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Frustulia lineata and *Frustulia magnifica*, two new species of diatom from south Brazil

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Abstract: During studies on the diversity of *Frustulia* in the state of Paraná, Brazil, two different morphological populations did not correspond exactly to any known described species. This paper describes these species as *Frustulia lineata* sp. nov. and *Frustulia magnifica* sp. nov. The samples were collected in lotic environments inserted in the south Brazil Atlantic Forest region. *Frustulia lineata* sp. nov. is mainly characterized by linear–lanceolate valves with small dimensions, sharing morphological similarities with *Frustulia marginata* Amossé and *Frustulia saxonica* f. *indica* Sarode et Kamat. *Frustulia magnifica* sp. nov. is significantly larger than other species of the genus, having morphological similarities with *Frustulia aotearoa* Lange–Bertalot et Beier, *Frustulia bahlsii* Edlund et Brant, *Frustulia rhomboides* f. *occidentalis* Sovereign, and *Frustulia sanctarosae* Lange–Bertalot et Sterrenburg. Studies using light and scanning electron microscopes have revealed that the morphology and dimensions of the central nodule and the porte–crayon were primary distinguishing features that substantiate the proposal of the new species.

Key words: Amphipleuraceae, Bacillariophyta, diatom, morphology, new taxon, taxonomy

Introduction

Frustulia is characterized by the internally thickened sternum, where longitudinal ribs are positioned along either side of the raphe and fuse distally with the helictoglossa, depicting the porte–crayon. In the central region of the valve, the ribs are connected at the central nodule, exhibiting or not median constrictions (Round et al. 1990). The striae are delicate, punctate, forming transapical and longitudinal rows (Spaulding et al. 2021). Currently, the shape and dimensions of the porte–crayon (ribs and helictoglossa) and the central nodule have been proved to be reliable taxonomic characters for characterizing and distinguishing *Frustulia* species (Bouchard et al. 2020; Morales, 2020).

According to Round et al. (1990) and Lange–Bertalot (2001), the genus occurs in freshwater, epipelic, or frequently associated with macrophytes with single cells (non–tube forming) or colonies within mucilaginous tubes, abundantly present in oligotrophic and naturally acidic habitats worldwide.

The genus is cosmopolitan and represented by 122 taxa (Guiry 2024) distributed worldwide (Kociolek 2018). The knowledge about the diversity and distribution of *Frustulia* in Brazil is mainly found in floristic surveys such as Metzeltin & Lange–Bertalot (1998; 2007), Diaz–Castro et al. (2003), Brassac & Ludwig (2005), Tremarin et al. (2009), Silva et al. (2011), Soares et al. (2011), and Costa et al. (2017) totalizing 31 infraspecific taxa recorded. So far, four new species have been described based on samples collected in Brazil: *F. pangae* Metzeltin et Lange–Bertalot (Metzeltin & Lange–Bertalot 1998), *F. crassipunctatoides* Metzeltin et Lange–Bertalot, *F. saxoneotropica* Metzeltin et Lange–Bertalot (Metzeltin & Lange–Bertalot 2007) and *F. lacrima* Graeff, Kociolek et Burliga (Graeff et al. 2012).

During a taxonomic survey in freshwater environments from the state of Paraná, two populations were found that could not be assigned to any known species of *Frustulia*. The new species *F. lineata* sp. nov. and *F. magnifica* sp. nov. are here described and illustrated based on light (LM) and scanning electron (SEM) microscopy analysis. In addition, comments on morphometric statistics and comparisons with similar taxa were included.

Materials and Methods

Frustulia lineata sp. nov. was collected in periphytic samples from Salto River (25°29'44"S, 48°59'23"W) and Carvalho River (25°29'37''S, 48°58'38''W), located in the Environmental Protection Area (APA) of Piraquara city, Paraná state, Brazil. The region is inserted in the Marumbi Park and covers the mountain streams in the Serra do Mar, Atlantic Forest (IAT 2023). *Frustulia magnifica* sp. nov. individuals were associated with epilithic *Rhacocarpus inermis* (Bryophyte), submerged or emerged depending on the water level of the river. The mosses were collected in Negro River (26°00'26.0"S, 49°11'11.2"W), located in Tijucas do Sul city, southern of Paraná state, inserted in the Atlantic Forest (Plano diretor municipal – Tijucas do Sul 2023).

Samples were fixed with Transeau solution in a proportion of 1:1 (Bicudo & Menezes 2017). Conductivity ($\mu S.cm^{-1}$), pH, and water temperature (°C) measurements were collected using a Gehaka G1400 multiparameter (Table 1). Liquid samples and the respective permanent slides and stubs were deposited in the Herbarium of the Department of Botany (UPCB) of the Federal University of Paraná (UFPR), under number 49409 (*F. magnifica* sp. nov.), 76016, 76017, and 76056 (*F. lineata* sp. nov.).

