observed in a historic sample collected by William Smith during his 1854 excursion in the Auvergne (France). The unknown species presented sufficient differences with all known taxa in the *truncatum-capitatum* group to warrant further morphological investigations. Detailed light and scanning electron microscopy investigations in comparison with all published literature revealed that the unknown species had a unique combination of morphological (uniseriate striae, lack of well-develop headpole) and morphometric (large valve width). Therefore, the species is described as new: *Gomphonema beaugerianum* sp. nov. The new species was observed in Lac de Guery, an oligotrophic, almost circumneutral lake in the Auvergne with a high ecological quality.

Key-words Europe, France, *Gomphonema*, morphology, historic material

Introduction

Gomphonema truncatum (Ehrenberg 1832: 88) is a very characteristic *Gomphonema* species with a clavate valve outline, a large, usually inflated head pole, a clear constriction under the headpole and, in the lower valve, gradually tapering margins towards the acute footpole. The areolae are often well discernible in LM. The species is often confused with *G. capitatum* Ehrenberg (1838: 217) although the latter has a much more pronounced headpole (Reichardt 2001). Reichardt (2001) thoroughly revised the entire *G. truncatum* complex in 2001 based on the analysis of original Ehrenberg material. The complex can be subdivided into two groups, one with strictly uniseriate striae such as *G. italicum* Kützing (1844: 85), and one with biseriate striae, at least near the valve margins such as in *G. clava* E.Reichardt (2001: 214) (see Reichardt 2001, plate 13, fig. 6). In addition, Reichardt (2001) described four new species, *G. latipes* E.Reichardt (2001: 196), *G. laticollum* E.Reichardt (2001: 199), *G. pala* E.Reichardt (2001: 212), and *G. clava*. Further revision in the *G. truncatum* group were made by Levkov *et al.* (2016) adding two new varieties of *G. italicum*, describing two new species and renaming one *G. olivaceum*-variety (*G. olivaceum* var. *capitata* Jurilj 1954: 26) transferring it to the species level as *G. juriljii* Levkov *et al*. (2016: 68). They also raised the variety *G. constrictum* var. *subcapitatum* Grunow (in Van Heurck 1880: plate 23, fig. 5) to the species level as *G. subcapitatum* (Grunow in Van Heurck 1880: plate 23, fig. 5) E.Reichardt & Levkov (in Levkov *et al.* 2016: 122). The Macedonian population of the species was characterised in having a valve width of 7.5–9 µm at mid-valve and 7.5–10 µm near the broadly rounded headpole, slightly lower than width of the valve illustrated by Grunow that was for the original description of the taxon (from a sample collected near Wedel, North Germany, sample Grunow 1077). Both the width at mid-valve and the width of the headpole of the drawing of *G. constrictum* var.

subcapitatum, are 10.5 µm (Van de Vijver, pers. obs.). Reichardt (2018) illustrated a *G. subcapitatum* population from a forest pond ('Waldtümpel') near Gundelsheim (Baden-Württemberg, Germany). Although one valve presented a headpole width of 12 µm, all other 12 illustrated valves had a mid-valve width never exceeding 8 µm and a headpole width of 7.5–9.5 µm (Van de Vijver, pers. obs.).

During the analysis of a historic sample from the William Smith collection, a small population of a large-celled *Gomphonema* taxon was observed showing some outline similarities with *G. subcapitatum*. The valves, however, were much larger (valve width almost 14 µm) giving the taxon a more robust outlook. Smith (1855, p. 5) most likely identified this *Gomphonema* taxon as *G. capitatum* Ehrenberg var. β illustrating one valve that shows some resemblance to the observed valves in the Lac de Guéry sample (Smith 1855, fig. 2β). Following a morphological comparison of the Lac de Guéry population with the *G. subcapitatum* populations from Macedonia (Levkov *et al.* 2016, plate 34) and Germany (Reichardt 2018, plate 300, figs 14–27), the French population should be separated as a new species: *Gomphonema beaugerianum* Van de Vijver, sp. nov. The new species is compared with other similar species from the *G. truncatum*-complex. Its ecological preferences are based on the survey of the associated diatom flora in the sample with ecological information taken from Lange-Bertalot *et al.* (2017).

