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Research article

Four new monoraphid diatom species (Bacillariophyta, Achnanthaceae) from the Maritime Antarctic Region

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Abstract. Four monoraphid taxa belonging to the genera *Achnanthes*, *Psammothidium* and *Planothidium* were found during the ongoing taxonomic revision of the freshwater and limno-terrestrial diatoms of the Maritime Antarctic region. The present paper describes these four taxa as new based on detailed light and scanning electron microscopy observations: *Achnanthes kohleriana* Kopalová, Zidarova & Van de Vijver sp. nov., *Planothidium wetzelectorianum* Kopalová, Zidarova & Van de Vijver sp. nov., *Psammothidium confusoneglectum* Kopalová, Zidarova & Van de Vijver sp. nov. and *Psammothidium superpapilio* Kopalová, Zidarova & Van de Vijver sp. nov. The morphology and ecology of all four taxa are discussed and the species are compared with morphologically similar taxa.

Keywords. *Achnanthes*, *Planothidium*, *Psammothidium*, new species, biogeography, Antarctica.

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Introduction

The past 10 years, the non-marine diatom flora of the Maritime Antarctic Region has been undergoing a serious revision following a fine-grained taxonomy that has been widely accepted nowadays. Prior to this revision, only very sparse literature existed on the diatom composition of the Antarctic region and the reported diatom flora was based on a very broad species concept, making the use of this literature in biogeographical and biodiversity studies less appropriate due to the many inconsistencies in the diatom

identification. The revision resulted in the description of a large number of new taxa, predominantly in biraphid genera such as *Luticola* D.G.Mann (Kopalová *et al.* 2011, Zidarova *et al.* 2014, Kohler *et al.* 2015), *Navicula* Bory (Van de Vijver *et al.* 2011), *Pinnularia* Ehrenb. (Zidarova *et al.* 2012) and *Muelleria* Freng. (Van de Vijver *et al.* 2010, 2014).

Apart from the biraphid genera, monoraphid diatoms represent likewise a considerable part of the diatom flora in the entire Antarctic region (including sub-Antarctica, Maritime Antarctica and the Antarctic Continent), both in number of species and number of individuals. Five genera have actually been regularly observed in Antarctic samples: *Achnanthes* Bory s.s., *Achnanthidium* Kütz., *Karayevia* Round & Bukht., *Planothidium* Round & Bukht. and *Psammothidium* Bukht. & Round representing a total of 38 different species (Oppenheim 1994; Van de Vijver *et al.* 2002; Sabbe *et al.* 2003; Le Cohu 2005; Ohtsuka *et al.* 2006). In 2014, Van de Vijver & Kopalová revised the genus *Achnanthidium* in the entire Antarctic region describing two new species. Analysis of the types of *Planothidium lanceolatum* (Bréb.) Lange-Bert. (Van de Vijver *et al.* 2013) and *Achnanthidium exiguum* (Grunow) Czarn. (Taylor *et al.* 2014), both often reported from the Antarctic region (Kellogg & Kellogg 2002), and comparisons of the Antarctic populations earlier assigned to these two taxa, led to the justification of another three new diatom species. The present paper continues the studies on monoraphid diatom species in Antarctica and describes four new monoraphid taxa belonging to the genera *Achnanthes* s.s., *Planothidium* and *Psammothidium* based on detailed light and scanning electron microscopy observations: *Achnanthes kohleriana* Kopalová, Zidarova & Van de Vijver sp. nov., *Planothidium wetzelectorianum* Kopalová, Zidarova & Van de Vijver sp. nov., *Psammothidium confusoneglectum* Kopalová, Zidarova & Van de Vijver sp. nov. and *Psammothidium superpapilio* Kopalová, Zidarova & Van de Vijver sp. nov.

Material and methods

During several austral summers (2004, 2006, 2008, 2009, 2013), material for diatom analysis has been sampled from James Ross Island and the South Shetland Islands (Livingston Island, Deception Island). In order to obtain a broad overview of the diversity and distribution of the diatom communities on the island, samples have been taken from different habitat types: freshwater lakes, seepage areas, wet rocks, rivers and mosses (ranging from aquatic to dry terrestrial). Samples were fixed in the field with 3% formaldehyde. Diatom samples for LM observation were prepared following the method described in Van der Werff (1955). Subsamples of the original material were oxidized using 37% H_2O_2 and heating to 80°C for approximately 1h. The reaction was further completed by the addition of $KMnO_4$. Following digestion and centrifugation (three times 10 minutes at 3700x g), the material free of organic matter was diluted with distilled water for sample mounting to avoid excessive concentrations of diatom valves on the slides. A subsample from the organic-free material was mounted in Naphrax® for diatoms community studies. The slides were analysed at BR using an Olympus BX53 microscope, equipped with Differential Interference Contrast (Nomarski). LM micrographs were taken using Olympus UC30 camera connected to the Cell Sense Standard program. For scanning electron microscopy (SEM), parts of the oxidized suspensions were filtered through polycarbonate membrane filters with a pore diameter of 1 µm, pieces of which were fixed on aluminium stubs after air-drying. The stubs were sputter-coated with a Gold-Palladium layer of 20 nm and studied in a ZEISS ULTRA SEM microscope at 3 kV. Terminology follows Hendey (1964), Barber & Haworth (1981), Round *et al.* (1990) and Lange-Bertalot (1993).

For the typification of the new species, we chose to use the entire slide as the holotype. In monoraphid diatoms, both valves of the same frustule show a different morphology, so two valves should be chosen to represent the holotype. Moreover, diatoms show a broad variability along their cell cycle making the choice for the entire population on the slide more obvious.

Results

Class Bacillariophyceae Haeckel emend. Medlin & Kaczmarska (Medlin & Kaczmarska 2004)
Subclass Bacillariophycidae D.G.Mann *in* Round *et al.* (1990)
Order Achnanthales P.C.Silva (Silva 1962)
Family Achnanthidiaceae D.G.Mann *in* Round *et al.* (1990)
Genus *Achnanthes* Bory (Bory 1822)

Achnanthes kohleriana Kopalová, Zidarova & Van de Vijver sp. nov.
Figs 1–24

Etymology

The species is named after our friend and colleague Dr. Tyler Kohler (Charles University in Prague and University of Boulder, Colorado, USA) in recognition of his diatom ecology work in the Dry Valleys of the Antarctic Continent.

Type

Deception Island, South Shetland Islands, Antarctica, sample D13 (62°58′24.5″ S 60°43′03.2″W) (leg. R. Zidarova), coll. date: 21 Jan. 2013 (holo-: slide no. BR–4436; iso-: slide PLP–292, University of Antwerp, Belgium).