The samples were oxidized according to Simonsen (1974). Permanent slides were mounted with Naphrax® (I.R.: 1.74). Photographic illustrations were obtained using DP71 capture camera accoupled in an Olympus BX40 microscope. For ultrastructural observations, the oxidized samples were deposited on aluminum supports, metalized with gold in a Balzers Union SCD 030 device, and analyzed in a JEOL JSM 6360 scanning electron microscope (Electron Microscopy Center of the UFPR).

The porte–crayon and central nodule measurements were obtained according to Bouchard et al. (2020).

Principal Component Analysis (PCA) was performed using the R 4.4.1 software (R–CORETEAM 2024) in RStudio (version 2024.04.2), the Packages 'stats' (version 4.3.1) for statistical analyses and the 'ggplot2' (version 3.4.3) for graphic representation. PCA analysis was carried out using standardized data.

Valvae length and width, ends shape, striae density (LM and SEM), and porte–crayon and central area measures (SEM) were considered for the statistical analysis of the following species: *F. magnifica* (22 valvae), *F. aotearoa* (3) (Beier & Lange–Bertalot 2007), *F. bahlsii* (14) (Edlund & Brant 1997), and *F. santaerosae* (6) (Lange–Bertalot & Sterrenburg 2004; Metzeltin & Lange–Bertalot 2007). Characteristics with high collinearity that could affect the model variance were eliminated from the PCA; only valve width, number of transapical and longitudinal striae in 10 µm, minimum transapical distance between raphe ribs at the central nodule, and helictoglossa length were considered.

Results and Discussion

***Frustulia lineata* P.C. Ferreira et T.V. Ludwig, sp. nov. (Figs 1–14)**

Description

Light microscopy (Figs 1–8): Valves linear–lanceolate, with rostrate ends. Valves 23–27.5 µm long, 5.5–6.5 µm wide (n=11) with a mean length/width ratio of 3.7–4.5. **Scanning electron microscopy (Figs 9–14):** Striae transapical and longitudinal parallel throughout, transapical striae 40 in 10 µm, longitudinal striae 40–44 in 10 µm, circumpolar striae present (Fig 10, 13). Axial area linear ending in a cuneate hyaline field (Fig 11). Areolae open externally through by small circular pores (Figs 11–12). Internally, areolae open through small linear pores (Figs 13–14). External raphe linear, with distal and proximal T–shaped endings (Figs 11–12). Internal longitudinal ribs extend from apex to apex, fusing distally with the helictoglossa, forming the cuneate porte–crayon (Fig 13). Porte–crayon 0.9–1 µm wide, helictoglossa 0.8 µm long. Central nodule slightly constricted (Fig 14), minimum width 1.3–1.4 µm and maximum width 1.4–1.5 µm.

Etymology: The specific epithet refers to the linear valvae shape of the species.

Holotype: UPCB! Naphrax slide UPCB76016, Herbarium of Universidade Federal do Paraná (UPCB), Curitiba municipality, Brazil. Holotype specimen is illustrated in Fig. 4, circled in slide.

Type locality: Brazil, State of Paraná, Piraquara municipality, Salto river, 25°29'44"S, 48°59'23"W, collected by R. Garbuio et al. on 09/29/2004.

Habitat: Aerophytic, epipelic, and epiphytic.

Ecology: The new species occurred in acidic water (pH

Table 1. Data of samples in which *Frustulia* species was found. (Con) = conductivity ($\mu S.cm^{-1}$), (Temp) = temperature (°C), (Alt) = altitude (m a.s. l.)

UPCB	Sampling date	pH	Con	Temp	Alt	Sample	Habitat	Coordinates	Locality
49409	07/2004	4.7	20.1	16	825	Aerophytic	Bryophyte	26°00'26.0"S 49°11'11.2"W	Negro River
76016	09/29/2013	6.2	19.6	15.5	946	Epiphytic	Macrophyte	25°29'44"S 48°59'23"W	Salto River
76017	09/29/2013	6.4	12.9	11.2	1063	Epipelic	Rock	25°29'37"S 48°58'38"W	Carvalho River
76056	04/30/2014	6.1	18.7	15	948	Epiphytic	Moss	25°29'45.0"S 48°59'21.9"W	Salto River

