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A new licmosphenioid, *Licmophora complanata* (Bacillariophyta: Fragilariophycidae), from Majuro Atoll, Central Pacific

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Abstract

A new *Licmophora* with an apical window and additional perforations in the septum was discovered in a sample from Majuro Atoll, Marshall Islands. Valves are so narrow that they almost always present in girdle view, when they appear triangular, the mantle comprising most of the valve surface. A eucentric stage was used to tilt specimens up to 80° to see the shape in valve view and to see rimoportulae. Valves were 92–140 µm long, 8 µm wide, with three expanded areas, the broadest in the middle. The areolae were elongated in the apical axis but separated by wide virgae and vimines, unlike the narrow and closely spaced areolae in *Licmophora abbreviata*, but with essentially similar vela. The morphology of *Licmophora complanata* is most like *Licmophora peragallioides* and *Licmophora clevei* in having a moderately long and wide rostrum with a moderately large apical window in the septum.

Key index words: areolae, biodiversity, coral reefs, Marshall Islands

Introduction

The genus *Licmosphenia* Mereschkowsky was characterized by the presence of an apical window in the septum, and many species have long rostrate extensions of the usual clavate *Licmophora* shape (Lobban 2013), but Lobban *et al.* (2015) concluded that *Licmosphenia* is conspecific with *Licmophora*. In that paper we also named some new species of licmosphenioid *Licmophora* and showed that not all have closely-spaced vimines (forming narrow, apically elongate areolae) like *Licmophora abbreviata* C.Agardh. In material collected on Majuro Atoll in 1991, I recently found another species with apical windows in the septa and widely spaced, apically elongated areolae not previously seen in *Licmophora*.

Methods

Material had been collected in 1991 during a collecting trip focused mainly on dinoflagellates, preserved in formalin, and stored in the GUAM Diatom Collection, sample M1, slides catalog # GUD600133 (donated to SZCZ in Jan. 2021) and GUD600600–603; SEM stub, catalog # GUD700151. The additional slides and the stub were prepared Jan. 2011. Comparative material of *Licmophora peragallioides* (Lobban) Lobban & Ashworth was from Guam (GU66G-5, GUD700709, Lobban 2013) and of putative *L. abbreviata* from Heron Island, Great Barrier Reef, Australia (GBR3-1, GUD701248, Lobban & Santos in prep.). The samples had been processed with acid cleaning in nitric acid (boiled 10 min, left 24 h), then rinsed 10 times with distilled water. Drops of suspension had been dried onto coverslips for light microscopy (LM) and Whatman cellulose nitrate filters for scanning electron microscopy (SEM). Permanent slides had been made with Naphrax® (Brunel Microscopes, Ltd., Chippenham, Wilts., U.K.). The stub was originally coated with Au-Pd in a SC7620 Mini Sputter Coater (Quorum Technologies, East Grinstead, West Sussex, UK). LM was carried out with a Nikon 80*i* microscope with differential interference contrast illumination and images recorded with a Nikon DS-Fi1 camera and DS-L2 controller (Nikon Instruments, Redmond, WA, USA). Initial SEM was done with a PhenomWorld G2 Pro desktop instrument (PhenomWorld US, Hillsboro, OR, USA), but the specimens were reimaged for this paper with a new Thermo-Fisher Phenom XL G2 (NanoScience Instruments, Phoenix, AZ, USA) running at 10 kV, after recoating the stub with a further 10 nm of gold using a Luxor Goldcoater sputter coater (NanoScience Instruments, Phoenix, AZ, USA). A eucentric stage for the XL was used for tilted views and the highest magnification images were taken in low-emission mode.

Specialized terminology follows Honeywill (1998), Lobban (2013) and Lobban *et al.* (2015, 2018). In particular, *septal bridge* is used to describe the part of the septum below the *apical window* (see Figs 18–20), and the shape of the valve is considered to be modified from the clavate form of *Licmophora* with a more or less extensive

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rostrum over the septal bridge and apical window. The cingulum in *Licmophora* comprises the valvocopula and four pleurae, of which the fourth is frequently delicate and narrow except for an apical cap, and often missed. Areolae on the girdle bands may be circular/oval (=porate) or elongated (=rimate: Fig. 28) (Lobban *et al.* 2018).