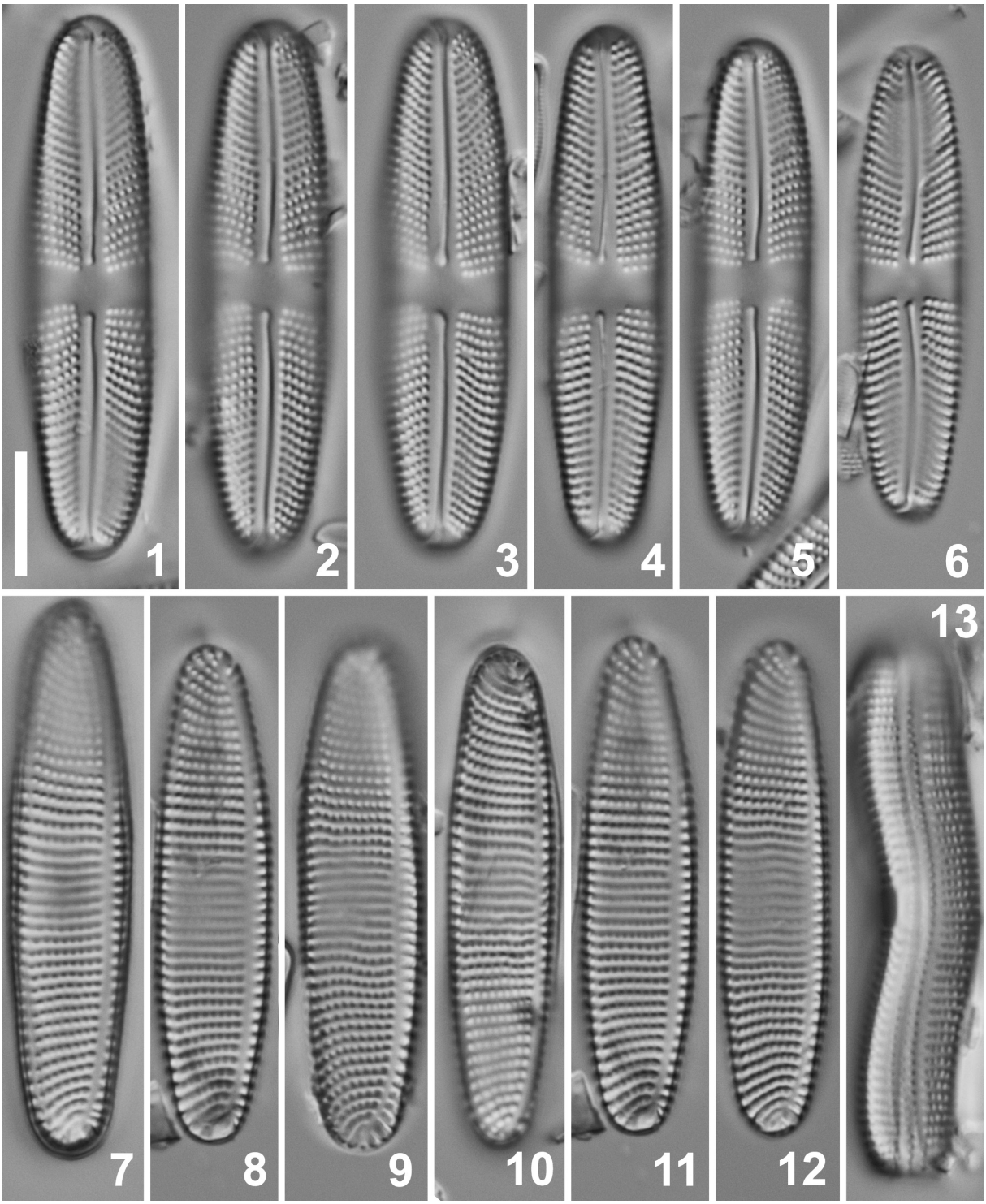
Description

Light microscopy (Figs 1–13)

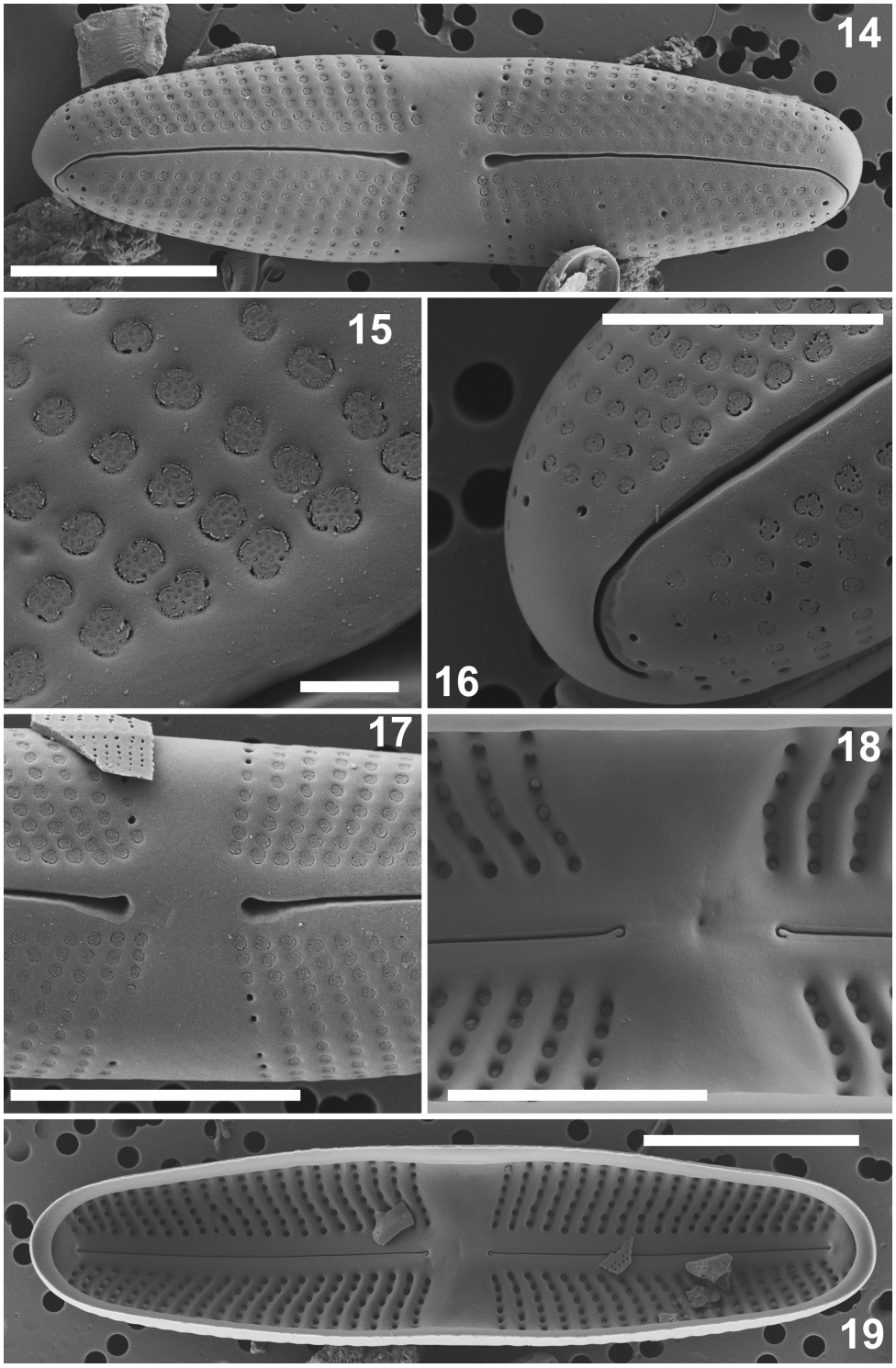
Frustules in girdle view bent, with concave raphe valve and convex rapheless valve (Fig. 13). Valves linear to linear-elliptic, with almost straight to weakly concave in the middle valve margins. Valve apices broadly rounded, not protracted. Valve dimensions (n = 24): length 38–45 µm, width 9.0–10.5 µm. Raphe valve (Figs 1–6): raphe distinctly lateral, curved. Proximal raphe endings deflected to one side terminating in drop-like expanded pores. Distal raphe fissures elongated and hooked. Axial area 1/4–1/5 of the valve width, almost linear, following the curvature of the raphe, not or only slightly widening toward the central area. Central area forming a rectangular to bow-tie-shaped fascia, lacking any striae near the margins. Transapical striae weakly to moderately radiate in the middle, becoming more radiate toward the apices, 11–12 in 10 µm. Areolae well discernible in LM, rounded, *c.* 14–18 in 10 µm. Rapheless valve (Figs 7–12): rapheless sternum narrow, located close to the valve margin. Striae parallel at the valve middle, becoming radiate toward the apices, 10–11 in 10 µm. Areolae well discernible in LM, rounded, *c.* 14–18 in 10 µm.