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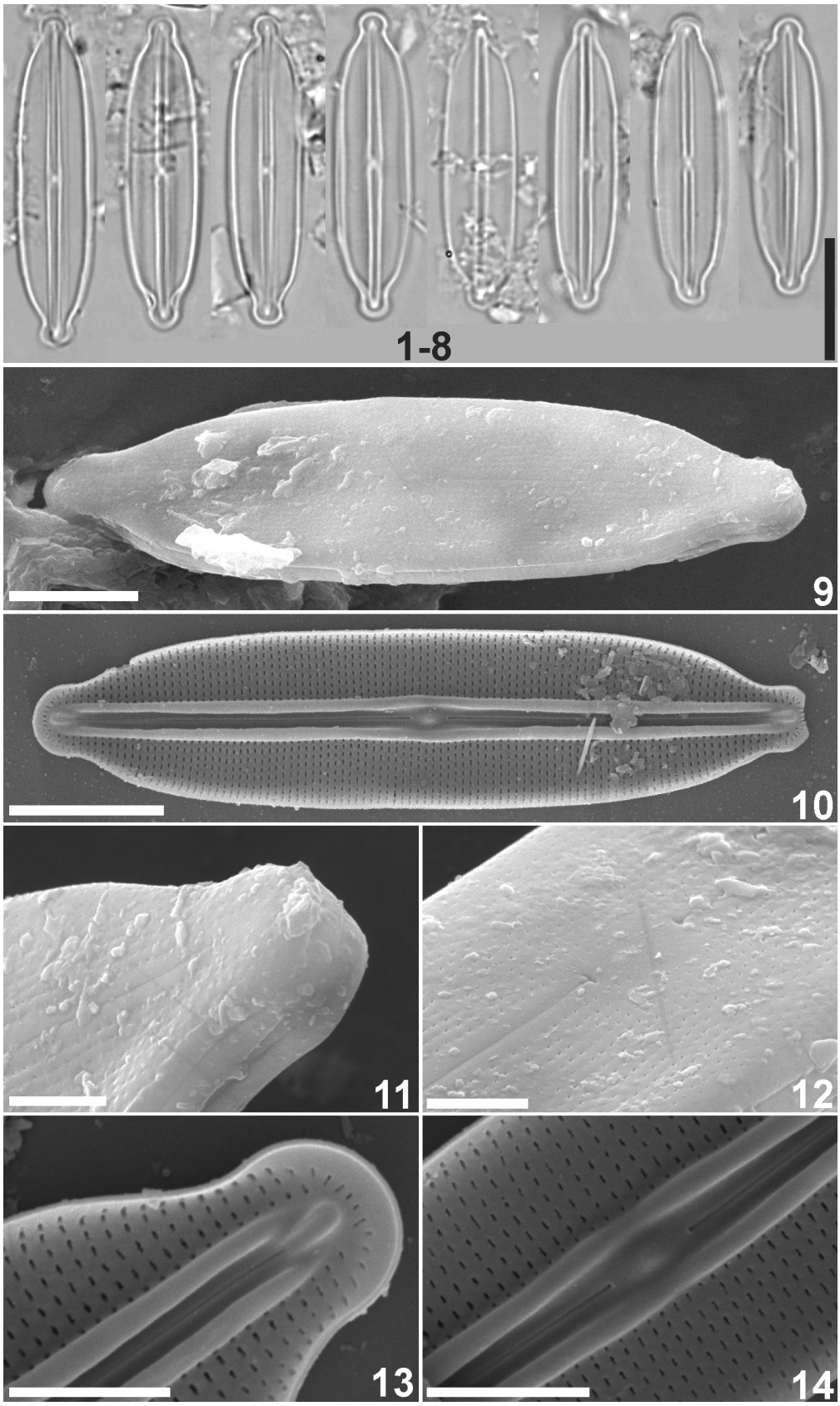
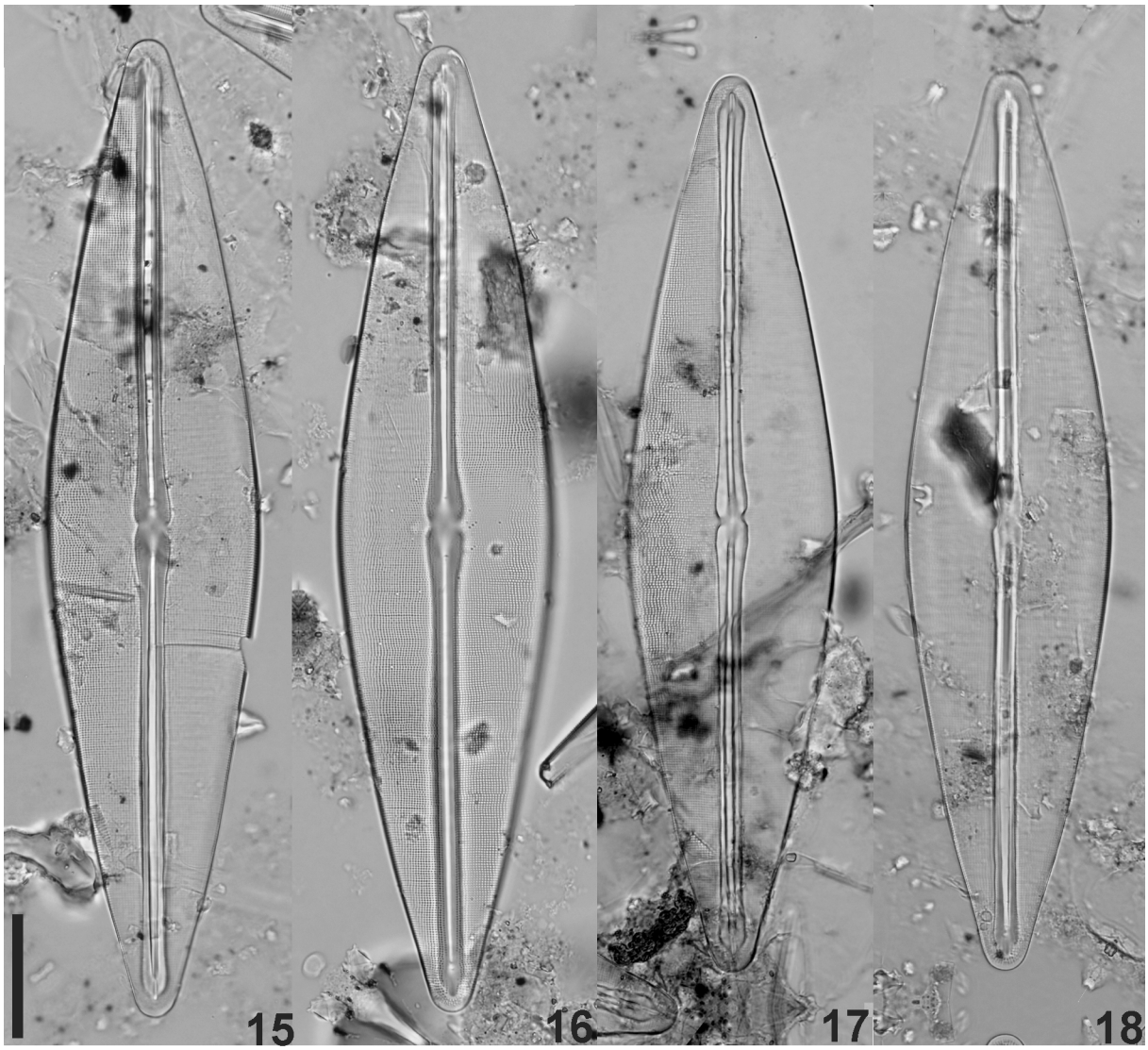