Results

Licmophora complanata Lobban sp. nov. (Figs 1–25).
Diagnosis: differing from other *Licmophora* spp. with apical windows in the septa by the extremely narrow valve faces and broad mantles, such that isolated valves and valvocopulae usually lie in girdle view. Differing from all known congeners in having apically elongate areolae with wide vimines. Septal bridge with pore fields and irregular holes.

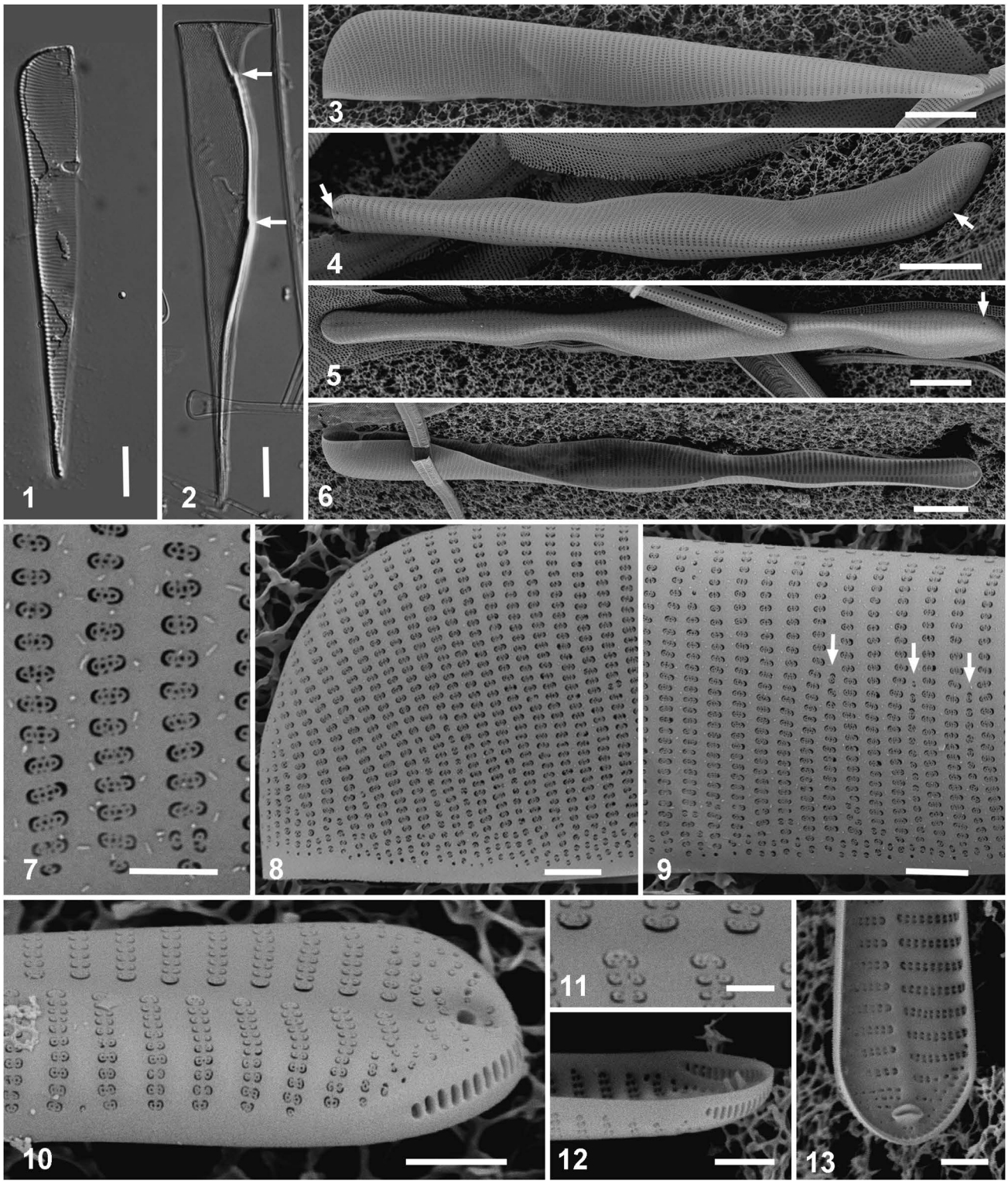
Description: In LM (Figs 1, 2) the valve and valvocopula were seen only in girdle view, where the valve appears as an asymmetrical cuneate form with a broadly rounded apical pole and an extremely narrow basal pole. In SEM (Figs 3–6), valve seen to have a relatively wide basal pole narrowing slightly before the first expansion, narrowing again before the widest expansion, then with a long narrow valve face before the apical expansion. Length 92–140 µm, widest at the middle (7.9 µm, as measured on valvocopula, Fig. 20) with a narrow rostrum ending in an enlarged apex, 6.6 µm wide. Depth of the valve near the apex 11 µm. Striae 10 in 10 µm near the base, increasing to 12 in 10 µm, readily visible in LM, offset across the sternum, the virgae 320 nm wide. Striae comprising apically oriented oval areolae, 26 in 10 µm, covered with vela having C-shaped apical and basal slits with one to several circular pores in between (Figs 7, 11). Areolae smaller near the margin and rows adjacent to sternum have one large C-shaped slit oriented distally, with a few circular pores (Figs 9, 11, 13). There are intercalated striae on both central and apical bulges as well as among the small marginal areolae (Figs 8, 9). Multiscissura with estimated 25–27 slits (Figs 10, 12, 13). Basal rimoportula external opening in a small depression (Fig. 10), internal structure oriented transapically and at 60° to valvar plane (Figs. 12, 13). Apical rimoportulae present on both valves, seen only by their external openings (Figs 4, 5).

