Acta Protozool. (2015) 54: 275–281
www.ejournals.eu/Acta-Protozoologica
doi:10.4467/16890027AP.15.022.3536

ACTA
PROTOZOOLOGICA

Ventimolina stellata gen. *et* sp. nov. (Haptophyta, Papposphaeraceae) from Warm Water Regions

Helge Abildhauge THOMSEN[1], Jette Buch ØSTERGAARD[2], Lluïsa CROS[3]

[1] National Institute of Aquatic Resources, Technical University of Denmark, Charlottenlund, Denmark; [2] Nørrebrogade 52a 5th, 2200 Copenhagen N, Denmark; [3] Institut de Ciències del Mar (CSIC), Barcelona, Spain

Abstract. It has been known for some time that the distinctive polar weakly calcified coccolithophores are also present in samples from lower latitudes. While polar species may actually have a geographic range that vastly extends beyond the polar realms, it is often the case that the warm water regions contribute species that can be allocated to genera previously described based on polar material. We are currently in the process of formally dealing with the warm water species diversity affiliated with the family Papposphaeraceae. In this paper we describe a new genus and species *Ventimolina stellata* based on material from the Andaman Sea (type locality) and the NW Mediterranean.

Key words: *Ventimolina*, *V. stellata*, Papposphaeraceae, Andaman Sea, NW Mediterranean, electron microscopy.

Abbreviations: TEM – transmission electron microscope; SEM – scanning electron microscope; LM – light microscope; CFC – circum flagellar coccolith; BC – body coccolith.

INTRODUCTION

Weakly calcified coccolithophores have become a trademark of polar water masses (see e.g. Thomsen 1981; Thomsen *et al.* 1988; Charalampopoulou *et al.* 2011; Thomsen *et al.* 2013; Thomsen and Østergaard 2014a, b, c). The vast majority of the forms encountered cluster within the Papposphaeraceae Jordan and Young 1990 (emend. Andruleit and Young 2010), comprising e.g. species of *Papposphaera* Tangen 1972 and *Pappomonas* Manton and Oates 1975. Other genera such as *Wigwamma* Manton *et al.* 1976 (see Thomsen *et al.* 2013) are often classified under genera incertae sedis aff. Papposphaeraceae (Young *et al.* 2003), while finally some polar genera (e.g. *Ericiolus* Thomsen in Thomsen *et al.* 1995 and *Mercedesia* Thomsen and Østergaard 2015) can only so far be categorized under 'nannoliths incertae sedis'. While some species may be biogeographically restricted to polar regions is has recently become evident (Thomsen and Buck 1998, Cros and Fortuño 2002, Young *et al.* 2003, Thomsen and Østergaard, unpubl. results) that most of the polar genera also contain species that thrive in significantly different water masses, and that new warm water genera closely affiliated with the polar forms occur.

Address for correspondence: Helge Abildhauge Thomsen, National Institute of Aquatic Resources, Technical University of Denmark, Jægersborg Alle 1, 2920 Charlottenlund, Denmark; E-mail: hat@aqua.dtu.dk

We are in the process of assembling material that can gradually elucidate the warm water diversity of weakly calcified coccolithophores. In this paper we describe a new genus, *Ventimolina* gen. et sp. nov., that bears a resemblance to both *Pappomonas* and *Wigwamma*.

MATERIALS AND METHODS

The Andaman Sea material originates from three Thai-Danish collaborative cruises on board the RV "Chakratong Tongyai" occupying stations along three transects almost perpendicular to the west coast of southern Thailand (Fig. 1). Sampling intended for taxonomic studies was carried out during two cruises in 1996 (11–27 March and 15–29 August) and one in 1997 (11–27 February). Water samples for TEM processing were collected from vertical profiles (5–80 m) at a sub-set of stations along the transects. The material used here originates from the August 1996 cruise. For further details on sampling strategy, hydrography of the area and lower trophic level communities, see Nielsen *et al.* (2004).

Nannoplanktonic organisms were selected by prefiltration (mesh size 20 µm) and concentrated through gravity filtration on top of a 2.0 µm membrane filter. Organisms collected on the filter were gently resuspended in a small volume of water and further concentrated by means of centrifugation. Whole mounts for examination in a TEM or using a LM were prepared from the resuspended pellet of material according to well-established procedures (Moestrup and Thomsen 1980, Thomsen 1982). The TEM grids were shadow cast with chromium at a low angle and examined on a JEM-100SX electron microscope at the Botanical Institute, Univ. Copenhagen.