Scanning electron microscopy (Figs 14–24)

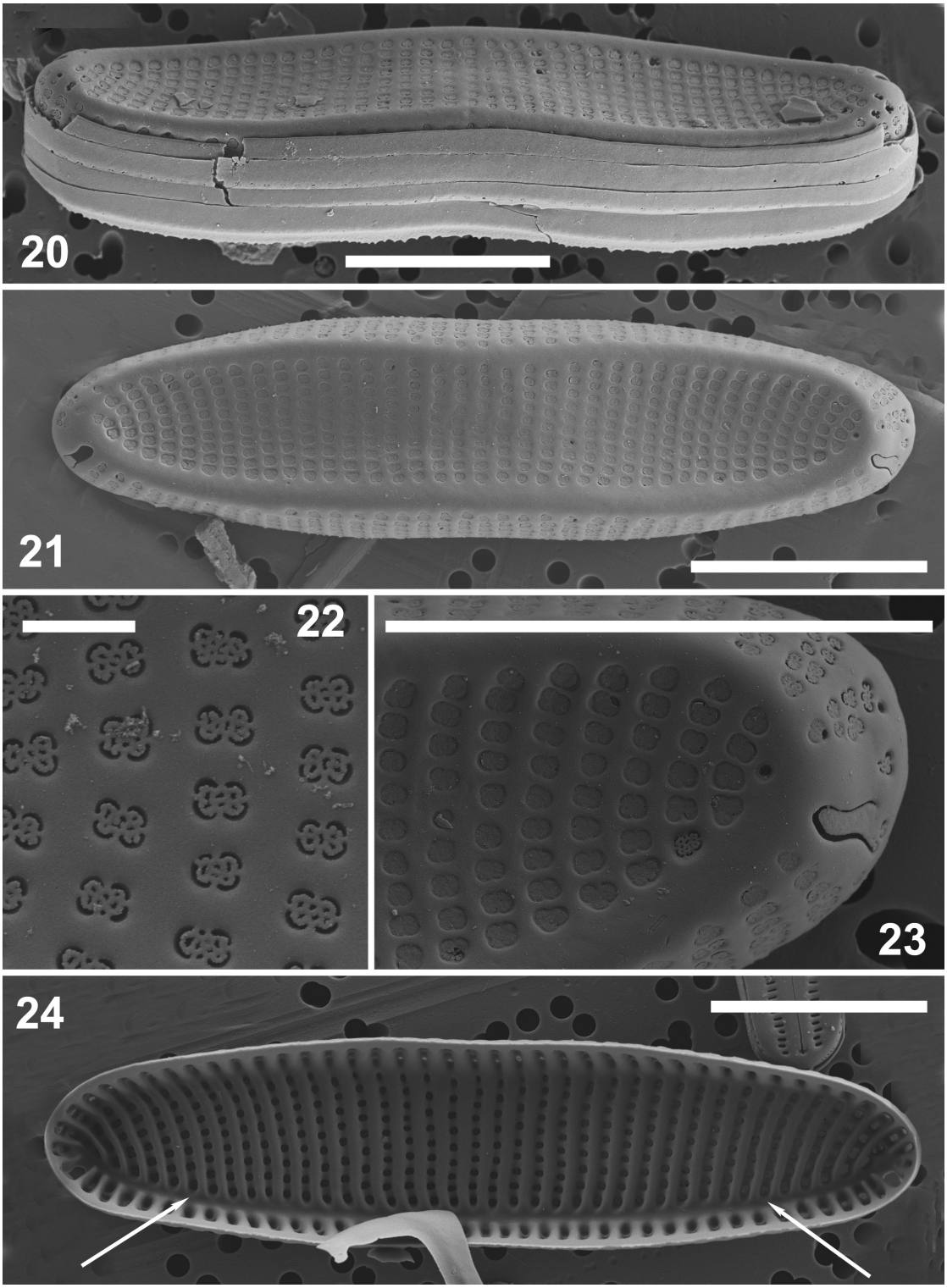
Raphe valve (Figs 14–19): valve face weakly concave in the middle. Apices presenting a rather larger hyaline zone (Figs 14, 16). Raphe slightly curved with tear-drop-shaped, weakly deflected proximal raphe endings, not extending in the central area (Figs 14, 17). Distal raphe fissures running a deep groove, hooked, elongated, continuing onto the mantle, terminating beyond the last striae (Figs 14, 16). Striae uniseriate, composed of almost rounded areolae with slightly recessed foramina, occluded by cribra with rounded perforations (Fig. 15). Small pseudosepta present near the valve apices (Fig. 19). Internally, proximal raphe endings strongly hooked backwards toward the poles (Fig. 18). Distal raphe endings straight, finishing onto small helictoglossae (Fig. 19). Striae separated by strongly thickened virgae (Fig. 19). Areolae with rounded foramina and recessed cribra (Fig. 19). Rapheless valve (Figs 20–24): valve face weakly convex (Fig. 20). A strongly thickened hyaline marginal ridge present at the valve face/mantle junction (Figs 20, 21). Spines absent. Rapheless sternum narrow, located near the valve margin (Fig. 21), internally well discernible as a narrow hyaline line close to the valve margin (Fig. 24, arrows). Terminal orbiculi present on the valve mantle near the apices, occluded by a single, structureless silica



Figs 1–13. *Achnanthes kohleriana* Kopalová, Zidarova & Van de Vijver sp. nov. Light micrographs of the type population from Deception Island (South Shetland Islands, Antarctica). **1–16**. LM views of raphe valves. **7–12**. LM views of rapheless valves. **13**. LM view of a girdle view. Scale bar represents 10 µm.



Figs 14–19. *Achnanthes kohleriana* Kopalová, Zidarova & Van de Vijver sp. nov. Scanning electron micrographs of the type population from Deception Island (South Shetland Islands, Antarctica). **14**. SEM external view of an entire raphe valve. **15**. SEM external detail of the areolae with the typical cribrate structure. **16**. SEM external view of the distal raphe ending. **17**. SEM external detail of the central area. **18**. SEM internal detail of the central area showing the hooked proximal raphe endings. **19**. SEM internal view of an entire raphe valve. Scale bars represent 10 µm for Figs 14 & 19, 1 µm for Fig. 15 and 5 µm for Figs 16–18.