Figs 1–14. *Frustulia lineata* P.C. Ferreira et T.V. Ludwig sp. nov.: (1–8) LM valves view, showing morphological variability, (4) holotype specimen; (9–14) SEM, (9) external valve view, (10) internal valve view, (11) external valve view, details of the external raphe with distal T–shaped endings, (12) external valve view, details of the external raphe with proximal T–shaped endings, (13) internal view of the end, detail of the porte–crayon and helictoglossae, (14) internal view of the central nodule. Scale bars 10μm (1–8), 5μm (9–10) and 2μm (11–14).



Figs 15–18. *Frustulia magnifica* P.C. Ferreira et T.V. Ludwig sp. nov.: (15–18) LM valves view, showing morphological variability, (16) holotype specimen. Scale bar 10µm.

6.2), associated with macrophytes and rocky substrates. In aerophytic samples, specimens were found associated with moss.

Distribution: The species has been found only in the type locality.

Remarks: *Frustulia lineata* is mainly characterized by small linear valves with parallel margins and rostrate ends. The specimens hereby described and illustrated are similar to *F. marginata* Amossé and *F. saxonica* f. *indica* Sarode et Kamat, two small species with rostrate ends and somewhat lanceolate valvae (Table S1). The type population of *F. marginata* was described from France and is distinguished by the elliptic valve, higher length (37 µm), lower striae density (32 in 10 µm), and a "longitudinal, submarginal line parallel to the outline" (Amossé 1932, Lange–Bertalot 2001), sharing with *F. lineata,* only the valve width, and the ends shape. The longitudinal submarginal line was documented by drawing and LM photo no scanning electron microscopy has been performed to date. Certainly, it is a displaced connective band, common in some species of the genus, and not a structure that can be considered a diagnostic feature. The other records of *F. marginata* are in Germany (Lange–Bertalot 2001; Hofmann et al. 2018), Netherlands (Lange–Bertalot 2001), Japan (Kihara et al. 2015), Argentina (Frenguelli 1942) and Brazil (Tremarin et al. 2009; Silva et al. 2011). The figures and descriptions in this literature were checked, and the identification corresponded to *F. marginata*. The records of Brazil are in catalogs (Tremarin et al. 2009, Silva et al. 2011), and the figures are available in Bigunas' (2005) and Delgado's (2006) master's dissertations. We reviewed the taxonomic identification of the specimens available in the monographs and concluded that one corresponds to *F. marginata* (Cap 3, Fig 3, Delgado 2006), and the other is identical to *F. lineata* sp. nov. (Fig 624,