The NW Mediterranean samples were collected during the MESO-96 cruise (see Cros and Estrada 2013 for details) on board the RV "Garcia del Cid" from 18 June to 3 July 1996. The material used here originates from station D6 (41°14.3′N/3°38.0′E) and was collected from a depth of 100 m. Water samples (ca. 200 cm^3) were filtered using a vacuum pump onto a polycarbonate membrane filter (0.8 µm pore size and 25 mm diameter) placed on top of a cellulose ester filter (3 µm pore size). Salt was removed by washing the filters with 1–2 cm^3 of bottled drinking water. The filters were air dried and stored under partial vacuum in hermetically sealed boxes until the SEM analysis. For preparation, a part of the membrane filter was placed on a SEM stub and coated with a film of gold or gold-palladium (ca. 150 Å). The sputter coater used was a Polaron SC-500. The SEM used was a Hitachi S-570 scanning electron microscope at the Institut Ciencies del Mar (CSIC) in Barcelona. For a detailed SEM preparational protocol see Cros and Fortuño (2002).

RESULTS AND INTERPRETATION

Ventimolina gen. nov.

Diagnosis: Small, dimorphic coccosphere. Flagellar pole coccoliths quasicircular and with a calicate central spine that arises from a cruciform central area. The longitudinally flattened calyx comprises four elements one of which is markedly hypertrophied. Body coccoliths oval with a central area cruciform calcification that leads into a short stem that is in turn terminated by a cruciform structure composed of four elements arranged in the shape of a windmill. The rim calcification in both CFC's and BC's is limited to a single cycle of directly butting, rod-shaped elements.

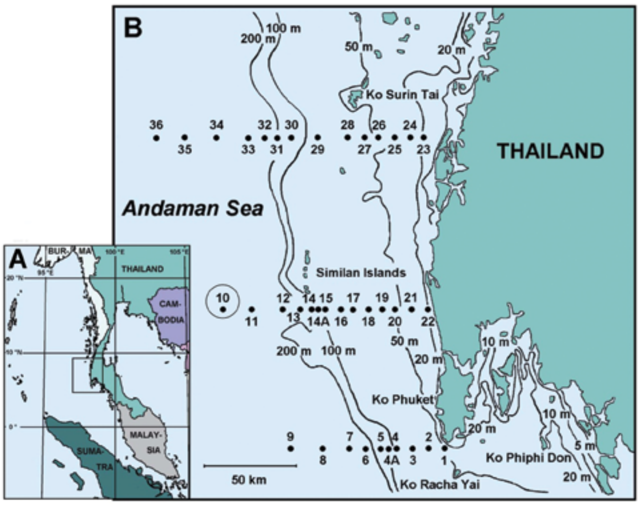


Fig. 1. A – study region and the Andaman Sea; **B** – area of investigation in the western part of the Andaman Sea, off the coast of Thailand. Transect sampling is indicated by lines of stations, contour lines illustrate bathymetry by isolines of 5, 10, 20, 50, 100 and 200 m bottom depth. The type locality of *V. stellata* is encircled.

Type species: *Ventimolina stellata* sp. nov. (Figs 2–6)

Etymology: from 'ventus' (L) meaning wind, 'mola' (L) meaning millstone, and 'ina' diminutive suffix. The generic name reflects the resemblance between a windmill and the body coccolith calyx.

Ventimolina gen. nov. is morphologically distinct and coccoliths even slightly reminiscent of those described here are not mirrored in any extant or extinct coccolithophore taxa. The new monospecific genus shares features with members of the Papposphaeraceae (Jordan and Young 1990, Andruleit and Young 2010) in particular species of *Pappomonas*. An extended discussion of the higher level affinities of *Ventimolina* gen. nov. is found below.