Figs 20–24. *Achnanthes kohleriana* Kopalová, Zidarova & Van de Vijver sp. nov. Scanning electron micrographs of the type population from Deception Island (South Shetland Islands, Antarctica). **20**. SEM girdle view of an entire frustule. **21**. SEM external view of a raphe valve. **22**. SEM external detail of the areolae with the typical cribrate structure. **23**. SEM external detail of the apex with the typical terminal orbiculus. **24**. SEM internal view of an entire rapheless valve. Arrows show the rapheless sternum. Scale bars represent 10 µm for Figs 20, 21 & 24, 1 µm for Fig. 22 and 5 µm for Fig. 23.

flap (Fig. 23). Striae uniseriate on the valve face, becoming bi-seriate on the valve mantle (Fig. 23). Each stria composed of recessed rounded areolae, occluded by cribra with rounded or irregular perforations (Fig. 22). Internally, striae separated by strongly thickened virgae (Fig. 24). Areolae with rounded openings with noticeably recessed cribra (Fig. 24). Girdle composed of several open copulae, bearing a single row of rounded areolae, occluded by cribra (Fig. 20).

Ecology and distribution

So far *Achnanthes kohleriana* sp. nov. has been observed with certainty on several islands of the South Shetland archipelago (Livingston Island, Deception Island and King George Island). The largest population was found on Deception Island among wet mosses growing on a rock, located inland and far from the influence of sea sprays and with no nutrient input from sea birds or seals suggesting that the species is typically aerophilic. Other taxa present in the sample include *Humidophila keiliorum* Kopalová *in* Kopalová *et al.* (2015), *H. deceptionensis* Kopalová *in* Kopalová *et al.* (2015), *Stauroneis pseudomuriella* Van de Vijver & Lange-Bert. *in* Van de Vijver *et al.* (2004), *S. pseudoschimanskii* Van de Vijver & Lange-Bert. *in* Van de Vijver *et al.* (2004) and several *Luticola* species.

Genus *Planothidium* Round & Bukht. (Round & Bukhtiyarova 1996)

Planothidium wetzelectorianum Kopalová, Zidarova & Van de Vijver sp. nov.
Figs 25–57

Etymology

The species is named after our dear friends and colleagues Dr. Carlos Wetzel and Prof. Luc Ector [Luxembourg Institute of Science and Technology (LIST)] in recognition of the long and fruitful collaboration we had (and have) with these two excellent diatom scientists.

Type

Monolith Lake, James Ross Island, Antarctica, sample JRI-011 (63°53′52.3″S 57°57′29.0″W) (leg. L. Nedbalová), coll. date: 1 Feb. 2008 (holo-: slide no. BR–4437; iso-: slide PLP–293, University of Antwerp, Belgium).

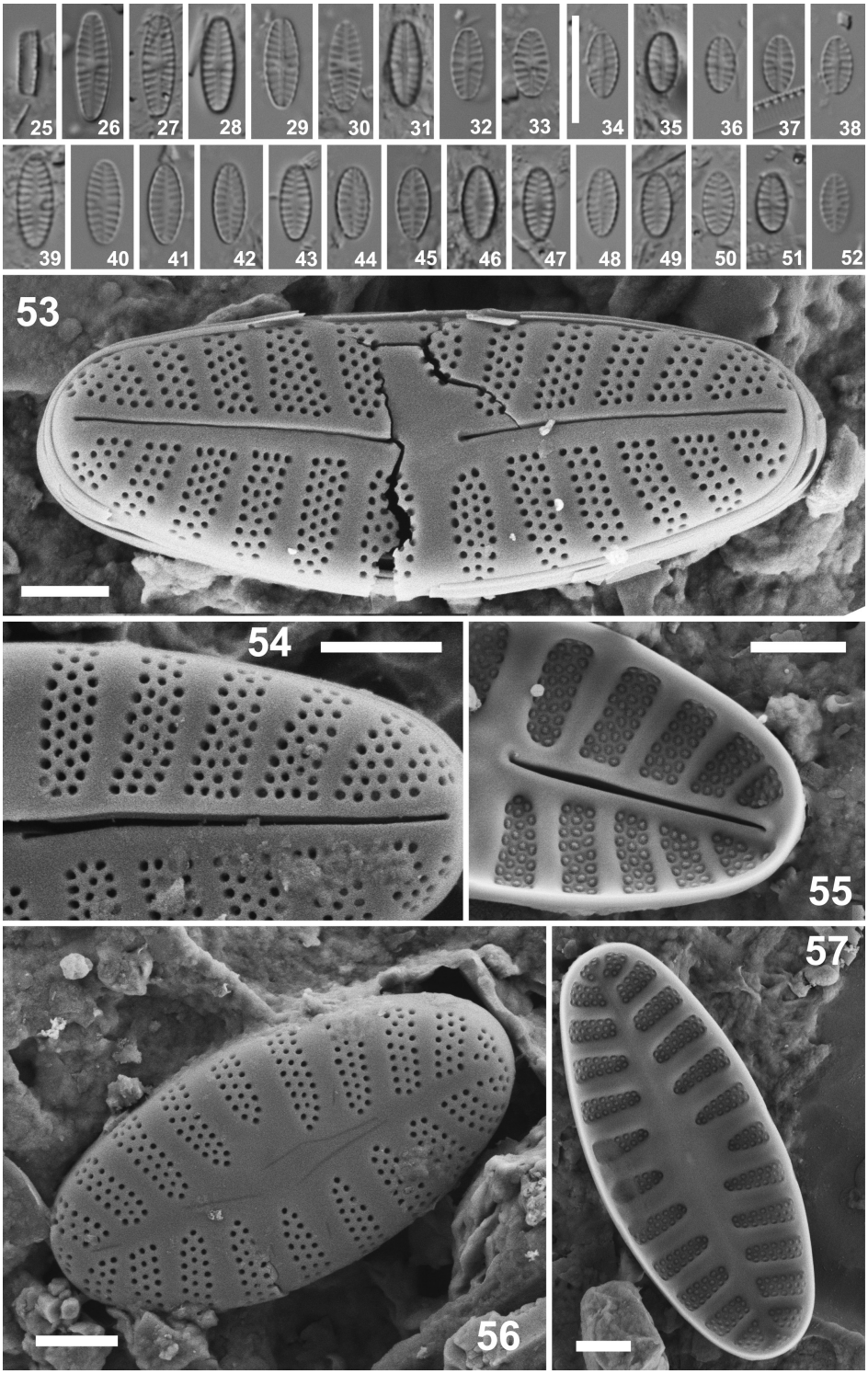
Description

Light microscopy (Figs 25–52)

Frustules in girdle view nearly straight to weakly curved (Fig. 25). Valves linear-elliptical becoming elliptical in smaller specimens. Valve margins convex with broadly rounded, never protracted apices. Neither cavum nor sinus present. Valve dimensions (n = 25): length 5.5–10.0 µm, width 2.6–3.2 µm. Raphe valve (Figs 26–38): axial area very narrow. Central area absent or weakly enlarged due to shortening of two central striae. Raphe straight, difficult to see in LM. Proximal raphe endings indistinct, straight. Distal endings not discernible. Transapical striae weakly radiate throughout the entire valve, clearly broader than the virgae, 14–15 in 10 µm. Areolae not discernible. Rapheless valve (Figs 39–52): axial area very narrow, linear. Central area asymmetrically enlarged due to shortening of one central stria, never forming fascia. Striae radiate throughout, more radiate near the apices, as broad as or broader than the virgae, 16–18 in 10 µm.