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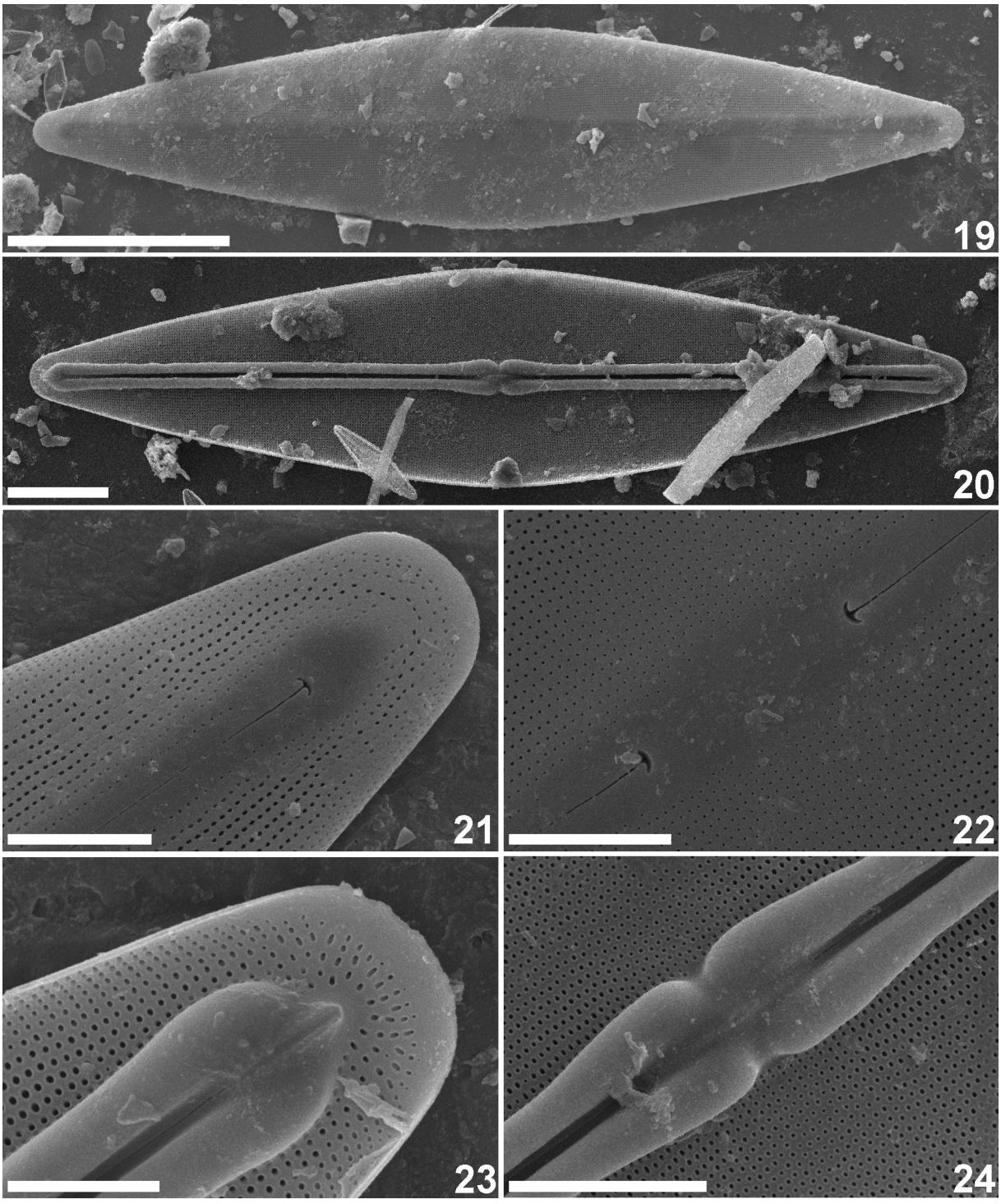

Figs 19–24. *Frustulia magnifica* P.C. Ferreira et T.V. Ludwig sp. nov., SEM: (19) external valve view; (20) internal valve view; (21) external valve view, details of the external raphe with distal T–shaped endings; (22) external valve view, details of the external raphe with proximal T–shaped endings; (23) internal view of the end, detail of the porte–crayon and helictoglossae; (24) internal view of the central nodule. Scale bars 50µm (19), 20µm (20) and 5µm (21–24).

Bigunas 2005).

Frustulia lineata sp. nov. has much longer and wider valves and denser longitudinal striae than *Frustulia saxonica* f. *indica*, recorded only for type–locality in India. Few morphological details are known, and only one species drawing is available for Sarode & Kamat (1984).

***Frustulia magnifica* P.C. Ferreira et T.V. Ludwig, sp. nov. (Figs 15–24)**

Description

Light microscopy (Figs 15–18): Valves rhombic–lanceolate, Attenuate–rounded ends (Figs 15–16), sometimes slightly detached from valve body (Figs 17–18). Valves 179–211 µm long, 42.5–45 µm wide (n=12) with a mean

length/width ratio of 4.2–4.6.

Scanning electron microscopy (Figs 19–24): Striae parallel throughout, transapical striae 16–24 in 10 µm, longitudinal striae 16–19 in 10 µm, circumpolar striae present (Figs 19, 21). Axial area linear ending in a cuneate hyaline field (Fig. 21). Areolae open externally through small circular pores (Figs 21–22). Internally, areolae larger, circular, and covered by an elevated hymen (Figs 23–24). External raphe linear with distal and proximal T–shaped endings (Figs 21–22). Internal longitudinal ribs extend from apex to apex, fusing distally with the helictoglossa, forming the cuneate porte–crayon (Fig 23). Porte–crayon 4.8–5.6 µm wide and helictoglossa 3.6 µm long. Central nodule constricted (Fig 24), minimum width 4.1–5.8 µm and maximum width 6–7.4 µm.

