

***Planothidium juandenovense* sp. nov. (Bacillariophyta) from Juan de Nova (Scattered Islands, Mozambique Channel) and other tropical environments: A new addition to the *Planothidium delicatulum* complex**

Catherine RIAUX–GOBIN ^{1,2*}, Andrzej WITKOWSKI ³, Anton IGRSHEIM ⁴, Christopher S. LOBBAN ⁵, Adil Y. AL–HANDAL ⁶ & Pierre COMPÈRE ^{7†}

¹ PSL Research University: CNRS–UPVD–EPHE, USR3278 CRIOBE

² Laboratoire d'Excellence 'CORAIL', University of Perpignan, F–66000 Perpignan, France; * Corresponding author e–mail: catherine.gobin@univ-perp.fr

³ University of Szczecin, The Faculty of Geosciences, Palaeoceanology Unit, PL–70–383 Szczecin, Poland, witkowski@univ.szczecin.pl

⁴ Herbarium W Naturhistorisches Museum Wien, Austria, anton.igersheim@nhm-wien.ac.at

⁵ University of Guam Mangilao, Division of Natural Sciences, GU 96923 USA clobban@guam.net

⁶ University of Gothenburg, Biological and Environmental Sciences, SE 405 30 Göteborg, Sweden, adil.alhandal@gmail.com

^{7†} Former address: Botanic Garden Meise, Domein van Bouchout, BE–1860 Meise, Belgium

Abstract: *Planothidium juandenovense* sp. nov. (Bacillariophyta) is described from the marine tropical environments of Juan de Nova I. (Mozambique Channel), Rodrigues I. (Mascarene Archipelago) and from Guam (Northern Mariana Is., Pacific). This small and relatively rare taxon has short multiseriate striae on the sternum valve (SV), hooked raphe valve (RV) terminal raphe endings and no SV cavum or hoof-shaped area. This taxon has similarities with *Planothidium delicatulum* (KÜTZ.) ROUND et BUKHT. and *Planothidium septentrionale* (Østrup) Round et BUKHT. ex RUMRICH et al., but also differences: e.g. a relatively narrow and rhombic SV sternum, void of areolae, with vestigial radiate structures and an uninterrupted marginal SV elevated crest or 'crista marginalis'. *P. juandenovense* sp. nov. is compared to some other Achnanthes with short SV striae. *Cocconeis quarnerensis* var. *lanceolata* JURILJ and *Planothidium quarnerense* f. *rhombica* (GIFFEN) comb. nov. may be close to our new taxon.

Key words: *Planothidium*, Achnanthes, tropical marine habitats, morphology, LM, SEM, allied taxa

INTRODUCTION

Achnanthes BORY 1822 is a widespread genus of heterovalvar, mostly small-celled taxa, that are often rare and difficult to study (RIAUX–GOBIN et al. 2011). The taxonomic history is complicated. LANGE–BERTALOT & KRAMMER (1989) distinguished two groups amongst *Achnanthes* sensu lato: one group based on *Achnanthes microcephala* (KÜTZ.) GRUNOW and *A. minutissima* KÜTZ. and a second group based on *Achnanthes lanceolata* BRÉB. ex KÜTZ. More or less at the same time, ROUND et al. (1990) distinguished a group of taxa, with the generitype *Achnanthes adnata* BORY, pertaining to the genus *Achnanthes* sensu stricto, while the other taxa were grouped under *Achnanthidium* KÜTZ. 1844 (ROUND et al. 1990). As argued by BUKHTIYAROVA & ROUND (1996): 'leaving all *Achnanthidium* species

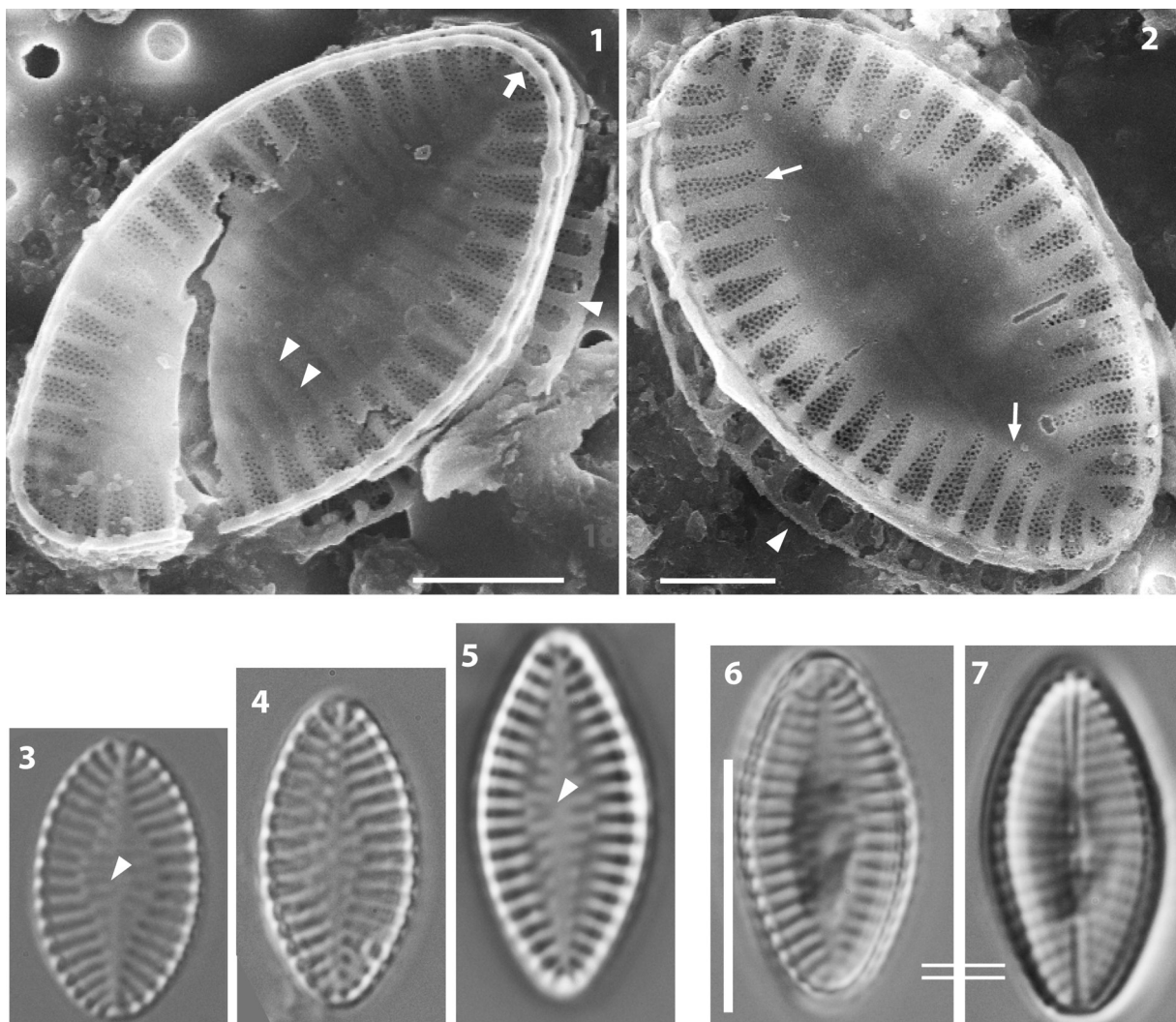
in a single genus is not a satisfactory situation'. Thus, BUKHTIYAROVA & ROUND (1996) established the new genera *Psammothidium* BUKHT. et ROUND (see comments in MONNIER et al. 2007) and finally, ROUND & BUKHTIYAROVA (1996) redefined the limits of the genus *Achnanthidium* and established four new genera: *Rossithidium* ROUND et BUKHT., *Planothidium* ROUND et BUKHT., *Karayevia* ROUND et BUKHT. and *Kolbesia* ROUND et BUKHT. The genus *Kolbesia* was subsequently subsumed into *Karayevia* (BUKHTIYAROVA 2006). Otherwise, several genera were created to accommodate diverse difficult taxa (taxa needing appropriate generic classification): e.g. *Platessa* LANGE–BERT., *Crenotia* WOJTAŁ, *Gliwiczia* KULIKOVSKIY, LANGE–BERT. et WITKOWSKI, *Astartiella* WITKOWSKI, LANGE–BERT. et METZELTIN (WITKOWSKI 1998), *Pauliella* ROUND et BASSON and *Lemnicola* ROUND et BASSON (ROUND & BASSON 1997), *Scalariella*

RIAUX–GOB. (RIAUX–GOBIN et al. 2012a), and some small marine taxa previously classified as ‘*Achnanidium* sensu lato’ (RIAUX–GOBIN et al. 2010; RIAUX–GOBIN et al. 2011), moved to *Madinithidium* WITKOWSKI, DESROSIERS et RIAUX–GOB. (DESROSIERS et al. 2014).