Ventimolina stellata sp. nov. (Figs 2–6)

Synonyms:

Unidentified sp. 2 in Cros 2001 (publ. in 2002) Plate 76 Figs 5–6

Unidentified sp. 2 in Cros and Fortuño 2002 l.c. Fig. 111D

Diagnosis: With the characteristics of the genus. The coccosphere measures ca. 10 × 5 µm (Fig. 2). Body coccoliths oval (ca. 1.0 × 0.6 µm). The stem of the calicate spine is a short (ca. 0.3 µm) continuation of the cruciform central area calcification (Fig. 4). The calyx is constructed of four right-angled triangular elements in which the hypotenuse is jagged (Fig. 6). The four elements are neatly arranged in a symmetrical wheel which is placed perpendicular to the stem (Fig. 4). There is a differentiation in size and robustness of the calyx structure, i.e. a gradual decrease in size (1.1–1.3 µm) from the anterior cell end towards the posterior end (Fig. 2). Flagellar pole coccoliths (ca. 12) with a quasicircular outline and a cruciform central area calcification that leads into a conspicuous calicate spine. The stem measures ca. 1.5 µm. The flattened calyx is arranged alongside the stem and comprises four elements. One element is hypertrophied, angled and pointed, and resembles the blade of an axe (Fig. 3). The length of the axe edge is 1.6–2.1 µm. The axe blade is on the proximal side supported by a triangular element reminiscent of those forming the body coccolith calyx. Opposite the axe blade are two elongate and narrow triangular elements that are joined end-to-end forming a spindle-shaped structure. The rim calcification is similar in BC's and CFC's and comprises a single cycle of rod-shaped elements (0.2–0.25 µm) joined end-to-end (Fig. 5).

Holotype: Figs 2–6 (same cell). Illustrations are used here as a substitute type specimen because the TEM images provide the most details, and because the TEM grid which carries the specimen in question does suffer from long time preservation problems.

Type locality: Collected from the Andaman Sea at #10 (8°24′N/97°03′W) on 19 August 1996 and from a depth of 80 meters (ca. 25°C and 34 psu).

Etymology: 'stellata' is derived from 'stellatus' (L) meaning in the shape of a star. The species name reflects the star-like appearance of the body coccolith calyx.