Valvocopula cuneate in girdle view (Figs 2, 14), large apical ligule on the abvalvar side, open ends tapered; 18–20 µm deep at apex; 29 striae in 10 µm, the areolae small, 25 in 10 µm (Fig. 16). Midrib crossing from abvalvar to advalvar side of band below the central bulge of the cell. Septum (Figs 15, 17–20), strongly swung (Figs 2, 14) in Hustedt's (1931) terms, with oval apical window, long septal bridge with large holes and small pores along the margin, the pattern not consistent (Figs 15, 18, 19), lower rim of the septal bridge probably thickened (Fig. 20). The *1st pleura* curved (Figs 21–23) 10 µm across the deepest part, striae 25 in 10 µm, the areolae larger than those on the valvocopula and becoming elongate along the eccentric midrib. Given the shape of the open ends and their fit against the valvocopula, the midrib is toward the advalvar margin of the band. The *2nd pleura* straight and tapered (Figs 24, 25), striae 26 in 10 µm, eccentric midrib, small areolae, like those of valvocopula. The 3rd and 4th pleurae not found. The 3rd pleura expected to be similar to 1st pleura; specimen in Figs 21–23 inferred to be 1st pleura because of its association with a valve and valvocopula. If this inference is correct, midrib on 2nd pleura (Figs 24, 25) eccentric toward advalvar margin.