Planothidium, with *Planothidium lanceolatum* (BRÉB. ex KÜTZ.) LANGE–BERT. as generitype [type material examined with scanning electron microscope (SEM) by VAN DE VIJVER et al. (2013)], has some particular characteristics: e.g. multiseriate striae on both valves, internally thickened virgae and a SV ‘cavum’, hoof–mark or simple depression (‘sinus’) present in several species. *Planothidium delicatulum* (KÜTZ.) ROUND et BUKHT. is one of the most common species in this genus, present in both marine and freshwater environments, with diverse varieties and forms grouped under the denomination *Planothidium delicatulum* ‘complex’ (i.e. ‘*Achnanthes delicatula*–Komplex’ in LANGE–BERTALOT & KRAMMER 1989). See remarks about the complexity of this group (Discussion). The latter taxon lacks a cavum or sinus.

Planothidium includes small species particularly difficult to identify using light microscope and for which SEM is needed to produce a complete description (see MORALES 2006; COMPÈRE & VAN DE VIJVER 2009; VAN DE VIJVER et al. 2013; BAĞ & LANGE–BERTALOT 2014; WETZEL & ECTOR 2014). All these papers refer to freshwater habitats. Marine and estuarine *Planothidium* are rarely investigated but there are many species in these habitats, especially in tropical and sub–tropical environments (ROVIRA et al. 2011; RIAUX–GOBIN et al. 2012b; ÁLVAREZ–BLANCO & BLANCO 2013).

This paper describes a marine and relatively rare *Planothidium*, *P. juandenovense* RIAUX–GOB. et WITKOWSKI sp. nov., from tropical environments (Scattered Islands, Rodrigues Island, Indian Ocean and Guam, Western Pacific). The morphological characteristics of the new taxon are assessed using light (LM) and scanning electron (SEM) microscopy and compared with several allied taxa.



Figs 1–7. *Planothidium juandenovense* sp. nov. (SEM, figs 1–2; LM, Figs 3–7): (1, arrow) Complete frustules with the *crista marginalis*, (2, arrows) longer SV striae on apices and (1, twin arrowheads) vestigial structures on the SV, (1, 2, arrowhead) RV still in place. (3–5, arrowheads) SV in LM, with the rhombic SV sternum with radiate shadows, (6) SV and (7) RV of a complete frustule. Scale bars 10 µm (3–7); 4 µm (1); 3 µm (2).

MATERIALS AND METHODS

Materials used in this study were from several sources:

- 1) Intertidal marine sediments and debris (coral and macroalgae) ‘JDN2–macroalgae’ were sampled from Juan de Nova Island (Scattered Islands, Indian Ocean, 17°02.798’S, 42°43.673’E, TAAF ‘EPARSES 2009’ expedition; April 2009) and from Port Mathurin ‘Port Mathurin 2’ (Rodrigues Island, Mascarenes; 19°40.6’S, 63°25.0’E; June 2007). The samples were preserved in formalin (10% final concentration),
- 2) Intertidal coral reef sediments (coral debris, macroalgae) from Saluglula Pools, Inarajan, Guam, Mariana Islands, 13°16’17.38’’N, 144°44’52.36’’E; field collection number GU21AM–2, coll. C. Lobban and M. Scheffter, 9 Oct. 2016, specimen in GUAM Diatom Herbarium, catalog number GUD004279, on SEM stub 965.
- 3) GRUNOW’s collection in W: e.g. two GRUNOW–capsules collection of *Amphora grevilleana* GREGORY, with mica–slides W–1901/3921–3922, examined at $\times 40$; sketches from GRUNOW’s hand illustrating taxa in GRUNOW’s ‘Bilder–Sammlung’ (W–1901/3630, W–1901/3631); GRUNOW’s accession book. A broken part of a slide covered with mica [GRUNOW–capsule collection of *Navicula ovulum*, from the locality ‘869’ Porto Subzanski, Sansago I. (Susak, Croatia) *Codium bursa* & *Udotea*, leg. Dr REICHARDT; W–1901/3162], permitted observations with SEM.
- 4) GIFFEN’s type raw material from Mahé (Seychelles Islands) was observed with SEM (i.e. a sample containing *Cocconeis quarnerensis* f. *rhombica* GIFFEN 1980).

For light microscopy (LM) examination, the samples were washed with distilled water to remove salts, treated with 30% H₂O₂ for 2 h at 70 °C to remove organic matter, rinsed several times in distilled water, alcohol–desiccated and mounted on glass slides using Naphrax®. Diatom slides were examined with a Zeiss Axiophot 200, with differential interference contrast (DIC) optics and photographed with a Canon PowerShot EOS1000D digital camera (CRIOBE–USR 3278, Perpignan, France). The mica–slides from the GRUNOW’s collection W were examined at $\times 40$, as recommended for the preservation of the slides.

For SEM examination of raw materials, samples were filtered through 1 μ m Nuclepore® filters and rinsed twice with deionised (milliQ) water to remove salts. Filters were air–dried and mounted onto aluminum stubs before coating with gold–palladium alloy (EMSCOP SC 500 sputter coater) and examined with a HITACHI S–4500 SEM operated at 5 kV, calibrated with a Silicon grating TGX01 (C2M, Perpignan, France).

For SEM examination of the material contained on a broken part of the GRUNOW’s slide 3162: after dissolving with toluene the material glued on the mounting medium, it was filtered through 0.2 μ m filter (Chromafil Xtra PTFE 20/13 from Macherey–Nagel GmbH & Co. KG) and rinsed twice with ethanol, before being treated for SEM examination as described above.

We designate as holotype a LM slide (BM 101 810) showing specimens of the new taxon, with Fig. 4 as an holotype illustration. Nevertheless, the LM illustration does not provide a perfect overview of the taxa described in this report, particularly concerning the fine structure of the SV striae and SV crista marginalis (uninterrupted marginal elevated ridge or crest), as a result the scanning electron microscope (SEM) was essential for their description. Therefore, according to Article 40.5 of the International Code of Botanical Nomenclature (MCNEILL et al. 2012), and although it is a challenge to permanently preserve specimens on a stub, we designate as an isotype

a stub (BM001223815) bearing several specimens showing diagnostic features of the new taxon. The slide and the stub were sent to NHM London.

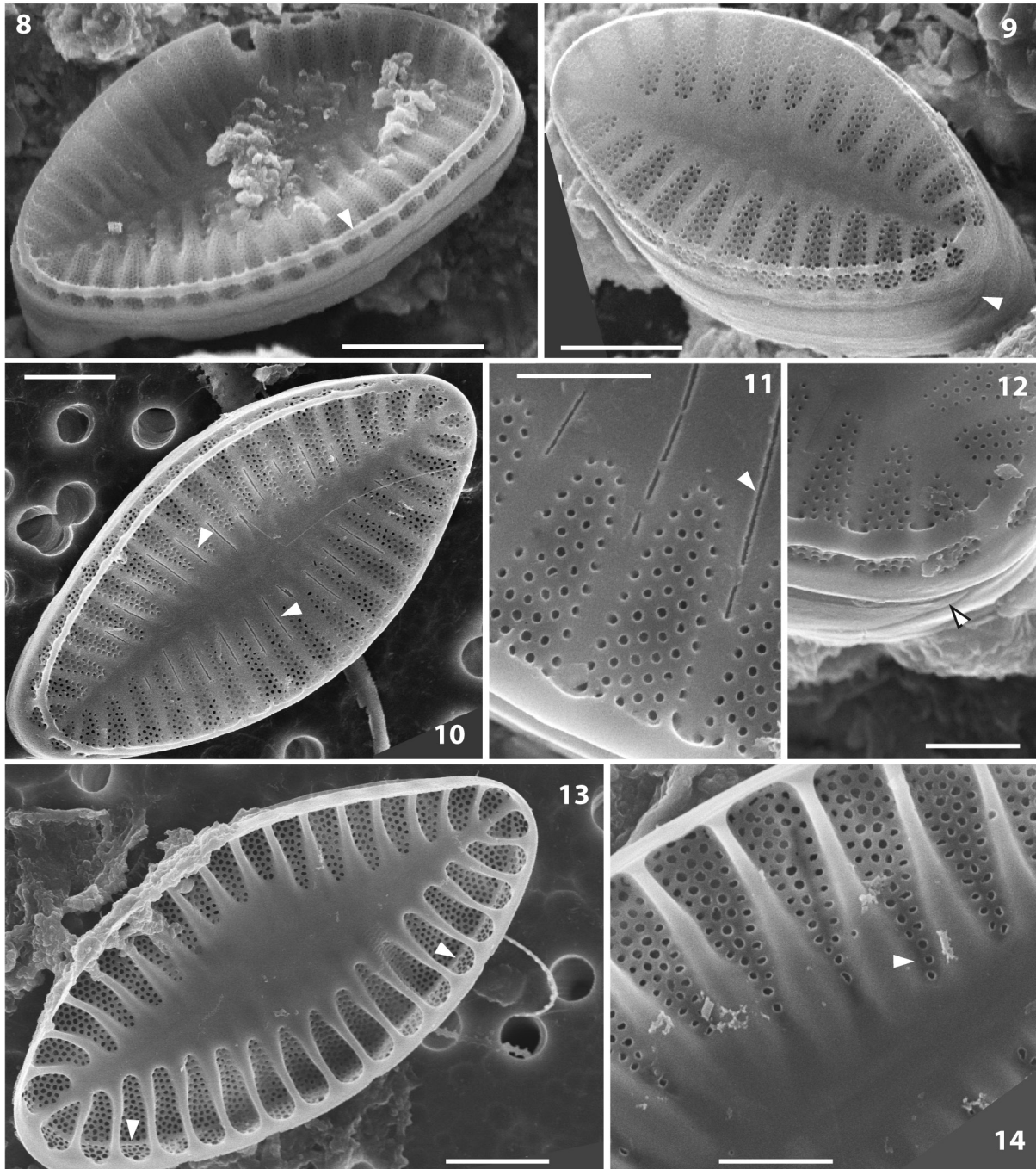
Terminology used for the diatom frustules follows ANONYMOUS (1975), ROSS et al. (1979) and ROUND et al. (1990). As previously proposed, in particular by RIAUX–GOBIN et al. (2013), we designate the valve with a raphe as the raphe valve (RV) and the valve without a raphe as the sternum valve (SV). Standardized abbreviations and spellings of taxa authorities follow the IPNI. The morphometrics (Table 1) are based on the SEM examination of 29 specimens of *P. juandenovense* (from Juan de Nova, Europa, Rodrigues and Guam) and 10 specimens of *P. cf. delicatulum* (from Rodrigues Island).