Material and Methods

In the Van Heurck diatom collection, part of the herbarium of Meise Botanic Garden (BR, Belgium), several samples, collected by the reverend Williams Smith in 1854 during his excursion in this region (Smith 1855), are conserved. One of these samples was gathered from

the Lac de Guéry, an oligotrophic, almost circumneutral lake in the Auvergne region (Central France). The sample was prepared for LM and SEM observations following the method described in van der Werff (1955à, by cleaning it with 37% H_2O_2 and heating to 80°C for about 1 h, after which the reaction was completed by addition of saturated $KMnO_4$. Following digestion and centrifugation (three times for 10 minutes at 3700 × rpm), the resulting cleaned diatom slurry was diluted with distilled water to avoid excessive concentrations of diatom valves on the slides, and mounted in Naphrax (refraction index 1.73). The slide was analysed using an Olympus BX53 microscope at 1000x magnification (N.A. 1.30), equipped with Differential Interference Contrast (Nomarski) optics and the Olympus UC30 Imaging System, connected to the CellSens Standard program. the Stria density was determined by counting striae from the central area onwards to the apices, as middle striae are often more spaced, underestimating that way the actual stria density. For SEM analysis, part of the suspension was filtered through 5-µm Isopore™ polycarbonate membrane filters (Merck Millipore), pieces of which were affixed with conductive double-sided adhesive carbon-tabs to aluminum stubs after air–drying. Stubs were subsequently coated with a platinum layer of 15 nm, and studied using a JEOL-JSM-7100F field emission scanning electron microscope at 2 kV and a working distance of 4 mm. Slide, sample and stub are stored at the BR-collection (Meise Botanic Garden, Belgium). Plates were prepared using Photoshop CS5.

Terminology used in the description of the various structures of the siliceous cell wall is based on Ross et al. (1979, areola structure), Cox and Ross (1981, stria structure), Round et al. (1990, raphe structure), and Reichardt (1999, genus features for *Gomphonema*). The new species was compared with other *Gomphonema* taxa from the *G. truncatum*-group described worldwide (Reichardt 2001, Kulikovskij et al. 2015, Levkov et al. 2016).

For typification of the species, we chose to use the entire slide as the type, following article 8.2 of the International Code for Botanical Nomenclature (Turland et al. 2018). Diatoms show a broad variability along their cell cycle making the choice for the entire population on the slide more obvious, but because of admixtures, one valve was indicated to illustrate the taxon best (see Figures). All novelties are registered proactively according to Art. 42.3 (Turland et al. 2018).

Results

***Gomphonema beaugerianum* Van de Vijver *sp. nov.* (Figs 1–15 LM, 16–20 SEM)**

Frustules solitary, clearly wedge-shaped (Fig. 1). Valve typically clavate, in valve outline gradually tapering from the broadly rounded headpole towards the acute footpole. Weak but still distinct constriction present right below the headpole, separating the inflated central part from the headpole. Valve dimensions (n=25): length 35–70 µm, width (headpole) 10–14 µm, width (mid-valve) 9.5–12.0 µm. Axial area moderately broad, almost ¼ of the total valve width, linear with almost parallel margins. Occasionally, irregularly scattered, shallow depressions present in the axial area (Fig. 18). Central area wedge-shaped due to radiate striae bordering the area. Central striae irregularly shortened, usually with one longer and two shorter striae. Longest central stria on the primary side terminating by the weakly isolated stigmoid. Stigmoid small, rounded, located close to the central raphe endings (Figs 16, 18). Raphe clearly lateral, undulating. Central raphe endings only weakly expanded (Figs. 16, 18), clearly deflected. Terminal raphe fissures deflected, bisecting the apical pore field on the footpole (Fig. 16). Apical pore field large, located on the valve mantle and partly on the valve face (Figs 16, 17). Striae radiate near the central area, becoming parallel to weakly radiate near the apices, 9–11 in 10 µm, more densely packed at the headpole (up to 16 in 10 µm) . Striae uniseriate, composed of large

areolae, occluded by semi-lunar, reniform siliceous flaps (Figs 16, 18). Areolae quite discernible in LM (Figs 2–15). Marginal ridge absent (Fig. 17). Valve mantle broad. Advalvar part with distinct mantle striae, continuing from the valve face striae. Abvalvar part usually hyaline with a few irregularly shattered small areolae (Fig. 17). Pseudosepta present on both apices (Fig. 19). Internally, striae sunken in long depressions (Fig. 19). Areolae large, rounded (Fig. 20). Siliceous struts separating the areolae absent (Fig. 20). Internal opening of the stigmoid slit-like. Central raphe endings long, right-angled and hook-shaped (Fig. 20).

Type:—FRANCE. Lac de Guéry, Auvergne, William Smith sample Lac de Guéry-River Mortes, leg. W. Smith, coll. date 26.vi.1854., elev. 4066 ft (holotype slide BR-4847= Fig. 5, isotype slide 447 in Collection University of Antwerp, Belgium).