Etymology: The specific epithet refers to the large size of the cells of the species.

Holotype: UPCB! Naphrax slide UPCB49409, Herbarium of Universidade Federal do Paraná (UPCB), Curitiba municipality, Brazil. Holotype specimen is illustrated in Fig. 16, circled in slide.

Type locality: Brazil, State of Paraná, Tijucas do Sul municipality, Negro River, 25°56'44.0"S, 49°17'04.0"W, collected by T.F. Neiva on 07/2004.

Habitat: Aerophytic, epiphytic.

Ecology: The new species was associated with *Rhacocarpus inermis* (Müll. Hal.) Lindb. The individuals were found in acidic water (pH 4.7), relatively cold water (16 °C), with a 20.1 $\mu S.cm^{-1}$ electric conductivity.

Distribution: The species has been found only in the type locality.

Remarks: *Frustulia magnifica* is one of the largest taxa of the genus. Few species have valve lengths greater than 200 µm, including *F. aotearoa* Lange–Bertalot et Beier (Beier 2007), *F. bahlsii* Edlund et Brant (Edlund & Brandt 1997), *F. rhomboides* f. *occidentalis* Sovereign (Sovereign 1963), and *F. sanctaerosae* Lange–Bertalot et Sterrenburg (Lange–Bertalot & Sterrenburg 2004) (Table S2). The characteristic that best distinguishes *F. magnifica* is the range of valve width dimensions (42.5–45 µm), the minimum width limit is higher than that of any other species mentioned in Table S2. *Frustulia aotearoa* differs by having obtusely rounded ends not detached from the valve body (LM), smaller measurements of valve width (25–38 µm), parallel, becoming subparallel to slightly convergent towards the ends, higher density of transapical (25–26/10 µm) and longitudinal striae (22–24 in 10 µm), slightly smaller porte–crayon (4.2–4.3 µm), longer helictoglossa (5 µm) and smaller maximum rib width (5 µm) in the central area (Beier 2007). *F. rhomboides* f. *occidentalis* differs in its much smaller width (30–32 µm) (Sovereign 1963). However, comparisons are restricted because the description of *F. rhomboides* f. *occidentalis* is very succinct, and no illustrations were provided. So far, it has not been possible to find other descriptions or illustrations of the species in the literature. The similar *F. bahlsii* differs from *F. magnifica* mainly by the spatulate shape and smaller measurements (2.9–4.1 µm) of the porte–crayon, smaller valve width (24–34 µm), higher length/width ratio (4.8–5.6), denser transapical striae (20–26/10 µm), shorter length of helictoglossa (2.9–3.5 µm) and smaller maximum rib width (5.4–5.8 µm) in the central area (Edlund & Brandt 1997; Bouchardt et al. 2020).

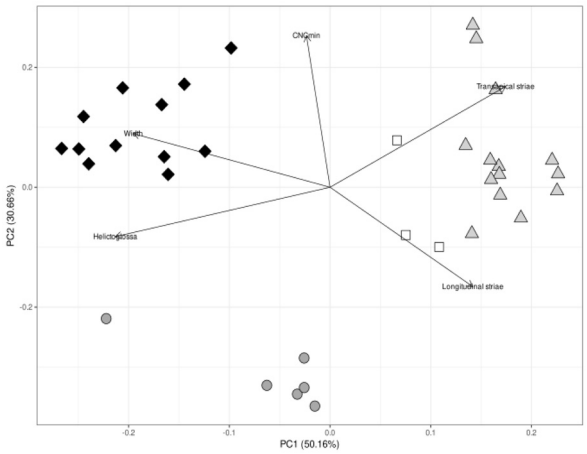

Fig 25. Principal components analysis (PCA) on the morphological characteristics (valve width, number of transapical and longitudinal striae in 10 µm, minimum transapical distance between raphe ribs at the central nodule, and helictoglossa length) of four *Frustulia* species (□ *F. aotearoa*, ▲ *F. bahlsii*, ○ *F. sanctarosae* and ♦ *F. magnifica* sp. nov.).

Frustulia sanctaerosae differs from *F. magnifica* by having higher density of transapical striae (25–28 in 10 µm), lower density of longitudinal striae (12–15 in 10 µm), smaller valve width (26–32 µm), and smaller measures of porte–crayon (3.3–4.1 µm) (Lange–Bertalot & Sterrenburg 2004; Metzeltin & Lange–Bertalot 2007).

The PCA analysis (Fig. 25), with 80.79% of explanation, clearly distinguished four similar species: *F. aotearoa, F. bahlsii, F. magnifica* sp. nov., and *F. sanctaerosae*. *Frustulia rhomboides* f. *occidentalis* was not considered due to a lack of data. The statistical variations of the analyzed data showed that *F. magnifica* sp. nov. is distinct from the other four related *Frustulia* based on valve width and helictoglossa length.