RESULTS

***Planothidium juandenovense* RIAUX–GOB. et WITKOWSKI sp. nov. (Figs 1–20, Table 1, LM: 3–7, SEM: 1–2, 8–20)**
n = 29; 7.5–19 μ m (av. 13.5 \pm 2) long; 4–10 μ m (av. 7 \pm 1.2) wide. SV: (8)10–17 striae in 10 μ m (av. 14 \pm 1.7). RV: 11–16 striae in 10 μ m (av. 14 \pm 1.7) (Table 1).

Diagnosis: Valves small and elliptical, apices round to very slightly elongate (never protracted), rhombic SV sternum more or less narrow with transapical slits or markings, SV crista marginalis always present, groups of areolae on the short mantle, multiseriata short SV striae radiate throughout, RV striae rarely shorter on the centre on the valve.

Description (SEM): Valves small, elliptic, with round apices. **SV:** Valve face flat with SV sternum slightly concave (Fig. 8). SV striae radiate and short, regularly spaced, multiseriata (up to 5 rows of areolae near the margin), marginally interrupted by a well–developed and uninterrupted crista marginalis (Figs 8–10). The striae terminate abruptly near the wide sternum in specimens from the Mascarenes (Figs 9,11) or extend in one row of areolae in Juan de Nova specimens (Figs 10, 14). On the elliptic and wide SV sternum, one slit–marking (sometimes two) occur as an extension of each virga, resembling radial vestigial structures (Fig. 10, arrowheads, Fig. 11, arrowhead). In LM, these vestigial structures appear as shadows on the sternum, alternating with the marginal striae (Figs 3–5). In internal view, the virgae are elevated, giving each stria the appearance of a loculus (Fig. 24). One row of grouped areolae on the short SV mantle (Fig. 9). Broad cingulum composed of open bands (Figs 9, arrowhead, Fig. 12, framed arrowhead). Sternum valve valvocopula (SVVC) not observed. **RV:** Valve face strongly convex (Fig. 16). Striae multiseriata, radiate, regularly spaced, virgae narrow (Figs 13, 15). Sometimes one shorter stria on one side of the valve (Fig. 15). In internal view the virgae and axial area are elevated (Fig. 17). Central raphe endings well apart, round, internally coaxial, central area reduced (Fig. 19). Terminal raphe endings hooked in the same direction (Fig. 15). Helictoglossae straight and small (Fig. 18, arrowhead). Raphe valve valvocopula (RVVC) with



Figs 8–14. *Planothidium juandenovense* sp. nov. (SEM): (8, arrowhead) SV with the uninterrupted *crista marginalis* and depressed SV sternum with particular structures. (9, arrowhead) High cingulum with open bands and (9) groups of areolae on the short mantle. (10, 11 arrowheads, individual from Mascarenes) Slits ‘vestigial structures’ between each stria (on each virga), (12, framed arrowhead) open cingular bands and (12) strong *crista marginalis*. (13, arrowheads) SV in internal view with sort of loculi, note the position of the *crista marginalis*. (14, arrowhead, individual from Juan de Nova Island) SV striae prolonged but a row of single areolae. Scale bars 5 μm (8); 2 μm (9–10, 13); 1 μm (11–12, 14).

possible short fimbriae (Fig. 18 arrow, to be confirmed).

Holotype designated here: BM 101 810 housed in BM, made from the sample ‘JDN2–macroalgae’

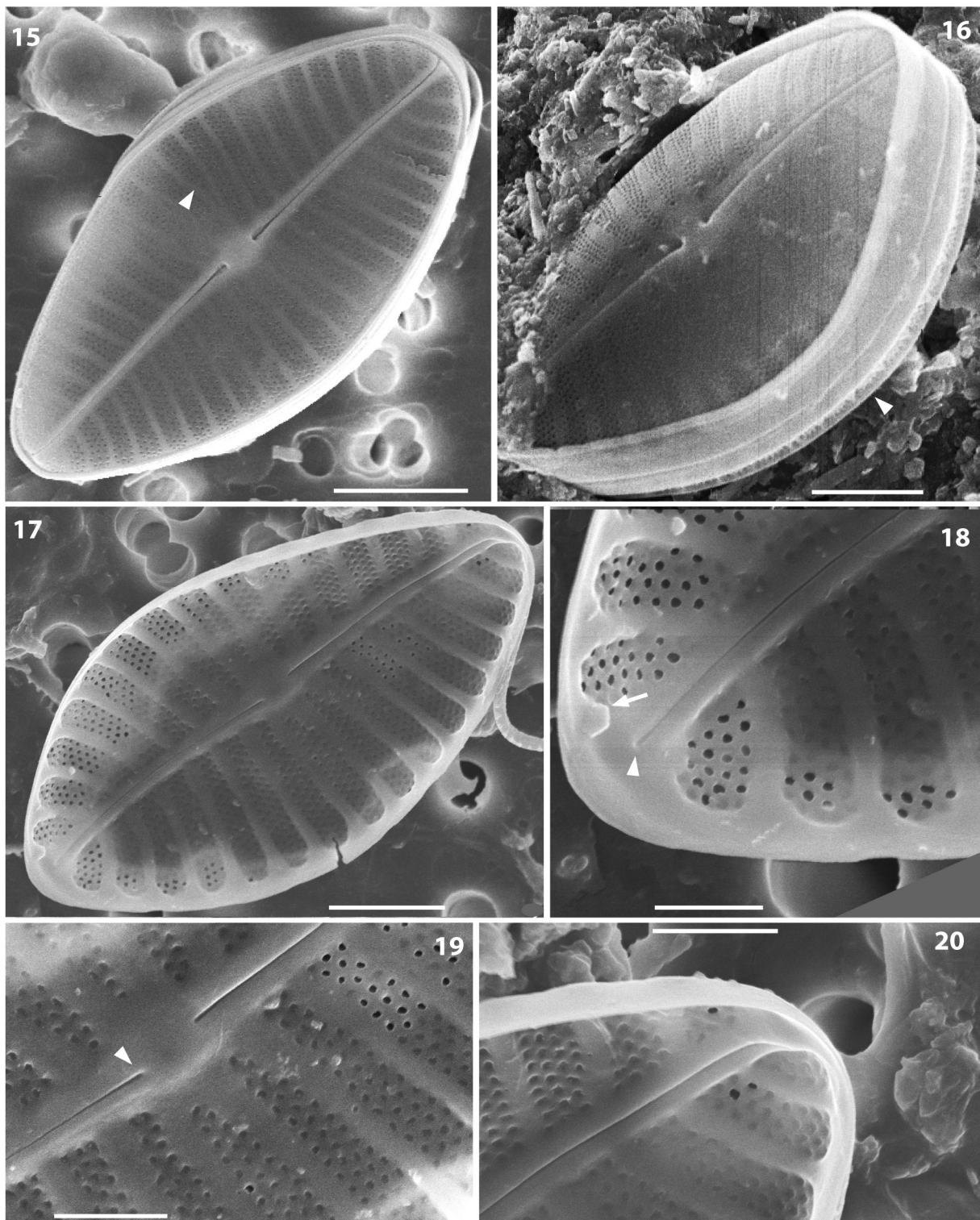
Holotype illustration: Fig. 4.