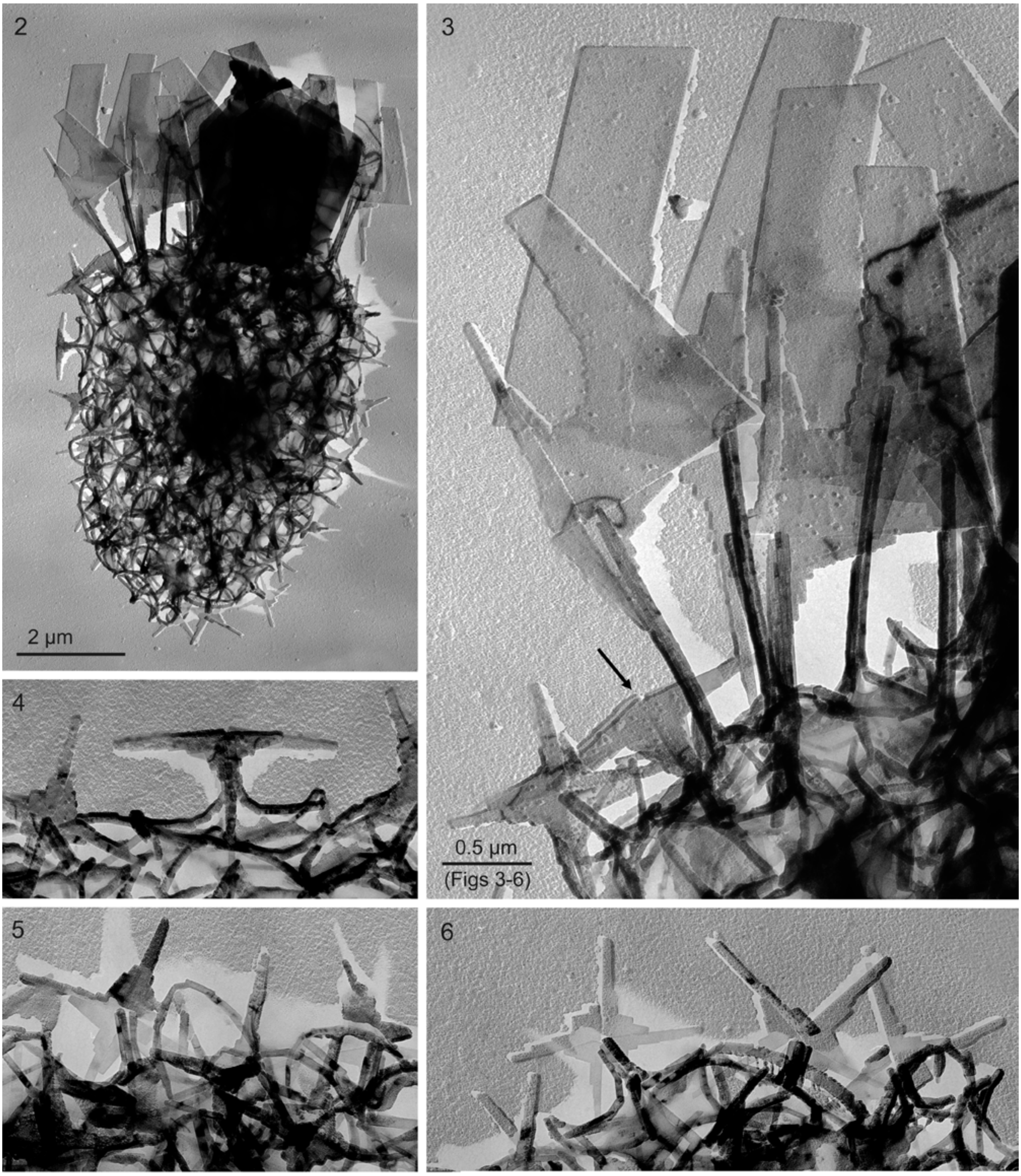
The description above of a single specimen observed in the Andaman Sea sample is fortunately corroborated by two additional specimens of *V. stellata* observed in a NW Mediterranean sample (Figs 7–10; see also Cros and Fortuño 2002 l.c. Fig. 111D). Despite the vast geographical distance between the NW Mediterranean and the SW Thailand coastline the cells appear convincingly similar. The morphological elaboration of both the CFC and BC central appendages are thus identical. The edge of the CFC axe blade is 1.6–2.1 µm and the BC calyx diameter 0.8–1.4 µm which are values that match those of the Andaman Sea type material. It is not possible based on the material available to ascertain whether the two-dimensional calyx is oriented parallel with or perpendicular to the longest axis of the CFC. However, when scrutinizing in particular the cell illustrated in Fig. 9 (arrow) it appears that the calyx is in fact perpendicular to the longest axis of the CFC. The difference in size of the BC 'windmills' from the anterior towards the posterior cell end is also pronounced in the NW Mediterranean cells (Figs 7, 9). It is evident that the BC superstructures are not completely flattened but distally slightly convex (Figs 8, 10; arrows) and apparently more so than in the Thailand type material. This is indicated when comparing Figs 3–4 showing BC's in side view with the BC's pointed out in Figs 8, 10. A schematic drawing of the BC and CFC in side and top view is included (Fig. 11).

There is no evidence of unmineralized under layer scales nor can we at this stage provide information with reference to a possible life history counterpart of *V. stellata*.