Scanning electron microscopy (Figs 53–57)

Raphe valve (Figs 53–55): raphe branches almost straight terminating in indistinct straight pores (Fig. 53). Distal fissures absent (Fig. 54). Raphe terminating immediately beyond the last stria (Fig. 54). Striae composed of 3–5 rows of small, rounded areolae (Figs 53, 54). Near the axial area, each stria composed of usually 4–5 rows of areolae, towards the valve margin only 3 rows of areolae present in the



Figs 25–57. *Planothidium wetzelectorianum* Kopalová, Zidarova & Van de Vijver sp. nov. Light and scanning electron micrographs of the type population in Monolith Lake (James Ross Island). **25**. LM view of a girdle view. **26–38**. LM views of raphe valves. **39–52**. LM views of rapheless valves. **53**. SEM external view of an entire raphe valve. **54**. SEM external detail of the areolae. **55**. SEM internal view of the raphe and the striae. Note the hymenes on the areolae. **56**. SEM external view of an entire rapheless valve. **57**. SEM internal view of an entire rapheless valve. Scale bars represent 10 µm for Figs 25–52, 1 µm for Figs 53–57.

stria (Fig. 54). Virgae clearly narrower than the striae (Fig. 53). Striae only shortly continuing onto the mantle (Fig. 53). Internally areolae covered by star-shaped hymenes (Fig. 55). Virgae clearly thickened and raised. Proximal raphe endings short, deflected (Fig. 55). Distal endings terminating onto small helictoglossae (Fig. 55). Rapheless valve (Figs 56–57): axial area weakly lanceolate. Striae always composed of 3 rows of small, rounded areolae (Fig. 56). Towards the axial area, striae becoming narrower (Fig. 56). Virgae usually as broad or slightly narrower than the striae (Fig. 56). Asymmetric central area clearly observable. Internally areolae covered by hymenes (Fig. 57). Virgae clearly thickened (Fig. 57).

Ecology and distribution

Planothidium wetzelectorianum sp. nov. was only found on James Ross Island in the epilithon and epipelon of Monolith Lake on the Ulu Peninsula. This relatively large lake has an almost circumneutral pH (7.2), a rather lower conductivity value (120 µS/cm) and low nutrient and sulphate values. The samples are dominated by several taxa from the *N. perminuta* complex [*N. kleinteichiana* Hamsher *et al.* (Hamsher *et al.* in press), *N. velazqueziana* Hamsher *et al.* (Hamsher *et al.* in press) and *N. annewillemsiana* Hamsher *et al.* (Hamsher *et al.* in press)], *Humidophila australis* (Van de Vijver & Sabbe) Lowe *et al.* (Lowe *et al.* 2014) and *Achnanthidium australexiguum* Van de Vijver *in* Taylor *et al.* (2014).

Genus *Psammothidium* Bukht. & Round (Bukhtiyarova & Round 1996)

Psammothidium confusoneglectum Kopalová, Zidarova & Van de Vijver sp. nov.
Figs 58–85

Etymology

The specific epithet refers to the possible confusion with *Psammothidium confusum* (Manguin) Van de Vijver.

Type

Byers Peninsula, Livingston Island, South Shetland Islands, Antarctica, sample BYM-051 (62°38′20.1″S 61°06′44.2″W) (leg. B. Van de Vijver), coll. date: 15 Jan. 2009 (holo-: slide no. BR–4438; iso-: slide PLP–294, University of Antwerp, Belgium).

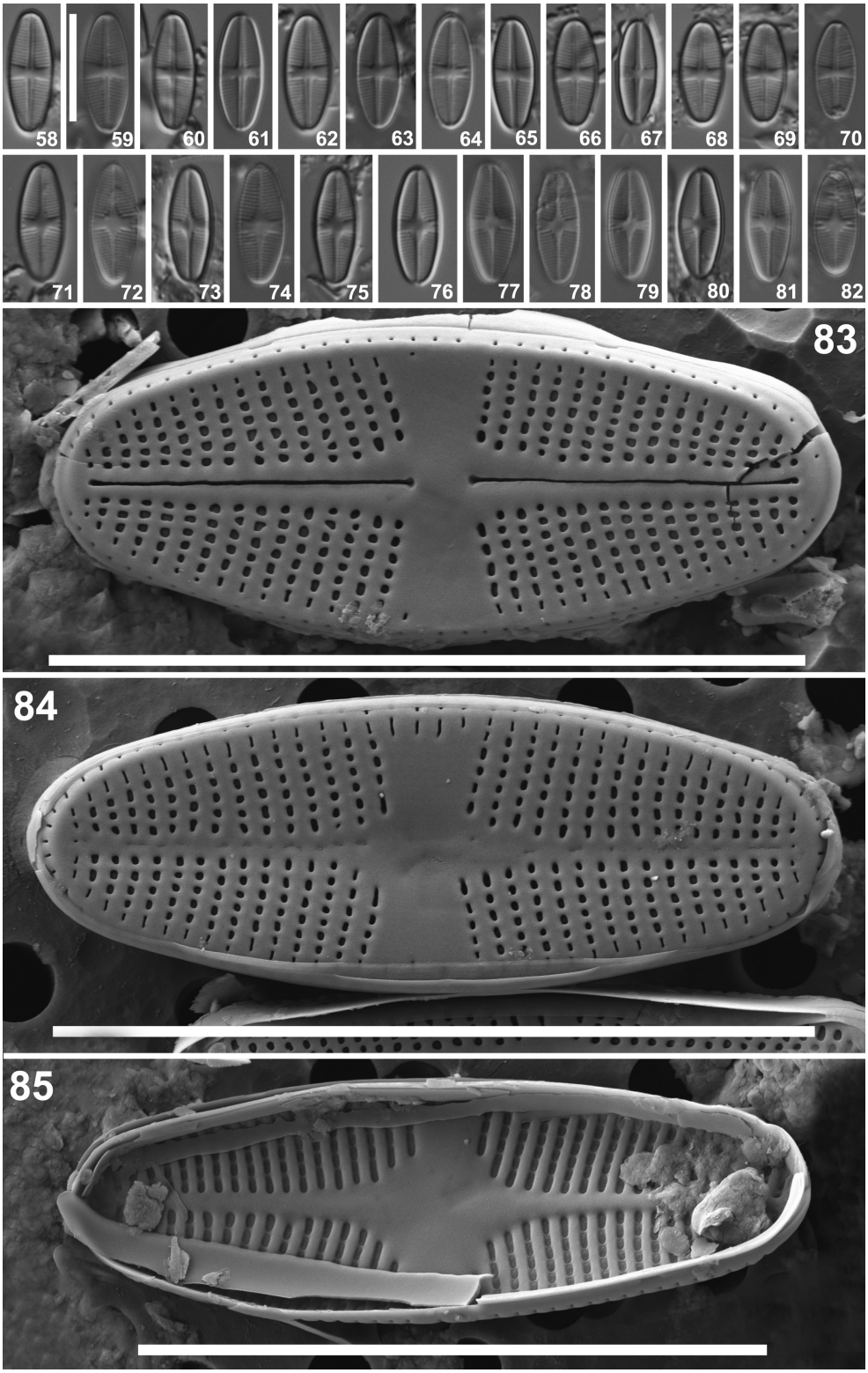
Description

Light microscopy (Figs 58–82)