Isotypes: Stub 2–280214 JDN2–macroalgae housed in BM (BM001223815), slide JDN2 in C. R.–G. collection (USR 3278, CRIOBE, F–Perpignan) and slides 16491–16492 in A.W. SZCZ collection (Palaeoceanology Unit, PL–Szczecin, Poland).

Type locality: Juan de Nova, sample ‘JDN2–macroalgae’ (26 April 2009). 17° 02.798' S, 42° 43.673' E.

Etymology: The epithet *juandenovense* refers to Juan de Nova Island from where the RV of the taxon was first observed.

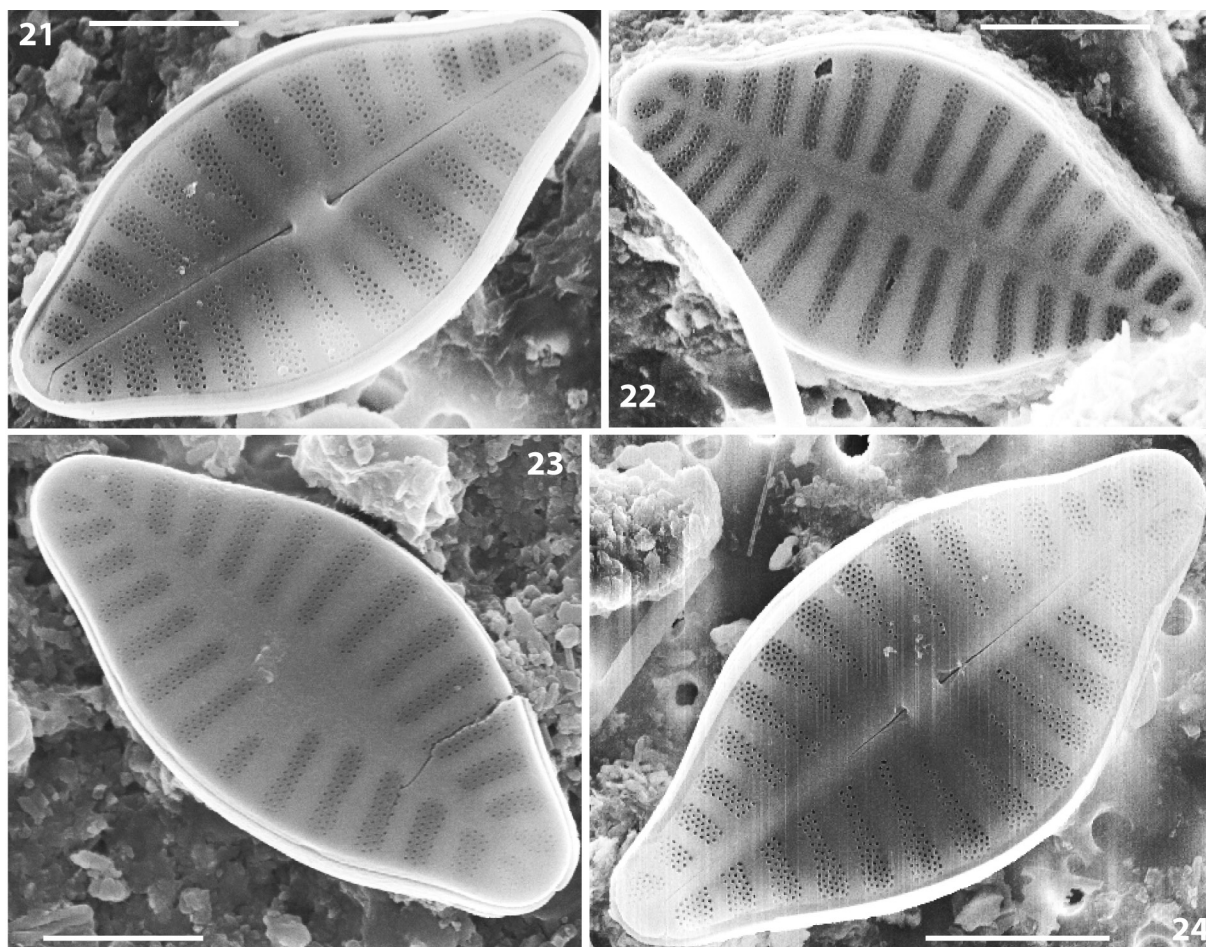
Additional materials examined: Rodrigues, sample ‘Port Mathurin 2’ (in C. R.–G. collection, USR 3278, CRIOBE, F–Perpignan); Guam, sample GU21AM–2.



Figs 15–20. *Planothidium juandenovense* sp. nov. (SEM): (15, arrowhead) RV with regularly spaced striae, narrow virgae and a marginal shorter stria. (16, arrowhead) Complete frustule in cingular view, with the convex SV with strong central raphe endings and the SV *crista marginalis*. (17) RV in internal view, with the straight raphe, and elevated virgae and axial area. (18, arrow) Possible RVVC short fimbriae and low and straight helictogloss (18, arrowhead). RV central area in internal view with the straight proximal raphe endings (18, arrowhead). (20) RV apex in internal view, with the subtle helictogloss. Scale bars 3 μm (15–16); 2 μm (17); 1 μm (18–20).

Remarks: *Planothidium juandenovense* sp. nov. is rare and its valvocopulae system is not yet elucidated, but the SV structure (Figs 9–10, Table 1) is different from that of *Planothidium cf. delicatum* from the Indian

Ocean (samples from Rodrigues, Figs 21–24, Table 1): e.g., the apices of the new taxon are not protracted, nor capitate, the striae of both valves are slightly denser and the virgae on both valves are narrower than in



Figs 21–24. *Planothidium* cf. *delicatulum* (SEM, from Rodrigues I.): (21) RV with large virgae and central area delineated by two shorter striae. (22) SV with a relatively narrow sternum. (23) SV with an elliptic sternum and a shorter stria on one side. (24) RV with spatulate proximal raphe endings. Scale bars 5 μ m (22); 4 μ m (24); 3 μ m (21, 23).

P. cf. delicatulum. In internal view, the *P. juandenovense* SV virgae are elevated and delineate short marginal chambers (cf. Figs 13–14). Furthermore the uninterrupted SV *crista marginalis* (see above) is not present in *P. cf. delicatulum*. See the following remarks about *Planothidium delicatulum* sensu stricto. *P. juandenovense* sp. nov. has some similarities with *P. quarnerense* (GRUNOW) WITKOWSKI, LANGE–BERT. et METZELTIN and allied taxa (see below). The illustrations in SAR et al. (2003: figs 7–8) may possibly refer to *Planothidium juandenovense*. The new taxon was first found in the Indian Ocean and Mozambique Channel, but recent investigations proved its presence in the Pacific Ocean (i.e., Guam), expanding its biogeography. This taxon is probably pantropical.

DISCUSSION

Planothidium juandenovense has similarities to other Achnanthes with multiseriate SV striae. We examine the similarities with, 1) *P. delicatulum* (sensu stricto and

sensu lato), 2) some Achnanthesiaceae D.G.MANN with short multiseriate SV striae, in *Platessa* and *Planothidium*, and finally 3) *P. quarnerense* and allied taxa.