Regarding the geographic distribution of larger species (length with maximum limit = or greater than 200 µm) *Frustulia aotearoa* and *Frustulia rhomboides* f. *occidentalis* were registered only in their type locality, respectively, New Zealand (Beier 2007) and the USA (Sovereign 1963).

Frustulia sanctarosae was registered in the type locality, in the state of Florida, USA, and it is assigned as a fossil species (Lange–Bertalot & Sterrenburg 2004). In addition, it was found in samples from Hustedt`s collection, from Lake Jurucuí, state of Pará, Brazil (Metzeltin & Lange–Bertalot 2007).

Frustulia bahlsii has a broader distribution, with records in Europe, North America, and South America

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(Edlund & Brant 1997; Lange–Bertalot 2001; Siver & Baskette 2004; Metzeltin & Lange–Bertalot 2007; Siver & Hamilton 2011; Bouchard et al. 2020). The only register of *F. bahlsii* from Brazil is the one registered in the catalog of Tremarin et al. (2009). The sample collected in Tijucas do Sul city was reanalyzed in the present study. The specimens found were studied under LM and SEM. We concluded that these specimens were not *F. bahlsii* but rather *F. magnifica* sp. nov. the new species proposed here. Consequently, the register of *F. bahlsii* does not occur in Brazil.

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References

Amossé, A. (1932): Diatomées de la Loire–Inférieure. – Bulletin de la Société des Sciences Naturelles de l'Ouest de la France (Nantes) 5, Sér. 2: 1–57.

Beier, T. & Lange–Bertalot, H. (2007): A synopsis of cosmopolitan, rare and new Frustulia species (Bacillariophyceae) from ombrotrophic peat bogs and minerotrophic swamps in New Zealand. – Nova Hedwigia 85: 73–91. DOI: https://doi.org/10.1127/0029–5035/2007/0085–0073

Bicudo, D.C. & Menezes, M. (2017): Gêneros de Algas de Águas Continentais do Brasil chave para identificação e descrições. − 508 pp., Rima, São Carlos.

Bigunas, P.I.T. (2005): Diatomáceas (Ochrophyta) do rio Guaraguaçu, litoral do Paraná, Brasil. − http://hdl.handle.net/1884/21299. [accessed: 19 June 2024].

Bouchard, A.J.; Hamilton, P.B.; Savoie, A.M. & Starr, J.R. (2020): Molecular and morphological data reveal hidden diversity in common North American *Frustulia* species (Amphipleuraceae). – Diatom research 34: 205–223. DOI: https://doi.org/10.1080/0269249X.2019.1704889

Brassac, N.M. & Ludwig, T.A.V. (2005): Amphipleuraceae e Diploneidaceae (Bacillariophyceae) da bacia do rio Iguaçu, PR. Brasil. – Acta Botânica Brasilica 19: 359–368. DOI: https://doi.org/10.1590/S0102–33062005000200019

Costa, L.F.; Wengrat, S. & Bicudo, D.C. (2017): Diatomáceas de diferentes habitats em um reservatório altamente heterogêneo, Complexo Billings, Sudeste do Brasil. – Hoehnea 44: 559–579. DOI: https://doi.org/10.1590/2236–8906–12/2017

Delgado, S.M. (2006): Levantamento florístico das Naviculales (Bacillariophyceae) perifíticas do Rio Descoberto, Goiás e Distrito Federal − https://repositorio.unb.br/handle/10482/2169. [accessed: 19 June 2024].

Díaz–Castro, J.G.; Souza–Mosimann, R.M.; Laudares–Silva. R. & Forsberg, B.R. (2003): Composição da comunidade de diatomáceas perifíticas do Rio Jaú, Amazonas. – Brazil. Acta Amazonica 33: 583–606. DOI: https://doi.org/10.1590/S0044–59672003000400005

Edlund, M.B. & Brant, L.A. (1997): *Frustulia bahlsii* sp. nov., a freshwater diatom from the eastern U.S.A. – Diatom Research 12: 207–216. DOI: https://doi.org/10.1080/0269249X.1997.9705415

Frenguelli, J. (1942): Contribución al conocimiento de las diatomeas Argentinas. Diatomeas del Neuquén (Patagonia). – Revista del Museo de La Plata Nueva 20: 73–219.

Graeff, C.L.; Kociolek, J.P. & Burliga, A.L. (2012): Valve morphology of four species of *Frustulia* (Bacillariophyta), including two described as new. – Phytotaxa 42: 62–76. DOI: https://doi.org/10.11646/phytotaxa.42.1.8

Guiry, M.D. & Guiry, G.M. 2025. *AlgaeBase*. World-wide electronic publication. – University of Galway. https://www.algaebase.org. [accessed: 19 June 2024]

Hofmann, G.; Lange–Bertalot, H.; Werum, M. & Klee, R. (2018): Rote Liste und Gesamtartenliste der limnischen Kieselalgen (Bacillariophyta) Deutschlands. – In: Rote Liste gefährdeter Tiere, Pflanzen und Pilze Deutschlands. – Naturschutz und Biologische Vielfalt 70: 601–708.