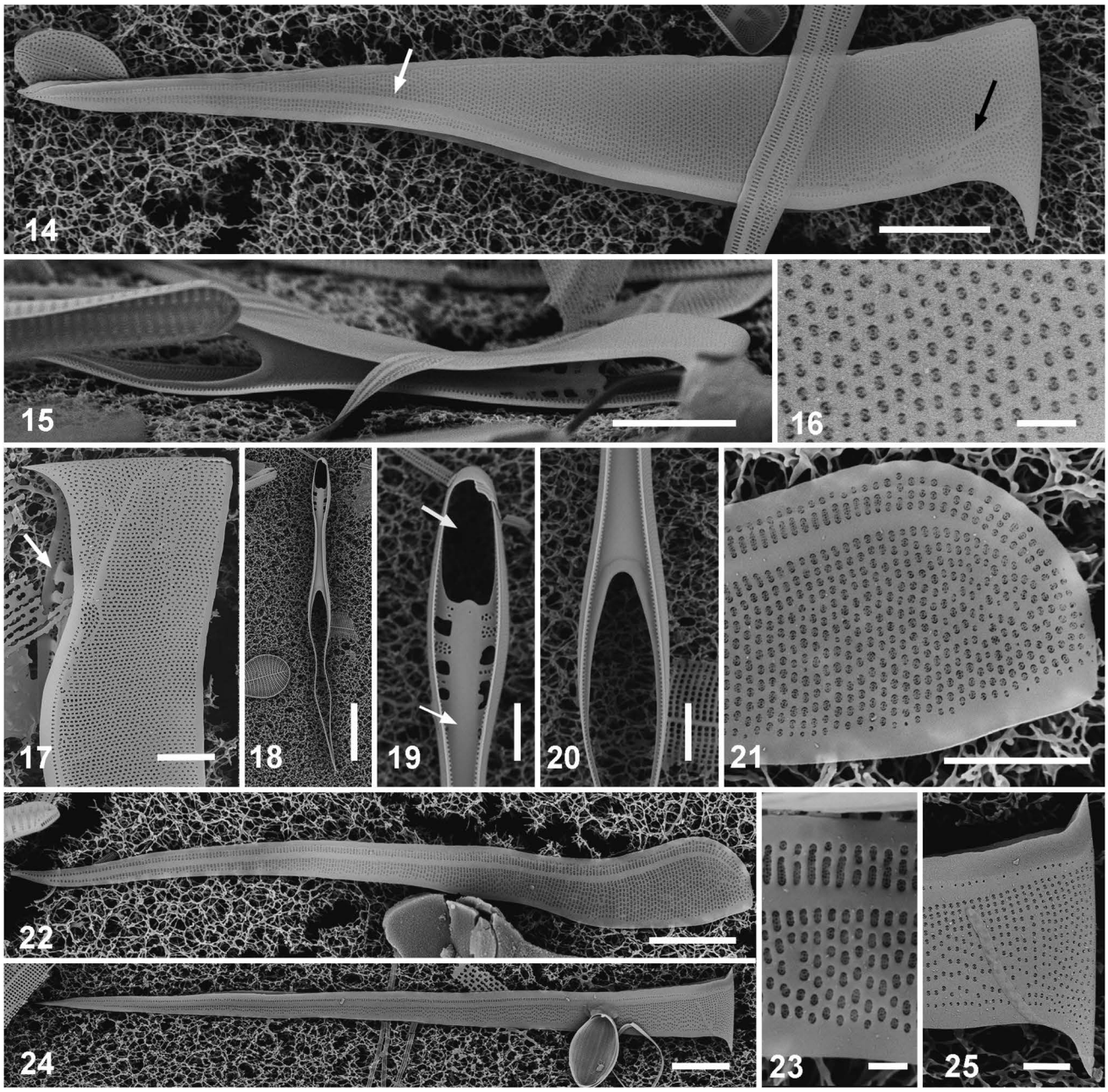
Holotype: Specimen at 10.3 mm E and 15.7 mm S of the mark on slide 600 [GUD600600], transferred to ANSP, accession number ~~[pending]~~ (Fig. 1).
Isotype slides in GUAM diatom collection catalog # GUD600601 through GUD600603.
Type locality: Shallow reef flat at Mile 28, South Laura, Majuro Atoll, Republic of the Marshall Islands, approx. 7°8′14"N, 171°2′17"E, sample M1, coll. C.S. Lobban and M. Schefter, 4 June 1991. Diatom community dominated by *Florella lindigiana* (Grunow) Lobban, J.N.Navarro & T.M.Schust., epiphytic on filamentous algae in farmer fish territory.
Etymology: Latin *complanatus*, flattened out, for the shape of the frustule.
Registration: http://phycobank.org/102927.