Registration:— http://phycobank.org/104621

Etymology:—The species is named after my colleague and friend Dr Aude Beauger (GEOLAB UMR 6042, Maison des Sciences de l'Homme, France) in honour of her extensive work on the diatoms of the Auvergne and Central Massif region.

Ecology & associated diatom flora:—The sample was taken from Lac de Guéry, a mountain lake in the Monts Dore area of the French Massif Central. The lake with a total surface of 25 ha, has a volcanic origin. Rioual (2002) analysed in 2002 more than 20 lakes in the Auvergne region including Lac de Guéry and measured a pH of 6.9, a conductivity of 33 µS/cm, and low levels of total phosphorus (12 mg/l) and nitrate (196 µg/l). These are of course recent physico-chemical and most likely do not entirely reflect the situation in 1854 when William Smith collected the sample. The diatom flora is quite diverse and dominated by *Staurosira neoproducta* (Lange-Bertalot 1993: 48) Chudaev & Gololobova (2012: 74), *Navicula radiosa* Kützing (1844: 91), *Fragilariforma undata* (W.Smith 1855: 7) Heudre *et al.* (2017: 264), *F.*

bicapitata (A.Mayer 1917: 21) D.M.Williams & Round (1988: 265), several *Aulacoseira* taxa, *Pseudostaurosira* cf. *brevistriata* (Grunow in Van Heurck 1885: 157) D.M.Williams & Round (1988: 276), *Gomphonema coronatum* Ehrenberg (1841: 211), *Cymbella cymbiformis* C.Agardh (1830: 10), *Cymbopleura naviculiformis* (Auerswald ex Heiberg 1863: 108) Krammer (2003: 56) and *Tabellaria* cf. *flocculosa* (Roth 1797: 192) Kützing (1844: 127). This diatom flora points to oligo- to weakly mesotrophic, occasionally weakly acid, conditions with a low to moderate electrolyte content on siliceous substrates (Lange-Bertalot *et al.* 2017).

Discussion

With its typical clavate outline, broadly rounded headpole, visible areolae and constriction just below the headpole, *Gomphonema beaugerianum* is a typical constituent of the *G. truncatum* group, as defined by Reichardt (2001). Abarca et al. (2020) included *G. truncatum* within the core group of *Gomphonema* as subclade 1, separated for instance from *G. capitatum*, that forms its own distinct subclade IV (see Abarca et al. 2020, fig. 1). All observed strains in the *G. truncatum* subclade have biseriate striae at the margins whereas the *G. capitatum* subclade strains, have uniseriate striae, composed of large, hemilunar areolae. The uniseriate striae of G. beaugerianum can be used as a criterion to separate the new speceis from *G. truncatum* and the related *G. pala* E.Reichardt (2001: 212) and *G. clava*, as these species all possess striae with a biseriate section in their striae (Reichardt 2001). On the other hand, *Gomphonema capitatum* presenting similarly shaped striae and areolae, has a very distinctly capitate headpole as illustrated in Reichardt (2001, plates 1 & 2), a feature not observed so far in *G. beaugerianum*. The same applies to *G. anglicum* Ehrenberg, a species described from Mexico showing similar capitate headpoles. *Gomphonema italicum* and *G. laticollum* E.Reichardt (2001: 199) both lack

the broadly rounded, inflated headpole and possess a marginal ridge on their valve face/mantle junction (see Reichardt 2001, plate 5, fig. 12), another morphological feature so far not found in *G. beaugerianum*. Both also have more radiate striae throughout the entire valve whereas *G. beaugerianum* has almost parallel striae between the central area and the headpole. The most similar one is without doubt *G. subcapitatum*, but the latter species is clearly narrower and smaller with a valve width never exceeding 10 µm, even when larger populations are considered. Whereas valve length should not be considered a discriminating feature, valve width is, justifying the separation of both taxa. Moreover, the general valve outline *in G. beaugerianum* is more clavate than in *G. subcapitatum* sensu Reichardt (2018, plate 300, figs 14–26). Most illustrated specimens of *G. subcapitatum* have almost straight, parallel valve margins as there is little or no difference in valve width between the headpole and middle of the valve. In *G. beaugerianum*, on the contrary, the valve margins are never parallel but clearly taper towards the footpoles, since the headpoles are always distinctly wider than the central part of the valve (14 µm for the headpole versus 10 µm mid-valve in the largest specimens).