Planothidium delicatulum sensu stricto, history

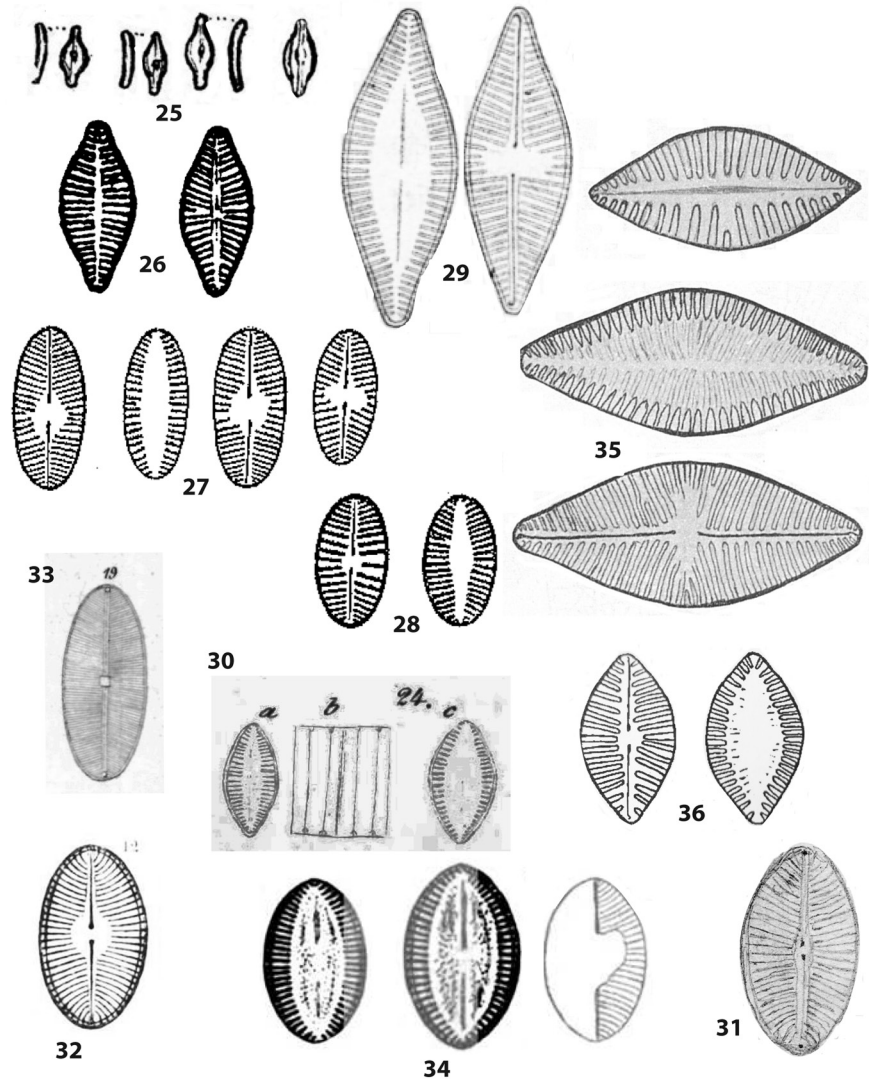
We note that a comparison of *Planothidium juandenovense* with *P. delicatulum* sensu stricto is hardly possible since KÜTZING's description and illustrations are so poor that it is difficult to reliably identify the species based on KÜTZING's drawings. Nevertheless, we can note that KÜTZING's drawings (KÜTZING 1844: as *Achnanthes delicatulum* KÜTZ., p. 75, pl. 3, fig. 21 reproduced in Fig. 25) evoke that the perivalvar bent frustule is round-elliptical, with clearly protracted apices, with a small round central area. The illustration of *Achnanthes delicatula* (KÜTZ.) GRUNOW in VAN HEURCK (1880–1885; pl. 27, figs 3–4, reproduced in Fig. 26) also clearly shows protracted apices. A 'neotype', slide BM 26545 (from VAN HEURCK's Types des Synopsis nr 234) was designated by LANGE–BERTALOT & RUPPEL (1980; pl. 1, figs 28–31) but this 'neotype' (see also LANGE–BERTALOT & KRAMMER 1989; pl. 80, figs 1–5) was rightly challenged by ÁLVAREZ–BLANCO & BLANCO (2013): since a part of the original material, i.e. the illustration, is still available,

Table 1. Morphometrics and features of *Planolithium cf. delicatulum*, *P. juandenovense* sp. nov., *P. quarnerense*, *Cocconeis quarnerensis* var. *lanceolata* and *C. quarnerensis* f. *rhombica* [(sd) standard deviation, (nd) no data, () specimens observed from GRUNOW's Collection (mica-slides '505' Herbarium W-1901/3922 and W-1901/3921)].

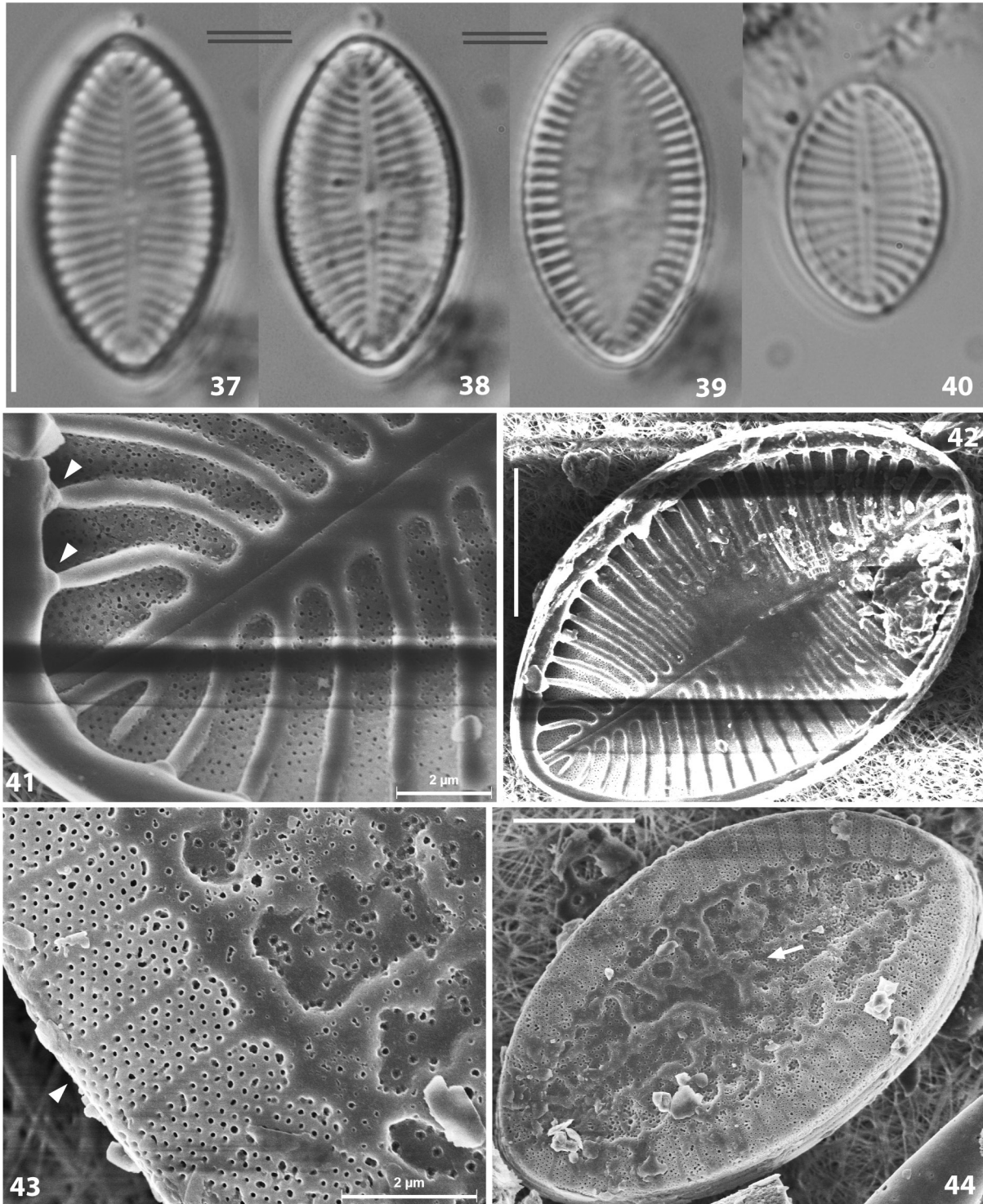
	<i>Planolithium cf. delicatulum</i> (KÜTZ.) ROUND et BUKHT.	<i>Planolithium juandenovense</i> sp. nov.	<i>Planolithium quarnerense</i> (GRUNOW) WITKOWSKI, LANGE-BERT, et METZELIN Basionym: <i>Rhaphoneis quarnerensis</i> GRUNOW 1862 Synonyms: <i>Cocconeis quarnerensis</i> (GRUNOW) SCHMIDT 1874 <i>Navicula ovulum</i> A. SCHMIDT	<i>Cocconeis quarnerensis</i> var. <i>lanceolata</i> JURILJ	<i>Planolithium quarnerense</i> f. <i>rhombica</i> (GIFFEN) comb. nov. Basionym: <i>Cocconeis quarnerensis</i> f. <i>rhombica</i> GIFFEN
Valve face	rostrate	elliptic, round apices	elliptic	oblong-elliptic, rostrate	pot-bellied, rostrate
Length (µm)	8.6–19.8	7.5–18.7	22–45	25–30	15–18
min–max	15.2 ± 4.3	13.5 ± 2.1	(20–34.5, 23.7 ± 4.2)		
Width (µm)	4.4–10.6	4.4–10.3	12–18	12	10–11
min–max	7.5 ± 2.3	7.1 ± 1.2	(12–18.4, 14.6 ± 1.8)		
SV stria density	9.4–14	(8)10–17	8–9	10–12	idem type
min–max	12.1 ± 2.4	13.8 ± 1.7	(8.3–10.5, 9.1 ± 0.6)		
RV stria density	9–13	11–15.6	9, robust	10–13	idem type
min–max	10.8 ± 1.5	13.7 ± 1.7	(9–10.5, 9.6 ± 0.5)		
SV sternum	elliptic, relatively narrow	rhombic, with vestigial radiate structures	elliptic, wide	elliptic, wide, with vestigial radiate structures	elliptic, wide
SV crista marginalis	no	present, uninterrupted	nd	nd	nd
RV central area	round, small	small	round	transapical oblong fascia	small
Proximal raphe endings	spatulate, straight	small, roundish, straight	straight, somewhat expanded	somewhat curved opposite to terminal raphe ends	spatulate, well separate, straight
Terminal raphe endings	deflected on the mantle	deflected on the mantle	in polar position	deflected	deflected on the mantle
RV virgae	large	narrow	nd	large	narrow, internally strongly silicified