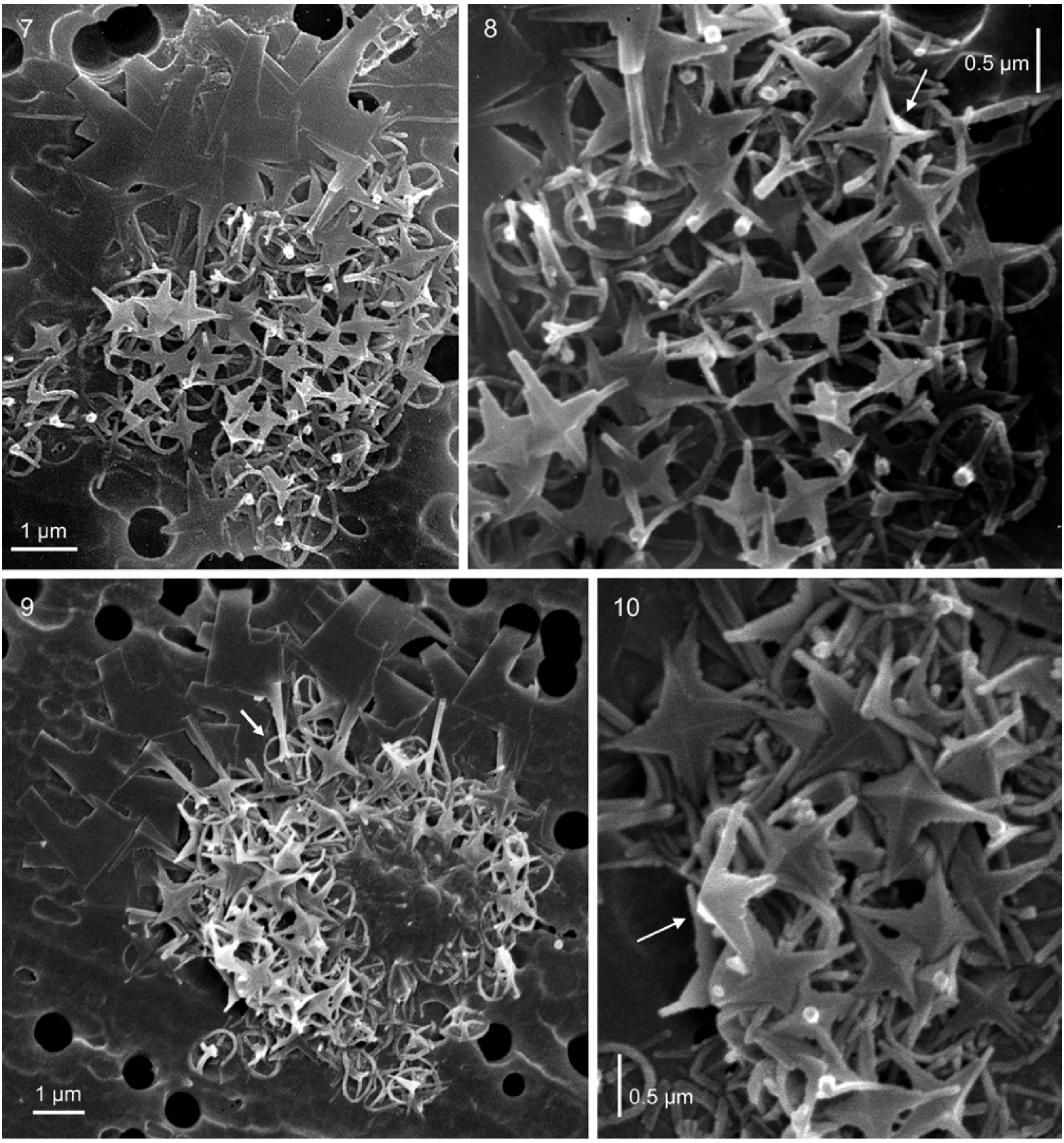
DISCUSSION

The fact that the description of *V. stellata* is based on convincingly similar specimens from widely separated geographical places strongly supports the circumscription of the new taxon and also lends evidence towards an expected global distribution of *V. stellata* in the tropical/subtropical warm water belt.

Ventimolina is reminiscent of *Pappomonas* (Thomsen *et al.* 2014b) with respect to the elaboration of the CFC calyx, which in both genera is a flattened, 2-dimensional plate made up of adjoining elements (2 in core species of *Pappomonas* and 4 in *Ventimolina*). Core species of *Pappomonas* comprise (Thomsen *et al.* 2014b) the generic type *P. flabellifera* Manton and Oates 1975 (emend. Thomsen and Østergaard 2014b), *P. borealis* (Manton, Sutherland and McCully 1976) Thomsen and Østergaard stat. nov. 2014b, and *P. weddellensis* Thomsen in Thomsen *et al.* 1988. *Ventimolina stellata* shares with *P. weddellensis* a marked hypertro-



Figs 2–6. *Ventimolina stellata* TEM whole mounts of a single specimen from the Andaman Sea. **2** – whole cell (holotype) with details accounted for in Figs 3–6; **3** – details of circumflagellar coccoliths. The arrow points to a distally slightly convex BC in side view; **4** – detail of body coccolith in lateral view showing clearly the rim and central area calcification and the central superstructure which is slightly convex distally; **5** – body coccoliths showing the single layer rim calcification; **6** – details of the body coccolith calyx ('windmills').



Figs 7–10. *Ventimolina stellata* SEM images of two cells from the NW Mediterranean. **7** – complete coccosphere; **8** – detail of BC from the cell shown in Fig. 7. The arrow points to a coccolith calyx that is clearly convex; **9** – complete coccosphere. The arrow points to a CFC that clearly shows the central are calcification and further lends support to the interpretation of the calyx being perpendicular to the longest axis of the CFC; **10** – detail of BC from the cell shown in Fig. 9. A distinctly convex coccolith calyx is pointed out by arrow.