Valves broadly elliptic-lanceolate with clearly convex margins gradually tapering towards the broadly rounded, non-protracted apices. Valve dimensions (n = 30): length 9–12 µm, width 3.8–4.5 µm. Raphe valve (Figs 58–70): axial area narrow, linear, not widening towards central area. Central area forming a rectangular to bow-tie-shaped fascia with occasionally one to several shortened striae near the valve margins (Figs 62–64, 68). Raphe straight with almost indistinct, straight proximal endings. Distal fissures not discernible in LM. Transapical striae weakly radiate near the central area, becoming more radiate towards the apices, 30–34 in 10 µm. Areolae not discernible in LM. Rapheless valve (Figs 71–82): axial area very narrow, linear distinctly widening towards the central area. Central area rounded to apically elliptical, bow-tie shaped widening towards the valve margins, almost forming a fascia. Regularly, shortened striae present near the valve margins. Transapical striae weakly radiate throughout becoming more radiate towards the apices, 33–36 in 10 µm.

Scanning electron microscopy (Figs 83–85)

Raphe valve (Fig. 83): striae uniseriate, composed of small, rounded to rectangular areolae, the largest areolae located close to the axial area. Number of areolae per stria diminishing towards the axial area. Near valve margins, last areola transapically elongated, slit-like. A row of slit-like areolae present on the



Figs 58–85. *Psammothidium confusoneglectum* Kopalová, Zidarova & Van de Vijver sp. nov. Light and scanning electron micrographs of the type population on Byers Peninsula (Livingston Island). **58–70**. LM views of raphe valves. **71–82**. LM views of rapheless valves. **83**. SEM external view of an entire raphe valve. **84**. SEM external view of an entire rapheless valve. **85**. SEM internal view of an entire rapheless valve. Scale bars represent 10 µm.

mantle. Raphe branches almost straight. Proximal raphe endings straight, drop-like expanded (Fig. 83). Distal endings short, weakly drop-like expanded. Rapheless valve (Figs 84–85): central area slightly depressed, forming a weak pseudoraphe (Fig. 84). Striae uniseriate composed of small, rounded to rectangular and transapically elongated areolae (Fig. 84). Slit-like areolae present near the valve margins and onto the mantle (Fig. 84). In the central area, several slit-like areolae visible near the valve margin. Internally areolae transapically elongated, covered by individual perforated hymenes (Fig. 85). Virgae slightly raised. Small silica bars separating the areolae (Fig. 85).

Ecology and distribution

This new species was up to now only observed on Livingston Island. The largest population was found living in mosses submerged in a large lake showing a circumneutral pH (7.3) and a low conductivity level (< 100 µS/cm). The sample was dominated by several *Psammothidium* taxa such as *P. subatomoides* (Hust.) Bukht. & Round (Bukhtiyarova & Round 1996), *P. abundans* (Manguin) Bukht. & Round (Bukhtiyarova & Round 1996) and *P. papilio* (D.E.Kellogg, Stuiver, T.B.Kellogg & Denton) Kopalová & Van de Vijver *in* Kopalová *et al.* (2012).

Psammothidium superpapilio Kopalová, Zidarova & Van de Vijver sp. nov.
Figs 86–109

Etymology

The specific epithet refers to the similarity with *P. papilio* and the larger valve dimensions.

Type

Byers Peninsula, Livingston Island, South Shetland Islands, Antarctica, sample BYM-008 (62°40′11.3″S 61°08′45.3″W) (leg. B. Van de Vijver), coll. date: 9 Jan. 2009 (holo-: slide no. BR–4439; iso-: slide PLP–295, University of Antwerp, Belgium).

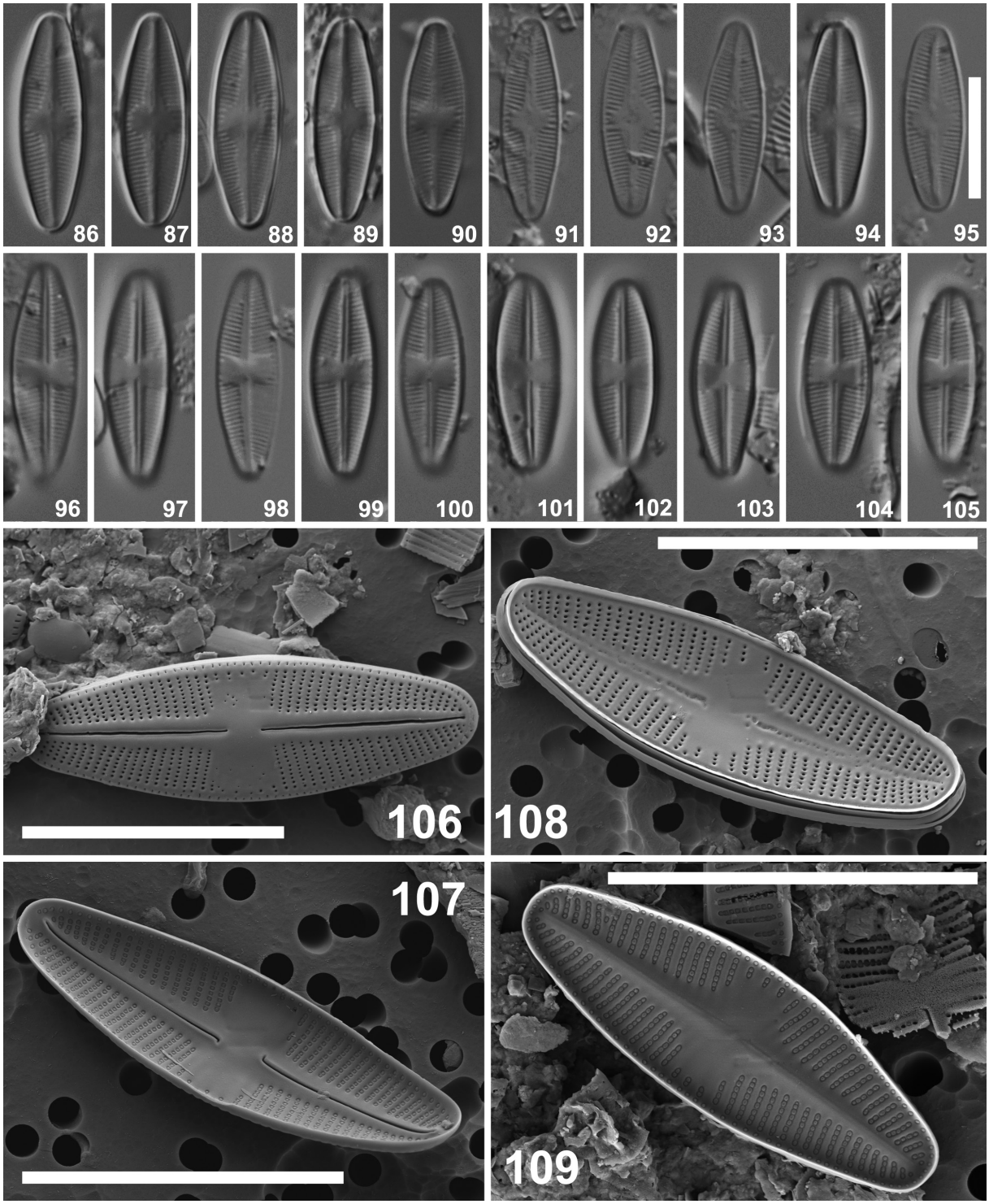
Description

Light microscopy (Figs 86–105)