Table 1 Cont.

Biogeography	specimens from Rodrigues I. (Mascarenes)	Indian Ocean, Mozambique Channel, Western Pacific	European coasts, also cited from New Zealand and Australia	<i>in schistum viride magaceum</i> (DII) (fossil from Jurassic) Croatia	Seychelles Is. (Indian Ocean)
Reference	C. R.-G. material from Rodrigues I.	present study	WITKOWSKI et al. 2000 ('505' GRUNOW slides 3921-3922)	JURILJ 1957	GIFFEN's type raw material from Mahé (Seychelles Is.)



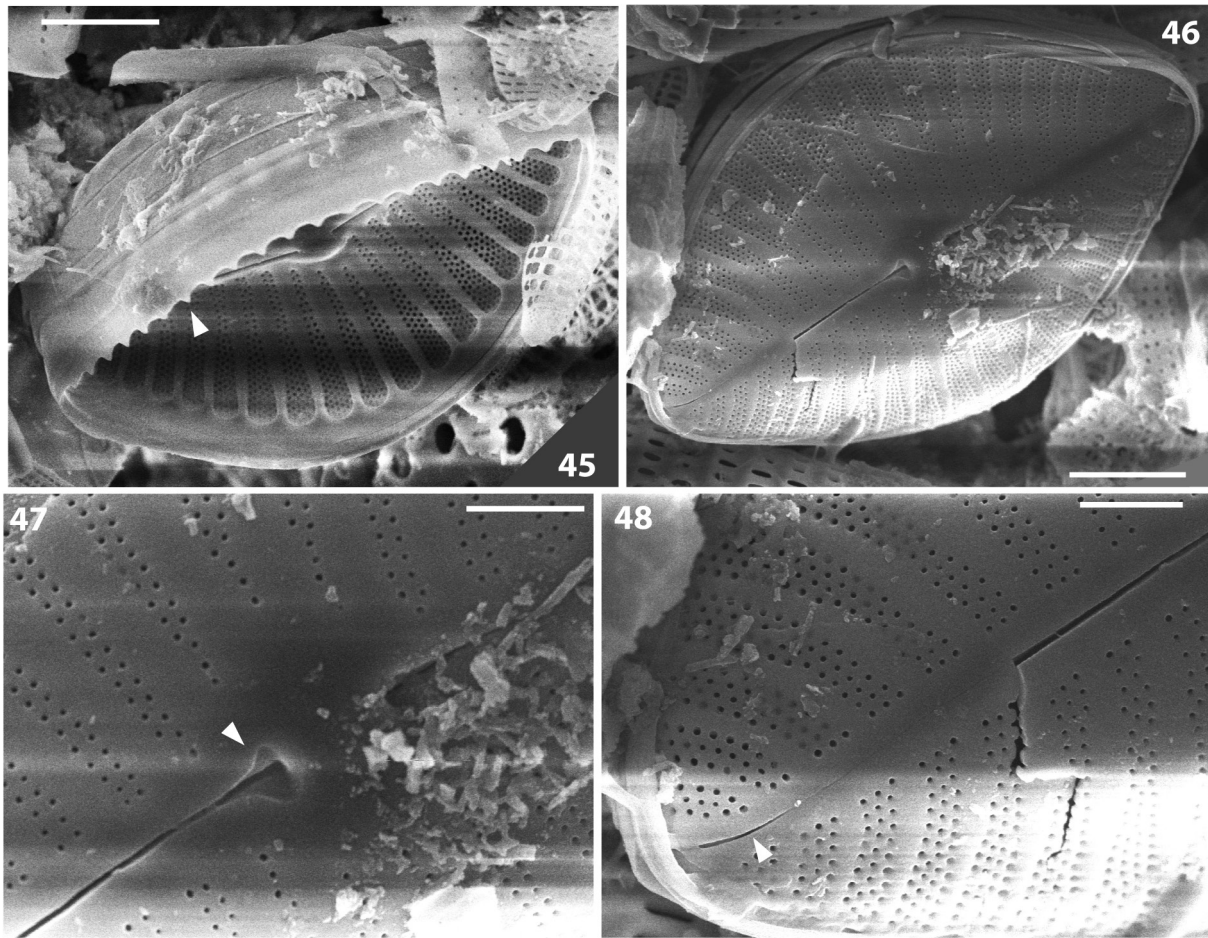
Figs 25-36. Reproduced from original figures: (25) *Achnanthis delicatulum* KÜTZ. (1844; pl. 3, fig. 21), (26) *Achnanthes delicatula* (KÜTZ.) GRUNOW in VAN HEURCK (1880-1885; pl. 27, figs 3-4), (27) *Platessa hustedtii* (KRASSKE) LANGE-BERT. (Basionym: *Cocconeis hustedtii* KRASSKE, illustrated in MANGUIN 1952: fig. 27), (28) *Achnanthes hauckiana* Grunow var. *elliptica* SCHULZ, f. *fossilis* in MANGUIN (1952; fig. 29), (29) *Planothidium holstii* (CLEVE) LANGE-BERT. (Basionym *Achnanthes holstii* CLEVE 1881; 13, pl. 16: figs 6-7), (30) *Raphoneis(?) quarnerensis* GRUNOW [1862; pl. 4, fig. 24a,(b),c], (31) *Cocconeis quarnerensis* (with GRUNOW no. 869.6) sketch in Grunow's 'Bilder-Sammlung' (Acqu. 1901/3630), (32) *Navicula ovulum* GRUNOW in SCHMIDT (1874; pl. 2, fig. 12), (33) *Navicula ovulum* GRUNOW (1860; pl. 1, fig. 19), (34) *Cocconeis quarnerensis* GRUNOW in SCHMIDT (1874; pl. 3, fig. 15-16), (35) *Cocconeis quarnerensis* var. *lanceolata* JURILJ (1957; pl. 16, figs 4a,b,c), (36) *Cocconeis quarnerensis* f. *rhombica* GIFFEN (1980; figs 13-14). Figures not at the same scale.



Figs 37–44. *Raphoneis quarnerensis* GRUNOW from ‘505’ slides–micas W–1901/3921–3922 (GRUNOW–capsule collection of *Amphora grevilleana*): (37–40) note the large elliptical SV sternum with a granular aspect (39) and the short and regular SV striae, *Navicula ovulum* GRUNOW from the broken ‘869’ slide–mica W–1901/3162 (GRUNOW–capsule collection of *Navicula ovulum*), (41–42) with a large RV central area (42) and the RVVC (RV valvocopula) with short–digit fimbriae (41, arrowheads), *Raphoneis quarnerensis* from the broken ‘869’ slide–mica W–1901/3162 (GRUNOW–capsule collection of *Navicula ovulum*), with short multiseriate striae, no *crista marginalis* (Fig. 43, arrowhead) and a large sternum with granular structure (Fig. 44, arrow). Scale bars 20 μm (37–40); 10 μm (42); 6 μm (44); 2 μm (41, 43).

it was mandatory to designate a lectotype rather than a neotype (MCNEILL et al. 2012; art. 9.12, 9.13) and moreover, the proposed ‘neotype’ was in serious morphological conflict with the protologue (MCNEILL et al. 2012; art. 9.19). ÁLVAREZ–BLANCO & BLANCO (2013) did

not designate a lectotype so that the name *Achnanthes delicatula* remains undefined. It can be noted that LANGE–BERTALOT & KRAMMER (1989) themselves show some hesitation in illustrating *Achnanthes delicatula* (KÜTZ.) GRUNOW ssp. *delicatula* since they give the comment:



Figs 45–48. *Planothidium quarnerense* f. *rhombica* (GIFFEN) WITKOWSKI et RIAUX–GOB. comb. nov. (SEM, from GIFFEN's type raw material from Seychelles Is.): (45) RV internal side, with multiserial striae and oval reduce and strongly silicified central area. Note the RVVC (RV valvocopula) with short-digit fimbriae (45, arrowhead). (46) External view of a RV, with characteristic pot-billed shape and protracted apices. (47) Details of the external RV, with spatulate proximal raphe ending and discrete central area and terminal raphe fissures deflected on the mantle (48). Scale bars 3 μm (45–46); 1 μm (47–48).