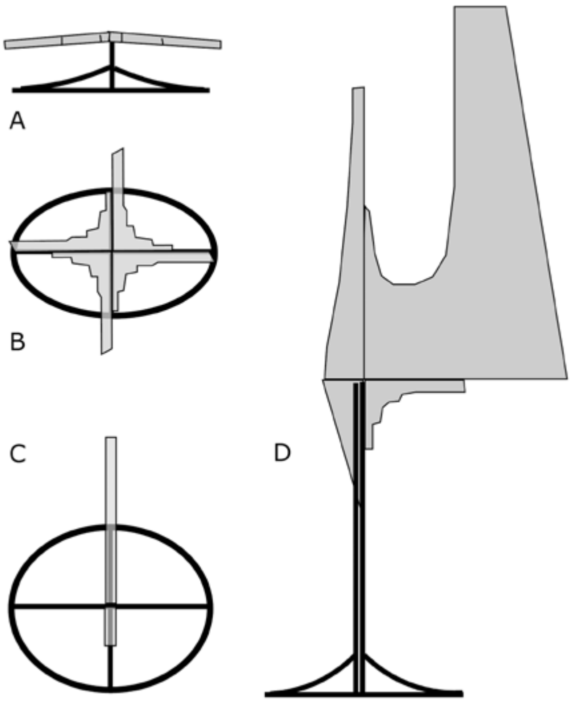


Fig. 11. Schematic drawings of *Ventimolina stellata* BC and CFC drawn approximately to scale. **A** – side view of BC; **B** – top view of BC; **C** – top view of CFC; **D** – side view of CFC.

phy of one element. In species of *Pappomonas* (Thomsen *et al.* 2014b) the body coccoliths display either a concentric central area calcification (*P. flabellifera* and *P. borealis*) or a cruciform calcification with additional longitudinal lines of elements (*P. weddellensis* and *P. garrisonii* Thomsen and Østergaard 2014b), and there is no evidence of a central spine. *Ventimolina* deviates substantially by having a cruciform central area calcification which leads into a calicate spine where the distal and right angled ornament is shaped like a 'windmill'. Species of *Pappomonas* have in accordance with key features of the family Papposphaeraceae, a narrow murolith rim comprising a lower cycle of elongate elements and an upper cycle of larger elements that unite to give the coccolith a characteristic serrated distal margin. The situation in *Ventimolina* is much different in as much as the rim is just a single circle of elongate elements which is possibly corresponding to the lower cycle described above for species of *Pappomonas*. Species of *Wigwamma* Manton, Sutherland and Oates 1977, are characterized by small murolith coccoliths with a narrow rim (typically two cycles of elongate elements) and elaborate central structures (see Thomsen *et al.* 2013). Whereas the *Wigwamma* central structures are markedly different from that described for *Ventimolina* there are similarities in rim morphology between the two genera in particular when a comparison is made with the type species *W. arctica* Manton, Sutherland and Oates 1977. In the monospecific *Pseudowigwamma* Thomsen in Thomsen *et al.* 2013 the rim is further reduced to a single circle as is also the case in *V. stellata*. However, in *P. scenozonion* (Thomsen 1980) Thomsen in Thomsen *et al.* 2013, there is no central structure.

While the discussion above leaves no doubt that the establishment of the new genus *Ventimolina* is justified, it is also important to stress that the documented similarity with both *Pappomonas* and *Wigwamma* in different aspects of its coccolith design, lends support to the idea of amalgamating *Wigwamma* and *Pseudowigwamma* within the Papposphaeraceae, and also suggests that the circumscription of the Papposphaeraceae should be formally expanded to accommodate *Ventimolina*. In as much as we are currently in the process of describing a number of weakly calcified 'papposphaeracean' coccolithophores from warm water regions, we prefer for the time being to suspend the formal emendation of the family until the full range of morphological variability has been documented and preferably also corroborated by molecular data.

Acknowledgements. The efforts of the captain and crew of the RV Chakratong Tongyai in facilitating the collection of data and samples are gratefully acknowledged. Thai principal investigators, Vudichai Janekarn and Pensri Boonruang, and the staff at PMBC (Phuket Marine Biological Center) provided excellent facilities that supported the land-based part of our joint research. J.-M. Fortuño provided SEM assistance and L. Arin collected Mediterranean samples. This research was supported by the CSIC and projects 2014 SGR 761 (Generalitat of Catalonia) and CODENET (FRMX – ET97-0113).