Abarca et al. (2020) questioned, however, the use of valve outline when analysing the *Gomphonema* core group stating that the "*Gomphonema* core group has been overdescribed due to the use of outline as the main criterion for species delimitation" (Abarca et al. 2020, p. 1). Within the *G. truncatum* and *G. capitatum* group, several 'morphodemes' (in the sense of Abarca et al. 2020) could be identified within each subclade but it proved to be impossible, solely based on outline to separate them as the lacked the underlying genetic differentiation. Nevertheless, ecologically, some of these taxa present different ecological preferences making it likely that there should be separated as distinct species, even if the current genetic information cannot exclude unambiguously conspecificity. Therefore, separating *G. beaugerianum*, observed in a

highly specific habitat in the Auvergne, can be justified. According to Lange-Bertalot et al. (2017), the *G. capitatum* and *G truncatum* group is broadly distributed in a broad array of environmental (mainly trophic) conditions but the lack of proper separation of the taxa hampers refined ecological preferences.

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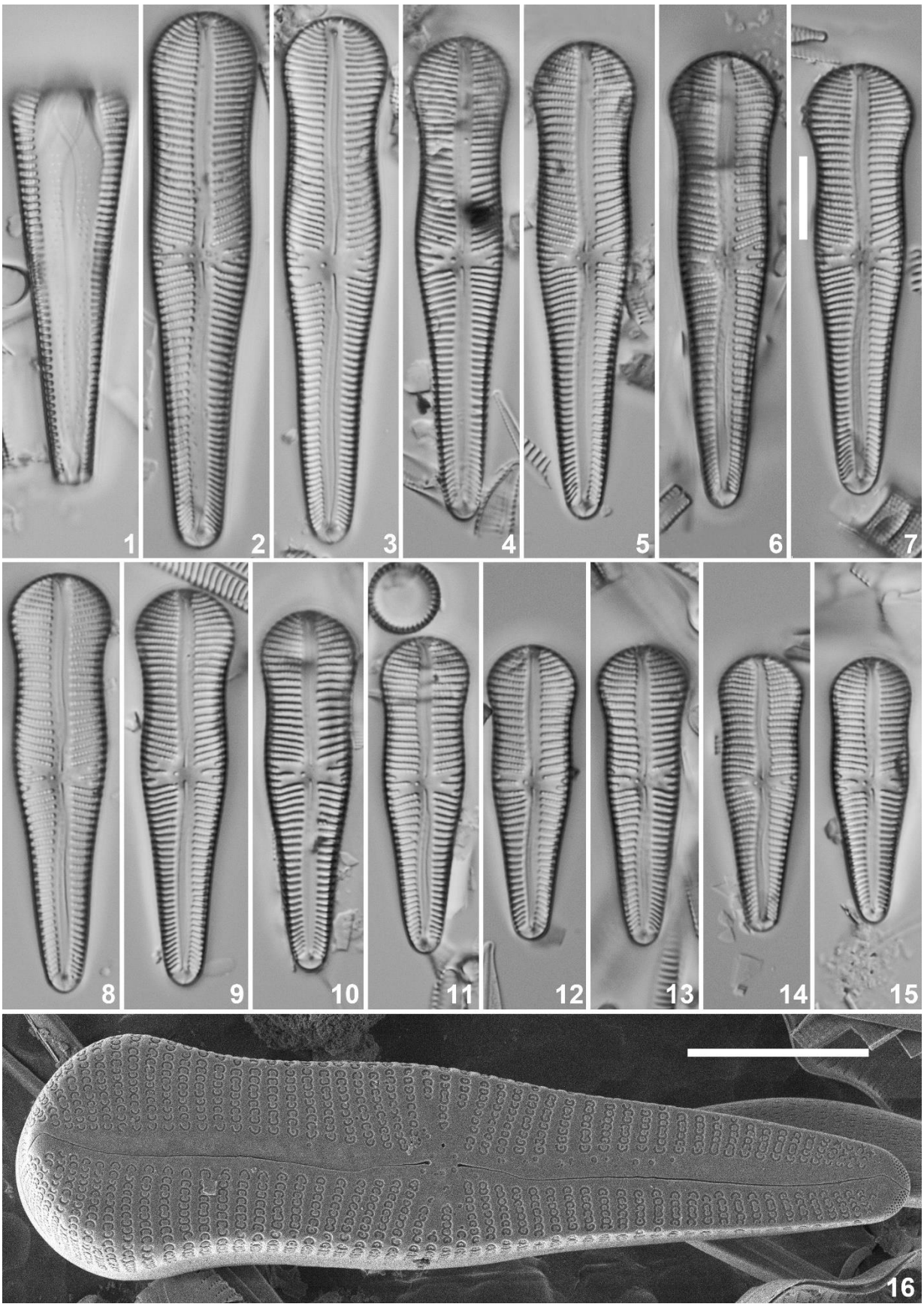
Figure captions

Figures 1–16. *Gomphonema beaugerianum* Van de Vijver, *sp. nov*. LM and SEM images taken from the holotype sample (BR-4847, Lac de Guéry, Auvergne, France, sample W. Smith). 1. LM view of a frustule in girdle view. 2–15. LM views of the population arranged in decreasing length. 16. SEM external view of an entire valve. Scale bars = 10 µm.