'heterogene Sippen, ergo 'sensu lato'. Finally, concerning *Planothidium delicatulum* sensu stricto, it can be noted that KÜTZING's raw material from Wangerooge was found by Pierre COMPÈRE and Bart VAN DE VIJVER in the VAN HEURCK collection (BR, Botanic garden, Meise). This material could belong to KÜTZING's original material. In LM, the latter material clearly shows protracted specimens (Bart VAN DE VIJVER, comm. pers.) matching the original drawings by KÜTZING (see above remarks).

Planothidium delicatulum sensu lato

Several other taxa can be compared to *Planothidium juandenovense*: e.g., *P. septentrionale* (Østrup) Round et BUKHT. ex RUMRICH et al. (2000) (Synonym: *Achnantheiopsis septentrionalis* (Østrup) LANGE–BERT.); *Achnanthes delicatula* ssp. *septentrionalis* (Østrup) LANGE–BERT.) as illustrated in LANGE–BERTALOT & KRAMMER (1989; 46, pl. 82, figs 1–24) with characteristics close to those of *P. delicatulum* as illustrated by the same authors, but with a more rhombic valve shape and less protracted apices; *P. australe* (MANGUIN) LE COHU (2005; pl. 5, figs 56–61) (Basionym: *Achnanthes delicatula* var. *australis*

MANGUIN in BOURRELLY & MANGUIN (1954; 20, pl. 2, fig. 18 a,b) with extremely protracted apices, from which a dubious RV external SEM view is proposed under *Achnantheiopsis robusta* in LANGE–BERTALOT (1997; fig. 21, as a possible synonym of *Achnanthes delicatula* var. *robusta* HUST., see illustration in SIMONSEN 1987; pl. 241, figs 31–32); *P. engelbrechtii* (CHOLNOKY) ROUND et BUKHT. (see identification and typification in COMPÈRE & VAN DE VIJVER 2009) and *P. galaicum* (Álvarez–BLANCO & BLANCO 2013). However, in contrast to all these taxa, *P. juandenovense* has an elliptic shape and apices round to very slightly elongate (never protracted), and systematically exhibits a more or less narrow rhombic SV sternum, a continuous and robust SV *crista marginalis*, and groups of areolae on the short mantle; the multiserial short SV striae are radiate throughout valve and the RV striae are rarely shorter in the centre on the valve.

Achnanthidiaceae D.G.MANN with short multiserial SV striae (i.e., *Platessa* and *Planothidium*)

Numerous Achnanthidiaceae D.G.MANN taxa, generally small and from freshwater environments, have short bi- to

multiseriate SV striae (see LANGE–BERTALOT & KRAMMER 1989; POTAPOVA 2011). In LM, the SV of *Platessa hustedtii* (KRASSKE) LANGE–BERT. (Basionym: *Cocconeis hustedtii* KRASSKE, see MANGUIN 1952; fig. 27 reproduced in Fig. 27) can be confused with the SV of our new taxon, but *P. hustedtii* has a RV completely different from that of the new taxon (see SEM illustration in POTAPOVA 2011) and it is a freshwater species. *Planothidium hauckianum* (GRUNOW) ROUND et BUKHT. 1996 [Basionym: *Achnanthes hauckiana* GRUNOW in CLEVE & GRUNOW 1880; Synonyms: *Achnanthes hauckii* GRUNOW (in VAN HEURCK 1880–1885; pl. 27, figs 14–15); *Achnanthes delicatula* ssp. *hauckiana* (GRUNOW) LANGE–BERT. et RUPPEL (1980; pl. 1, figs 1–18; LANGE–BERTALOT & KRAMMER 1989; Lectotype, coll. GRUNOW 1238, Rekaquellen bei Triest/Jugoslawien, pl. 87, figs 14–23); *Achnanthidium hauckianum* (GRUNOW) CZARN. (1994)] is oblong–elliptical, with a SV showing a sternum wider than that in *Planothidium delicatulum*, multiseriate striae (LANGE–BERTALOT & RUPPEL 1980; pl. 8, figs 268a–c and LANGE–BERTALOT & KRAMMER 1989; pl. 90, figs 5–6) and two SV (and RV?) striae more distant on one side of the valve. A poor LM of *P. hauckianum* can be found in DWIVEDI & MISRA (2014; pl. 2, fig. 11). A SV of a taxon presented as *P. cf. hauckianum* in KELLY et al. (2005) <http://craticula.ncl.ac.uk/EADiatomKey/html/Planothidium.html> has features very close to those of our new taxon (with the characteristic shadows on the sternum, see above). '*Achnanthes hauckiana* GRUNOW, var. *elliptica* SCHULZ–DANZIG, fo. *fossilis* nov. fo.' is illustrated by MANGUIN (1952; fig. 29, reproduced in Fig. 28). The latter has a wide SV sternum and a RV with a small central area that may be close to our new taxon, but its flattened apices are quite different from those of *Planothidium juandenovense*. SEM examination of the type of MANGUIN's taxon would elucidate its true structure (particularly the stria structure). *P. holstii* (CLEVE) LANGE–BERT. (Basionym *Achnanthes holstii* CLEVE 1881; 13, pl. 16: figs 6–7, reproduced in Fig. 29) has some similarities with our new taxon, but the RV of *P. holstii* has a characteristic bow–tie central area, while the central area is reduced in *P. juandenovense* (Fig. 19). The RV striae in *P. holstii* are narrow, while quadriseriate in our new taxon. Furthermore, the SV sternum of *P. holstii* is lanceolate, narrowing into linear endings, contrary to what is observed in *P. juandenovense*. On the short SV mantle of *P. holstii* (as illustrated by OTU & SPAULDING 2011) is a row of regular small areolae, while in our new taxon a *crista marginalis* delineates groups of areolae facing the striae (Fig. 9). We incidentally note that the specimens in OTU & SPAULDING (2011) have terminal raphe endings turned to opposite sides while they are turned to the same side in CLEVE (1881). *P. liljeborgei* (GRUNOW) WITKOWSKI, LANGE–BERT. et METZELTIN (2000; pl. 51, figs 27–29) may also be close to our taxon, with a similar valve shape and SV sternum, but with a lower SV stria density. Furthermore, a taxon illustrated by LANGE–BERTALOT & KRAMMER (1989; SEM, pl. 78,

figs 5–6; LM, pl. 87, figs 25–29) as '*Achnanthes* species I aus Süd–Chile' has short multiseriate SV striae, but it has no *crista marginalis* and no vestigial structures on the SV sternum.

***Planothidium quarnerense* and allied taxa**

Planothidium quarnerense (Basionym *Raphoneis quarnerensis* GRUNOW) and allied taxa, are also close to *P. juandenovense*. The original Latin description of *Raphoneis quarnerensis* GRUNOW 1862 is: *Raphoneis minor* late ovato lanceolata, apicibus obtusis, striis brevibus marginalibus 20–24 in 0.001" (= 7.9–9.4 striae in 10 µm), area media irregulariter et subtiliter punctata late lanceolata. Longit. 0.0008–0.0013" (= 20–33 µm). Latid. 0.0005–0.0007" (= 12.7–18 µm). Habitat in fundo maris adriatici. [Strandsand von Martinsica (i.e. Martinscia, Croatia), 2–4 Fuss tief, leg. Dr. LORENZ] pl. 7, fig. 24 a–c(b ?) (400/1), reproduced in Fig. 30. There is neither permanent type slide of *Raphoneis quarnerensis* GRUNOW in the GRUNOW–slide collection (W), nor raw type material for SEM examination.