REFERENCES

Andruleit H., Young J. R. (2010) *Kataspinifera baumannii*: a new genus and species of deep photic coccolithophores resembling the non-calcifying haptophyte *Chrysochromulina*. *J. Micropalaeontology* **29:** 135–147

Charalampopoulou A., Poulton A. J., Tyrrell T., Lucas V. I. (2011) Irradiance and pH affect coccolithophore community composition on a transect between the North Sea and the Arctic Ocean. *Mar. Ecol. Progr. Ser.* **431:** 25–43

Cros L. (2002) Planktonic coccolithophores of the NW Mediterranean. PhD thesis (2001) at University of Barcelona. Publicacions de la Universitat de Barcelona

Cros L., Estrada M. (2013) Holo-heterococcolithophore life cycles: ecological implications. *Mar. Ecol. Progr. Ser.* **492:** 57–68

Cros L., Fortuño J.-V. (2002) Atlas of the northwestern Mediterranean coccolithophores. *Scientia Marina* **66**, Suppl. 1**:** 1–186

Jordan R. W., Young J. R. (1990) Proposed changes to the classification system of living Coccolithophorids. *Intl. Nannoplankton Assoc. Newsletter* **12:** 15–18

Moestrup Ø., Thomsen H. A. (1980) Preparation of shadow-cast whole mounts. In: Handbook of Phycological Methods. Vol. III, (Ed. E. Gantt). Cambridge, 385–390

Nielsen T. G., Bjørnsen P. K., Boonruang P., Fryd V., Hansen P. J., Janekarn V., Limtrakulvong V., Munk P., Hansen O. S., Satapoomin S., Sawangarreruks S., Thomsen H. A., Østergaard J. B. (2004) Hydrography, bacteria and protist communities across the continental shelf and shelf slope of the Andaman Sea (NE Indian Ocean). *Mar. Ecol. Prog. Ser.* **274:** 69–86

Thomsen H. A. (1981) Identification by electron microscopy of nanoplanktonic coccolithophorids (Prymnesiophyceae) from West Greenland, including the description of *Papposphaera sarion* sp. nov. *Br. Phycol. J.* **16:** 77–94

Thomsen H. A. (1982) Planktonic choanoflagellates from Disko Bugt, West Greenland, with a survey of the marine nanoplankton of the area. *Meddelelser om Grønland, Bioscience* **8:** 3–35

Thomsen H. A., Buck K. R. (1998) Nanoflagellates of East Pacific coastal waters: Morphology, taxonomy, and biogeography of weakly calcified coccolithophores (Haptophyceae, Prymnesiophyceae). *Cryptogamie. Algol.* **19:** 29–48

Thomsen H. A., Buck K. R., Coale S. L., Garrison D. L., Gowing V. V. (1988) Nanoplanktonic coccolithophorids (Prymnesiophyceae, Haptophyceae) from the Weddell Sea, Antarctica. *Nord. J. Bot.* **8:** 419–436

Thomsen H. A., Østergaard J. B., Heldal V. (2013) Coccolithophorids in polar waters: *Wigwamma* spp. revisited. *Acta Protozool.* **52:** 237–256

Thomsen H. A., Østergaard J. B. (2014a) Cocolithophorids in polar waters: *Calciarcus* spp. revisited. *Acta Protozool.* **53:** 145–157

Thomsen H. A., Østergaard J. B. (2014b) Cocolithophorids in polar waters: *Pappomonas* spp. revisited. *Acta Protozool.* **53:** 235–256

Thomsen H. A., Østergaard J. B. (2014c) Cocolithophorids in polar waters: *Trigonaspis* spp. revisited. *Acta Protozool.* **54:** 85–96

Thomsen H.A., Østergaard J. B. (2015) Coccolithophorids in polar waters: *Mercedesia* gen. nov., *Ericiolus*, *Quaternariella* and *Porsildia* gen. nov. *Acta Protozool.* **54:** 155–169

Young J., Geisen V., Cros L., Kleijne A., Sprengel C., Probert I., Østergaard J. (2003) A guide to extant coccolithophorid taxonomy. *J. Nannopl. Res., Special Issue* **1:** 1–132

Received on 26th November, 2014; revised on 19th February, 2015; accepted on 20th February, 2015