Valves lanceolate to lanceolate-elliptic with convex to sometimes more straight margins gradually tapering towards the broad cuneately rounded apices. Valve dimensions (n = 40): length 15–20 µm, width 4.5–5.5 µm. Raphe valve (Figs 96–105): valves clearly convex. Axial area narrow, linear, almost not widening towards the central area. Central area forming a broad rectangular to bow-tie-shaped subfascia with several (3–5) shortened striae present near the valve margins. Raphe straight with indistinct, straight proximal endings. Distal fissures not discernible in LM. Transapical striae weakly radiate near the central area, becoming more strongly radiate towards the apices, 28–30 in 10 µm. Areolae not discernible in LM. Rapheless valve (Figs 86–95): thickened marginal crest clearly visible in LM. Axial area very narrow, linear-lanceolate, clearly widening towards the central area. Pseudoraphe clearly present as a series of irregular depressions in the axial area. Central area rounded to rhombical, bordered by several shortened striae. Fascia never present. Transapical striae weakly radiate throughout becoming more strongly radiate towards the apices, 26–29 in 10 µm.

Scanning electron microscopy (Figs 106–109)

Raphe valve (Figs 106–107)*:* axial area weakly raised and more heavily silicified (Fig. 106). Striae uniseriate, composed of long series of very small, rounded to rectangular areolae (Fig. 106). Number of areolae per striae diminishing towards the axial area (Fig. 106). On the valve face/margin junction, one transapically elongated areola present. Raphe branches almost straight (Fig. 106). Proximal raphe endings straight, simple, never expanded (Fig. 106). Distal endings short, terminating near the last striae at the apices (Fig. 106). Internally, areolae rectangular, covered by perforated hymenes



Figs 86–109. *Psammothidium superpapilio* Kopalová, Zidarova & Van de Vijver sp. nov. Light and scanning electron micrographs of the type population on Byers Peninsula (Livingston Island). **86–95**. LM views of rapheless valves. **96–105**. LM views of raphe valves. **106**. SEM external view of an entire raphe valve. **107**. SEM internal view of an entire raphe valve. **108**. SEM external view of an entire rapheless valve. **109**. SEM internal view of an entire rapheless valve. Scale bars represent 10 µm.

(Fig. 107). Proximal raphe endings bent into opposite directions. Distal endings terminating onto small helictoglossae (Fig. 107). Rapheless valve (Figs 108–109): Valve clearly concave. Thin, raised marginal crest bordering the entire valve. Axial area with irregular depressions, forming a clear pseudoraphe (Fig. 108). Striae uniseriate composed of small, rounded areolae. Internally areolae covered by individual perforated hymenes (Fig. 109). Virgae not raised.

Ecology and distribution

This new species was up to now only observed with certainty on Livingston Island. The largest population was found living in a terrestrial moss vegetation, at the edge of a shallow lake. The sampling site was clearly influenced by animals with remains of penguins present on the mosses. The sample was dominated by several *Psammothidium* taxa such as *P. germainii* (Manguin) Sabbe (Sabbe *et al.* 2003), *P. aretasii* (Manguin) Le Cohu (Le Cohu 2005) and *P. incognitum* (Krasske) Van de Vijver & Beyens (Van de Vijver *et al.* 2002).

Discussion

Although the Antarctic Region is characterized by a large number of *Achnanthes*, *Psammothidium* and *Planothidium* taxa, the new survey nevertheless resulted in the description of four new taxa. When separating these new taxa from all similar taxa known so far worldwide, the entire combination of features of each taxon has been taken into account to justify their status as independent taxa. Valve outline, raphe structure and striation pattern and structure are the main features that are investigated and compared between species.

Recently Tofilovska *et al.* (2014) revised the type material of *A. coarctata* (Bréb.) Grunow *in* Cleve & Grunow (Cleve & Grunow 1880) and some of its varieties. Based on their and our observations, it is clear that *Achnanthes kohleriana* sp. nov. belongs to the group of species around *A. coarctata*: both taxa present a similar position of the rapheless sternum, a comparable orbiculus, a similar raphe structure and similar cribrate areolae. *Achnanthes kohleriana* sp. nov. can however be easily separated from *A. coarctata*, often found in aerial habitats in Antarctica (Kopalová *et al.* 2012), by its valve outline, lacking the prominent constriction in the valve middle, typical for *A. coarctata*, by the marginal ridge which is less developed in *A. kohleriana*, and the lower stria density (10–11 in *A. kohleriana* sp. nov., 12–14 in *A. coarctata*). *Achnanthes sinaensis* (Hust.) Levkov *et al.* (Tofilovska *et al.* 2014) shows a comparable valve outline, although the valve middle is slightly more tumid (Tofilovska *et al.* 2014) and the apices are weakly protracted and more truncated and less broadly rounded, compared to *A. kohleriana* sp. nov. The marginal ridge in *A. sinaensis* is more developed (see for instance Tofilovska *et al.* 2014, fig. 13c). Moreover, the striae on the mantle in the latter are uniseriate, contrary to *A. kohleriana* sp. nov. which has biseriate striae on the mantle.