Figures 17–20. *Gomphonema beaugerianum* Van de Vijver, *sp. nov*. LM and SEM images taken from the holotype sample (BR-4847, Lac de Guéry, Auvergne, France, sample W. Smith). 17. SEM external view of an entire valve in oblique view showing the valve mantle. 18. SEM external detail of the central area showing the isolated pore and the depressed areolae with the reniform siliceous flaps. Note also the shallow depressions in the axial area. 19. SEM internal view of an entire valve. 26. SEM internal detail of the central area showing the slit-like isolated pore and the hooked central raphe endings. Note the absence of silica struts separating the areolae. Scale bars = 10 µm (Figs 17–19) = 1 µm (Fig. 20).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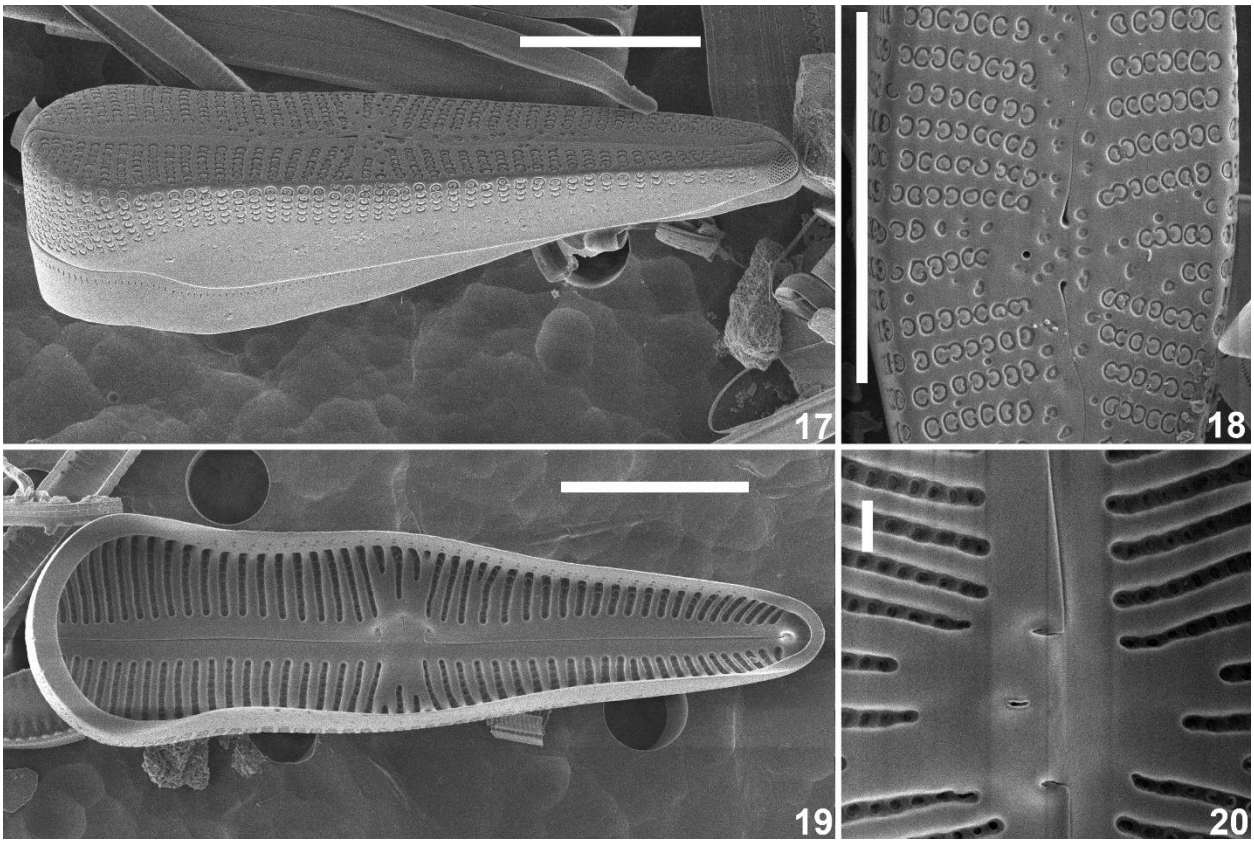
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