IAT – Instituto Água e Terra. (2023): Classificação da Vegetação – Litoral Paranaense. −https://www.iat.pr.gov.br/Pagina/Dados–e–Informacoes–Geoespaciais–Tematicos. [accessed: 10 June 2024]

Kihara, Y.; Tsuda, K.; Ishii, C.; Ishizumi, E. & Ohtsuka, T. (2015): Periphytic diatoms of Nakaikemi Wetland, an ancient peaty low moor in central Japan. – Diatom 31: 18–44. DOI: https://doi.org/10.11464/diatom.31.18

Kociolek, J.P. (2018): A worldwide listing and biogeography of freshwater diatom genera: a phylogenetic perspective. – Diatom Research 33: 509–534. DOI: https://doi.org/10.1080/0269249X.2019.1574243

Lange–Bertalot, H. & Sterrenburg, F.A.S. (2004): New *Frustulia* species (Bacillariophyceae) from fossil freshwater deposits in Florida, U.S.A. – Nova Hedwigia 78: 527–537. DOI: https://doi.org/10.1127/0029–5035/2004/0078–0527

Lange–Bertalot, H. (ed.) (2001): *Navicula* sensu stricto, 10 genera separated from Navicula sensu lato, *Frustulia,* Diatoms of Europe, Vol. 2: diatoms of the European inland waters and comparable habitats. – 526 pp., A.R.G. Gantner Verlag K.G, Ruggell.

Metzeltin, D. & Lange–Bertalot, H. (1998): Tropical Diatoms of South America I. – Iconographia Diatomologica 5: 1–695.

Metzeltin, D. & Lange–Bertalot, H. (2007): Tropical Diatoms of South America II. Iconographia Diatomologica 18: 1–877.

Morales, E.A. (2020): *Frustulia tunariensis* sp. nov. (Bacillariophyceae) from the Andes of Bolivia, South America. – Diversity 12: 362. DOI: https://www.mdpi.com/1424–2818/12/9/362

Plano Diretor Municipal – Tijucas do Sul. (2023): Aspectos regionais. −https://portaldosmunicipios.pr.gov.br/download/public/arquivos/documentos/334/2019/03/18/ta7u977317qEHSMILVqUPq4YZ8FVql5nh1t5uyfS.pdf. [accessed: 10 June 2024].

R–CoreTeam. (2024): R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.r–project.org/.

Round, F.E.; Crawford, R.M. & Mann, D.G. (1990): The diatoms. Biology & morphology of the genera. – 747 pp., Cambridge University Press, Cambridge.

Sarode, P.T. & Kamat, N.D. (1984): Freshwater diatoms of Maharashtra. – 338 pp., Saikripa Prakashan, Aurangabad, India.

Silva, W.J.; Nogueira, I.S. & Souza, M.G.M. (2011): Catálogo de diatomáceas da região Centro–Oeste brasileira. – Iheringia 66: 61–86.

Simonsen, R. (1974): The diatom plankton of the Indian Ocean Expedition of R/V "Meteor", 1964–65 Meteor. − Forschungsergebnisse Reihe D–Biologie 19: 1–66

Siver, P.A. & Baskette, G. (2004): A morphological examination of *Frustulia* (Bacillariophyceae) from the Ocala National Forest, Florida, USA. – Canadian Journal of Botany 82: 629–644.

Siver, P.A & Hamilton, P.B. (2011): Diatoms of North America: the freshwater flora of waterbodies on the Atlantic Coastal Plain. – Iconographia diatomologica 22: 1–916.

Soares, F.S.; Konoplya, B.I.B.; Silva, J.F.M.; Andrade, C.G.T.J. (2011): Amphipleuraceae (Bacillariophyceae) do alto da bacia do Ribeirão Cambé, Londrina, Brasil. – Revista Brasileira de Botânica 34: 39–49. DOI: https://doi.org/10.1590/S0100–84042011000100005

Sovereign, H.E. (1963): New and rare diatoms from Oregon and Washington. – Proceedings of the California Academy of Sciences 31: 349–368.

Spaulding, S.A.; Potapova, M.G.; Bishop, I.W.; Lee, S.S.; Gasperak, T.S.; Jovanoska, E.; Furey, P.C. & Edlund, M.B. (2021): Diatoms.org: supporting taxonomists, connecting communities. – Diatom Research 36: 291–304. DOI: https://doi.org/10.1080/0269249X.2021.2006790

Tremarin, P.; Freire, E.; Bertolli, L. & Ludwig, T.A.V. (2009): Catálogo das diatomáceas (Ochrophyta–Diatomeae) continentais do estado do Paraná. – Iheringia 64: 79–107.

Supplementary material

The following supplementary material is available for this article:

Table S1. Comparison of *Frustulia lineata* P.C. Ferreira et T. Ludwig, sp. nov. with similar species.

Table S2. Comparison of *Frustulia magnifica* P.C. Ferreira et T. Ludwig, sp. nov. with similar species.

This material is available as part of the online article (http://fottea.czechphycology.cz/contents)

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