Additional observations on *Licmophora peragallioides* and *L. abbreviata*:
Details of the areolae in the morphologically similar *L. peragallioides* could not be seen with instrument in use at the time it was described (Lobban 2013), so I reexamined the material with the new SEM (Figs 26–28). Depth of the valve 6 µm near the apex. Striae 16 in 10 µm near apex, virgae 110 nm wide. Vela of apically elongated areolae on valve were often bordered by a ring of small pores with crescent-shaped openings at one or both ends (Fig. 27). In the lower part of the mantle the striae often biseriate or even triseriate while stria width remained the same. Areolae on valvocopula oval and oriented in the pervalvar axis, vela usually perforated by a ring of small pores with one in the middle. Areolae on 1st pleura mostly elongated (rimate) in the pervalvar axis (Figs 26, 28), vela with a rim of small pores and some in the middle, occasionally a C-shaped slit at one or both ends.

Putative *Licmophora abbreviata* was examined in the same microscope to see if the appearance of the areolae was the same as in *L. peragallioides*, and it was, although



Figs 1–13. *Licmophora complanata* sp. nov., LM views and SEM of valves. Fig. 1. Valve in girdle view (holotype). Fig. 2. Valvocopula in girdle view, arrows point to top and bottom of the septal bridge (measured to middle of arcs) (cf. Fig. 18). Fig. 3. Valve in girdle view. Figs 4–6. Valves tilted to 60° to show valve view, valve in Fig. 4 the same as that in Fig. 3. Valve in Fig. 4 has apical and basal rimoportulae, Fig. 5 only apical (arrows), showing there are 3 rimoportulae total. Fig. 6 showing internal surface. Fig. 7. Detail of areolae on valve. Figs 8, 9. Closer views of valve in Fig. 3 to show apical striae and (Fig. 9) striae and intercalated striae (arrows) around widest part. Fig. 10. External, oblique view of basal pole showing offset striae on opposite sides of sternum and recessed rimoportula opening. Fig. 11. Detail of areolae adjacent to sternum. Fig. 12. Oblique view of basal pole showing angle of rimoportula. Fig. 13. Same valve tilted 60° to internal surface of basal pole with rimoportula. Scale bars: Figs 1–6 = 10 µm, Fig. 7 = 1 µm, Figs 8, 9, 10, 12, 13 = 2 µm, 11 = 500 nm.