Most other *Achnanthes* s.s. taxa showing a similar valve outline to *A. kohleriana* sp. nov., are usually typically marine or brackish taxa such as varieties of *A. brevipes* C.Agardh (Agardh 1824) or *A. parvula* Kütz. (Kützing 1844). *Achnanthes parvula* has smaller valves with a length not exceeding 30 µm and coarser areolae (Witkowski *et al.* 2000). *Achnanthes parvula* also shows a more laterally located rapheless sternum (McIntire & Reimer 1974, figs 4a, b), compared to *A. kohleriana* sp. nov. where the sternum is situated close to the margin. *Achnanthes brevipes* var. *intermedia* (Kütz.) P.T.Cleve (Cleve 1895) has a similar valve outline but a slightly coarser striation usually having 3 areolae per stria with much coarser areolae. Additionally, *A. brevipes* var. *intermedia* has square-shaped areolae and not rounded as is the case in *A. kohleriana* sp. nov., Fig. 22 (Toyoda & Williams 2004). *Achnanthes subsessilis* Kütz. (Kützing 1833) has a similar valve outline, but narrower valves with a width of around 7 µm (Hendey 1951), and not above 9 µm as in *A. kohleriana* sp. nov. Internally the central area is clearly panduriform and elevated from the rest of the valve (Blunn & Evans 1981, fig. 4). Several (poorly known) varieties

of *A. subsessilis* also show some resemblance. *Achnanthes subsessilis* var. *angusta* Cleve & Möller (Cleve & Möller 1878) has a very narrow central area (contrary to the relatively broad central area in *A. kohleriana* sp. nov.). *Achnanthes subsessilis* var. *multiarticulata* Kütz. (Kützing 1844), (illustrated by Cox 2006, figs 6, 7 from type slide BM 18469) has a different valve outline with more lanceolate valves with less radiate striae and much smaller central area, as well as a lateral position of the sternum. Moreover, all *A. subsessilis* varieties are only found in marine conditions whereas *A. kohleriana* sp. nov. is a typical terrestrial taxon. Of the known aerophilic *Achnanthes* species, a few share similar features to *A. kohleriana* sp. nov. *Achnanthes prominula* Levkov & Tofilovska (Tofilovska *et al.* 2014), a recently described species from Osogovo, Macedonia, differs in having lanceolate or elliptic-lanceolate valves with narrowly rounded apices (and not linear to linear-elliptic valves with rounded apices), and with slightly coarser striation of 12–13 striae in 10 µm with only 5 areolae per stria (Tofilovska *et al.* 2014), opposite to *A. kohleriana* sp. nov. where the number of the striae in 10 µm does not exceed 12. Several other *Achnanthes* s.s. taxa are present in the Antarctic Region such as *A. muelleri* Carlson (Carlson 1913) and *A. taylorensis* T.B.Kellogg *et al.* (Kellogg *et al.* 1980). Although the latter was described from the Antarctic Continent (Kellogg *et al.* 1980), it was recently observed on James Ross Island in the Maritime Antarctic Region (Kopalová *et al.* 2012, figs 5C, 5D). *Achnanthes taylorensis* has smaller valves (length 31–33 µm and width of 8.8–9.3 µm) with a more lanceolate outline. *Achnanthes muelleri*, described from South Georgia in (Carlson 1913), has a different valve outline with larger, more rhombic-lanceolate valves with clearly convex margins, making confusion with *A. kohleriana* sp. nov. that shows more linear-elliptic valves less likely.

Planothidium wetzelectorianum sp. nov. can be confused with several small-celled *Planothidium* taxa that all lack the presence of a cavum or a sinus. Several of these species co-occur in the Maritime Antarctic Region. *Planothidium renei* (Lange-Bert. & Rol.Schmidt) Van de Vijver *in* Van de Vijver *et al.* (2002) has a similar valve outline but differs in having typically only two rows of areolae in both rapheless and raphe valve (Schmidt *et al.* 1990; Oppenheim 1994). Moreover, *P. renei* has elongated external distal fissures continuing beyond the last stria whereas *P. wetzelectorianum* sp. nov. has only short distal fissures. The other Antarctic species, *P. quadripunctatum* (Oppenheim) Sabbe *in* Sabbe *et al.* (2003) has typically four rows of small, equally sized areolae per stria separated by very small virgae whereas *P. wetzelectorianum* sp. nov. has 3–4 areolae per stria, separated by rather broad virgae, with the largest areolae in the outer rows and the smaller areolae in the inner rows. *Planothidium werumianum* Lange-Bert. & Bąk *in* Bąk & Lange-Bertalot (2014) is also quite similar but has a more elliptic valve outline and typically has only 2–3 rows of small rounded areolae, separated by very large virgae, both on the raphid and rapheless valve. The axial area is usually broader (Bąk & Lange-Bertalot 2014). Finally, *Planothidium granum* (Hohn & Hellerman) Lange-Bert. (Lange-Bertalot 1999) has a different valve outline (elliptic-lanceolate with slightly rostrate apices), narrow virgae separating striae with 4 rows of very small areolae on the rapheless valve and strongly hooked external distal fissures.

Psammothidium confusoneglectum sp. nov. belongs to a group of small *Psammothidium* species that are widespread in the Antarctic Region. Similar species include *P. confusum* (Krasske) Bukht. & Round (Bukhtiyarova & Round 1996), *P. stauroneioides* (Manguin) Van de Vijver & Beyens *in* Van de Vijver *et al.* (2002), *P. papilio* and *P. abundans*. *Psammothidium confusum* is the most similar based on valve outline but the latter has a very different rapheless valve morphology with striae composed of maximum three transapically elongated, slit-like areolae (the longest ones being near the margin) and the absence of a clear central area whereas *P. confusoneglectum* sp. nov. has a typical fascia bordered by a series of only one areola. The raphe valve in *P. confusum* has a rectangular central area contrary to the wedge-shaped central area in *P. confusoneglectum* sp. nov. (Van de Vijver *et al.* 2002, Le Cohu 2005). *Psammothidium abundans*, present in the same locality as *P. confusoneglectum* sp. nov. has an almost linear valve outline with broadly rounded, slightly protracted apices contrary to the lanceolate valve outline in *P. confusoneglectum* sp. nov. The striae in *P. abundans* are more or less parallel in both valves whereas

they are clearly radiate in *P. confusoneglectum* sp. nov. (Van de Vijver *et al.* 2008). *Psammothidium papilio*, widespread in the Maritime Antarctic Region has a more elliptic valve outline with a typical marginal crest on the rapheless valve, which has never been observed in *P. confusoneglectum* sp. nov. Moreover, *P. papilio* has a larger, more rounded, never wedge-shaped central area on both valves and a much lower stria density (26–28 in 10 µm vs 33–36 in 10 µm in *P. confusoneglectum* sp. nov.). The last similar species, *Psammothidium stauroneioides* has a broad lanceolate valve outline, larger valve dimensions (width 4.5–6.5 µm vs 3.8–4.5 µm) and a large, lanceolate axial area on the rapheless valve.

Finally, *Psammothidium superpapilio* sp. nov. can be separated from *P. papilio* in having larger valve length (15–20 µm vs 9–12 in *P. papilio*) giving the valves a more slender outlook since the valve width in both species is the same. The valves of *P. superpapilio* sp. nov. have a more lanceolate outline with weakly protracted apices whereas in *P. papilio* valves usually are elliptic even in the longest valves lacking any protracted apices (Schmidt *et al.* 1990). The raphe valves of *P. superpapilio* sp. nov. have a larger, more rectangular to even wedge-shaped central area, often forming almost a fascia. *Psammothidium papilio* on the other hand has a raphe valve with a more rounded to rhomboid central area with several shortened striae, always bordering the central area. Although both species co-occur in some samples, a continuum between *P. papilio* and *P. superpapilio* sp. nov. has never been noticed, justifying the separation of the two species. Other *Psammothidium* species such as *P. abundans* or *P. stauroneioides* differ sufficiently in valve outline, striation pattern and dimensions to exclude conspecificity.

Conclusions

The description of these four new monoraphid species once more confirms the unique character of the Maritime Antarctic non-marine diatom flora. The new data improve our knowledge of the biodiversity and biogeography of the Antarctic diatoms.

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