The original illustrations of *Raphoneis quarnerensis* mention GRUNOW's number '505', and some sketches used for this publication are available in W. These small drawings are not very instructive relative to the terminal raphe endings of the taxon, and fig. 24b (in GRUNOW 1862, reproduced in Fig. 30b) may, as remarked by A. GRUNOW himself, equally well illustrate *Dimeregramma gregoriana* abundantly present in the sample. In Grunow's accession book the same locality (Strandsand von Martinsica) has been mentioned under Grunow no. 505. The examination of two slides covered with mica, from the '505' locality, in the GRUNOW capsule collection annotated *Amphora grevilleana* (W–1901/3921–3922), examined at x40, did not permit us to detail the terminal raphe endings of *Cocconeis quarnerensis* (Figs 37–40). A sketch (W–1901/3630), annotated with *C. quarnerensis* (with no. '869.b') illustrates terminal raphe endings as simple (reproduced in Fig. 31). On the other hand, the SEM examination of material from the broken slide '869' W–1901/3162 annotated with *Navicula ovulum* GRUNOW (as illustrated in SCHMIDT 1874; 88, pl. 2, fig. 12, reproduced in Fig. 32), allows us to conclude that the latter is a *Planothidium* (Figs 41–42). It can be incidentally noted that the original illustration of *Navicula ovulum* GRUNOW (1860; pl. 1, fig. 19, reproduced in Fig. 33) is quite different from the one produced in SCHMIDT (1874; pl. 2, fig. 12, reproduced in Fig. 32). The Grunow material ('869' W–1901/3162) also contained an SV [probably mentioned as *Raphoneis quarnerensis*(?) in the accession book] with short pluriseriate striae (Fig. 43), no *crista marginalis* (Fig. 43 arrowhead) and a large elliptic sternum with vermiform structures (Fig. 44 arrow).

Navicula ovulum is recognized as a heterotypic synonym of *Cocconeis quarnerensis* GRUNOW in SCHMIDT (1874; 93, pl. 3, fig. 15–16, reproduced in Fig. 34). In the original illustration of *C. quarnerensis* (Fig. 34), the

RV is broken (central area unreadable, Fig. 34 right) and the SV sternum is ornamented with granulations, while in HUSTEDT (1931–1959; fig. 814, surprisingly annotated as ‘original’), the RV central area is large and circular, very similar to the illustration of *Navicula ovulum* (Fig. 32). In previous illustrations by GRUNOW (see *C. quarnerensis* sketch in GRUNOW’s ‘Bilder–Sammlung’, W–1901/3630, reproduced in Fig. 31) and in SCHMIDT (1874–1959; pl. 192, figs 20–24), the RV central area is almost absent, the SV striae are very short and regular, with granular ornamentation on the large and elliptical SV sternum. Some other illustrations of *C. quarnerensis* GRUNOW were presented in SCHMIDT et al. (1874–1959; pl. 192, figs 20–24). WITKOWSKI et al. (2000; pl. 55, figs 2–7, no type checking), created the new combination *Planothidium quarnerense* (originally wrongly spelled *P. quarnerensis*), with the comment (but no illustration): ‘apical endings unlike in *Cocconeis* terminate in polar position not below apices’.

Several illustrations assigned to *Planothidium quarnerense* (e.g. RIAUX–GOBIN 1991; pl. 4, figs 6–9; WITKOWSKI et al. 2000; pl. 55, figs 2–7; SAR et al. 2003; fig. 43 and RIAUX–GOBIN et al. 2014; figs 15–20) show very short and regular SV striae and granular ornamentation on the large and elliptical SV sternum. In *P. juandenovense*, the SV striae are relatively long (Figs 8, 10) and they often end irregularly (Fig. 2), furthermore the SV sternum is not regularly elliptical, but fusiform to rhombic, the SV striae being often shorter in mid–valve and longer on apices (Figs 2, 3–5, 13). In *P. juandenovense*, the SV sternum is ornamented with straight slits in the prolongation of each virga (Fig. 11 arrowhead). A main difference of *P. juandenovense* from *Cocconeis* (*Planothidium*) *quarnerensis* such as illustrated in RIAUX–GOBIN et al. 2014, from ‘Arran57’ slides, is the length of *Planothidium quarnerensis* three times higher (32.4–36.7 μm , mean 34.3 ± 1.5) and the lower stria densities (SV: 8.5–9 striae in 10 μm , mean $8.6 \pm .5$ and RV: 9.5–10.5 striae in 10 μm , mean 9.8 ± 0.5 , Table 1). The measurements from the GRUNOW’s slides ‘505’ (3921–3922 collection GRUNOW in W) confirm the latter points (Table 1).

From 1926 to 1980, several varieties and formae of *Planothidium quarnerense* were published: *Cocconeis quarnerensis* f. *rhomboidale* SCHULZ–DANZIG (1926; 195, fig. 52), *C. quarnerensis* var. *borgesensis* J.N. MISRA (1956; 559, fig. 51), *C. quarnerensis* var. *lanceolata* JURILJ (1957; 68, pl. 16, fig. 4a,b,c, reproduced in Fig. 35) and *C. quarnerensis* f. *rhombica* GIFFEN (1980; 144, pl. 1, figs 13–14 reproduced in Fig. 36). Among the latter taxa, *C. quarnerensis* var. *lanceolata* might correspond to our taxon except for the valve shape (more acuminate than in *P. juandenovense*), the RV central area that is much more developed and the proximal raphe endings turn on the same side (while straight–coaxial in our taxon). On the other hand, the drawing of the SV in JURILJ (ref. cit.: middle illustration in Fig. 35), is very close to ours, with the characteristic vestigial and straight slits

on the sternum. *C. quarnerensis* f. *rhombica* GIFFEN, except for its pot–bellied shape and tapered to capitate apices (versus oblong–elliptical with rounded apices in the new species), is close to our taxon. The SEM illustration (Figs 45–48) of the type material permits to transfer this taxon under *Planothidium quarnerense* f. *rhombica* (GIFFEN) WITKOWSKI et RIAUX–GOB. comb. nov., due to its terminal raphe fissures characteristic of the genus (Fig. 48, arrowhead) and RV striae composed of multiple rows of areolae (Figs 47–48), while its shape, and slightly bigger dimensions, differentiate it from *P. juandenovense* (Table 1). The Fig. 45 permits description of the SVVC (sternum valve valvocopula) of *P. quarnerense* f. *rhombica* as large, with short–digit fimbriae (Fig. 45, arrowhead), and the RV central area as very restricted (Fig. 45). Unfortunately the SV of *P. quarnerense* f. *rhombica* was not found.

New combination: *Planothidium quarnerense* f. *rhombica* (GIFFEN) WITKOWSKI et RIAUX–GOB., **Basionym:** *Cocconeis quarnerensis* f. *rhombica* GIFFEN (1980; A checklist of marine littoral diatoms from Mahé, Seychelles Islands. Bacillaria 3; 129–159, p. 144, pl. 1, figs 13–14).

CONCLUSION

Planothidium quarnerense, *Cocconeis quarnerensis* var. *lanceolata*, *P. quarnerense* f. *rhombica* and *P. juandenovense* have similar morphometrics and features (Table 1). Nevertheless *P. juandenovense* is slightly smaller and has a RV and SV striation denser than other taxa. Furthermore, the SV *crista marginalis* and SV vestigial structures in *P. juandenovense* may be unique features. The SV sternum also shows different shape and width among all, and their biogeography also differs (Table 1). *Planothidium juandenovense* is morphologically close to *P. delicatulum* and *P. septentrionale* and probably belongs to the same morphological complex of species. The unique vestigial structures on the SV sternum may suggest that *P. juandenovense* has lost some ancestral characters and represents a recent splitting from the *P. delicatulum* group. Genetic analyses are needed to strengthen this hypothesis, but the new taxon is relatively rare and probably difficult to cultivate.

The *Planothidium delicatulum* complex is, however, a polymorphic group from which several varieties of the basionym *Achnanthes delicatula* were subsequently recombined and renamed as separate species (e.g., *A. delicatula* ssp. *engelbrechtii* (CHOLNOKY) LANGE–BERT., *A. delicatula* ssp. *hauckiana*, *A. delicatula* ssp. *septentrionalis*, *A. delicatula* var. *robusta* HUST., *A. delicatula* var. *australis*, see above). Furthermore, *P. delicatulum* var. *delicatulum* has to be lectotypified, which would allow description of its morphological characters. Comments by the ‘Diatom Key Development Team’ (KELLY et al. 2005; <http://craticula.ncl.ac.uk/EADiatomKey/html/Authors.html>) are relevant about the need for caution

related to the taxonomy of *P. delicatulum*, since the morphological characteristics of such a taxon depend on cell size (TROPPER 1975; KOCIOLEK & STOERMER 2010).

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