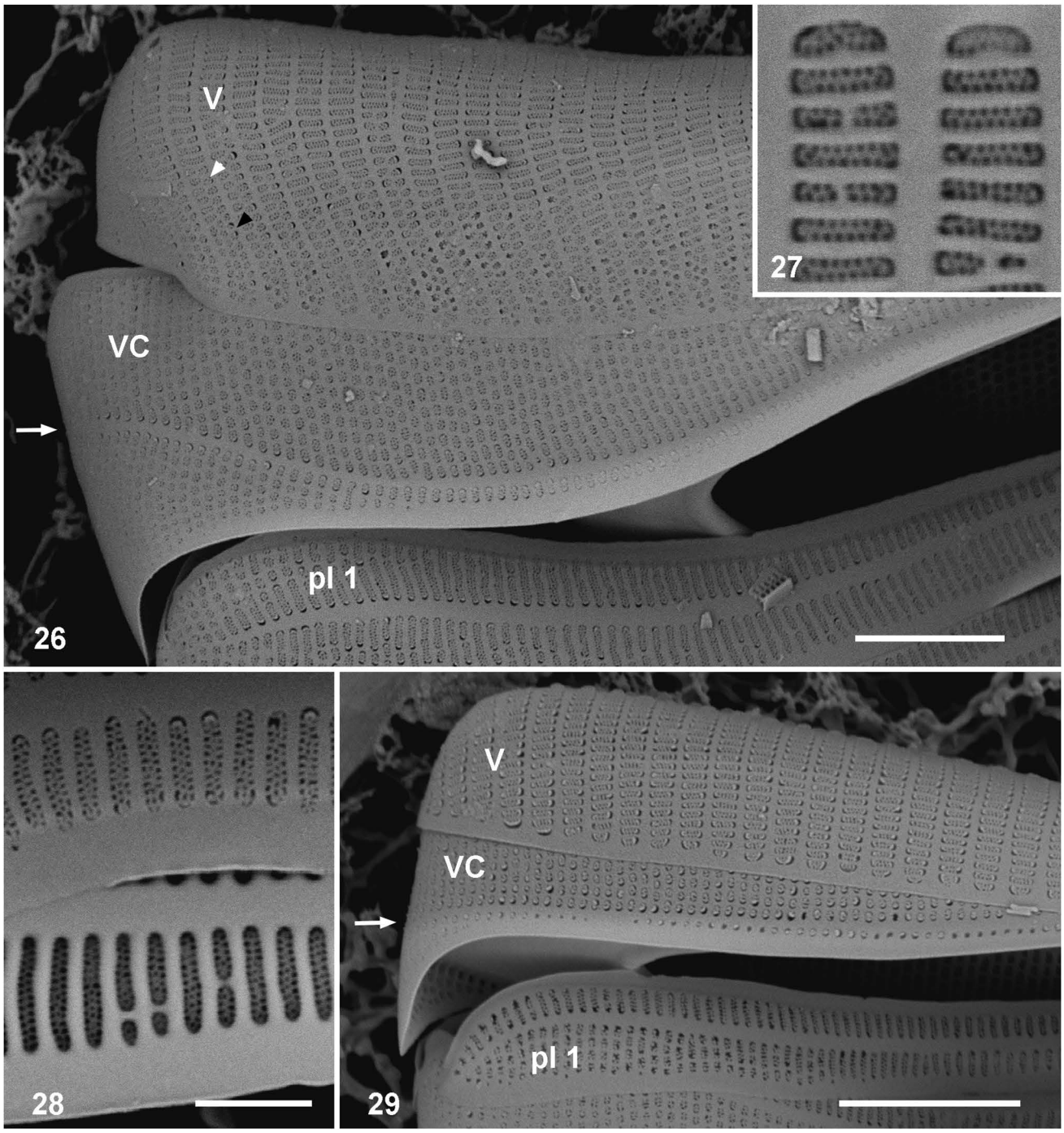


Figs 14–25. *Licmophora complanata* sp. nov., SEM of girdle bands. Figs 14, 15. Valvocopula in girdle view and tilted 80° to show the septal bridge. White arrow in Fig. 14 shows where midrib crosses band from ab- to advalvar side, black arrow shows path of midrib along the apical window. Fig. 16. Detail of areolae near apex on same specimen. Fig. 17. Apex of a different specimen, showing part of the septal bridge (arrow). Figs 18–20. Valvocopula in advalvar view, entire and details of apical and central portions. On Fig. 19, large arrow points to apical window, smaller arrow to septal bridge. Figs 21, 22. 1st pleura, one arm at two magnifications; midrib strongly eccentric toward the valvocopula. Fig. 23. Same specimen, detail of internal surface. Figs 24, 25. Straight 2nd pleura, showing very small areolae. Scale bars: Fig. 18 = 20 µm, Figs 14, 15, 22, 24 = 10 µm, Figs 17, 19, 20, 21 = 5 µm, Figs 16, 24 = 1 µm.

the apically elongate areolae continued to the margin (Fig. 29). Areolae on the valvocopula were also similar. Specimens in this population from the Great Barrier Reef were 31 µm long, 6 µm wide, striae 15 in 10 µm in the basal half, 19 in 10 µm near the apex, multiscissura with 9 slits. Septum straight. The 1st pleura rimate except porate on the abvalvar side near the apex.

Discussion

The range in size and shape of the rostrum in the licmosphenioid *Licmophora* species is large, from *Licmophora garyi* Ulanova with a tiny window at the end of a short rostrum, to *L. pisciformis* with a wide window and no rostrum, and *Licmophora clevei* (Mereschkowsky) Car & Herwig and *L. peragallioides*



Figs 26–29. Comparison species. Fig. 26. *Licmophora peragallioides* apex of frustule showing areola patterns on valve (V), valvocopula (VC) and 1st pleura (pl 1). White arrowhead shows biseritate part of stria and black arrowhead triseriate part. Arrow shows "swung" path of midrib/septum. Fig. 27. Portions of two striae, adjacent to sternum, interior view. Vela bordered by a ring of small pores and with crescent-shaped opening at one or both ends. Fig. 28. Detail of 1st pleura internal and external sides showing rimate areolae. Fig. 29. *Licmophora abbreviata* valve, valvocopula and 1st pleura, abbreviations as Fig. 26; arrow shows straight path of septum. Scale bars: Figs 26, 28 = 3 µm, Fig 27 = 1 µm.

with intermediate-size windows in long rostra (Lobban 2013, Lobban *et al.* 2015). *Licmophora complanata* is most like the latter two in having a long rostrum with a medium window. The widths of the apices are similar in the three species, but *L. complanata* differs in that the septal bridge is wider than the apical window, i.e., the widest part of the apical bulge is not across the middle of the window. The depth of the valve at the apex is relatively large in *L. peragallioides* compared to most *Licmophora* spp. but *L. complanata* is still deeper, and its maximum width is only 8 µm compared to 14–16 µm maximum width in *L. peragallioides*. Thus, the very nar-

row valves and copulae almost always settled in girdle view (Figs 18–20 show the one exception), requiring a high tilt angle to see the valve faces. *Licmophora clevei* is only 5–6 µm wide, but its mantle is very shallow so that valves usually settle in valve view. The pore fields and irregular holes along the sides of the septal window are unique, although scattered pores and pits have been seen in other species [e.g. *L. albertmannii* (Lobban) Lobban & Ashworth (Lobban 2013)].

Licmophora clevei and *L. peragallioides* have coarse striae with apically elongate areolae, like the pattern in *L. abbreviata* and *Licmophora ehrenbergii* (Kützing) Grunow, where the striae are described from TEM as "divided up by very fine vimines, with the vela of this third type of areolae…suspended by pegs from the vimines" (Honeywill 1998:263, figs 17 g, h). It was hard to equate the pattern seen in *L. peragallioides* in SEM with Honeywill's TEM, but observation of *L. abbreviata* with the new SEM (Fig. 29) confirmed that they are the same. The pattern of pores in the vela of *L. complanata* may also be fundamentally similar, although the areolae are shorter; if so, the strikingly different appearance would be due to the spacing of the areolae: the vimines are much wider in *L. complanata*, areola density thus only 26 in 10 µm, compared to 55–60 in 10 µm in three species listed by Honeywill (1998). The virgae are also relatively wide: 320 nm in *L. complanata* vs. 110 nm in *L. peragallioides*, so that whereas *L. peragallioides* has 16 striae in 10 µm, despite longer areolae, *L. complanata* has only 12 in 10 µm. Whether the Australian specimens can be classified as *L. abbreviata* is a matter I will take up in another paper. For now, it will suffice for the comparison made, and I would just note that there are differences from the stria densities cited by Hustedt (1931) and Honeywill (1998), and perhaps more important, Hustedt described and illustrated the midrib of the valvocopula as "+/− strongly swung," whereas in these specimens it is straight (arrow, Fig. 29).

There are other *Licmophora* species with areolae that do not fit the patterns found in Britain by Honeywill (1998). Among these are *Licmophora antarctica* M.Peragallo and *Licmophora belgicae* M.Peragallo, which both have small circular areolae but very wide vimines, resulting in stria densities of 6–12 and 10–12 in 10 µm, respectively (Fernandes *et al.* 2014), and *Licmophora luxuriosa* Heiden with closely spaced, apically oriented areolae but striae separated by very wide virgae, resulting in stria densities of 5–7 in 10 µm (Fernandes *et al.* 2014).

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