J. Nannoplankton Res. **27** (2), 2005, pp.135-139 © 2005 International Nannoplankton Association
ISSN 1210-8049 Printed by Cambridge University Press, UK

Sphaerocalyptra dermitzakii and *Sphaerocalyptra youngii*, two new holococcolithophore species from the Aegean Sea (eastern Mediterranean)

Margarita D. Dimiza, Maria V. Triantaphyllou*, Spyros Theodoridis
University of Athens, Faculty of Geology, Department of Historical Geology-Paleontology, Panepistimiopolis, 15784, Athens, Greece;
*mtriant@geol.uoa.gr

Manuscript received 21st July, 2004; revised manuscript accepted 10th March, 2005

Abstract Living coccolithophores were collected, in August, 2001, from eight stations in the Gulf of Korthi (Andros Island, middle Aegean Sea, eastern Mediterranean), in order to determine the cell density, species composition and biogeographical (spatial and vertical) distribution in this coastal marine ecosystem. The holococcolithophore assemblages in the sampled stations sometimes reached more than 50% of the total standing crop, tending to be dominant especially at the shallower stations. Two new species of *Sphaerocalyptra* were identified and are described and figured here: *Sphaerocalyptra dermitzakii* sp. nov. and *Sphaerocalyptra youngii* sp. nov.

Keywords Living coccolithophores, biocommunities, holococcolithophores, Aegean Sea, *Sphaerocalyptra*

1. Introduction

Holococcolithophores are part of the life-cycle of taxa which also have heterococcolithophore stages (*e.g.* Houdan *et al.,* 2004; Billard & Inouye, 2004). Nevertheless, a lot of taxonomic work has been conducted on holococcolithophores where the matching heterococcolith stage has not yet been identified (*e.g.* Kleijne, 1991; Cros, 2001; Cros & Fortuño, 2002). These holococcolithophores have traditionally been assigned to the Family Calyptrosphaeraceae (*e.g.* Jordan & Green, 1994; Jordan & Kleijne, 1994). However, the Family Calyptrosphaeraceae is now known to be polyphyletic, as the type species of the family, *Calyptrosphaera oblonga*, is a junior synonym of the type species of the Family Syracosphaeraceae (Cros *et al.,* 2000; Geisen *et al.,* 2002), therefore, recent publications have suggested abandoning the use of Calyptrosphaeraceae altogether (Young *et al*., 2003; Jordan *et al*., 2004). This would be easy if past taxonomic work had been conducted to the extent whereby all pairs of hetero- and holococcolith-bearing taxa were fully documented. Until this is achieved, however, we think it reasonable to carry on keeping together the holococcolithophore-bearing taxa that have not yet proven to be phases in the life-cycles of heterococcolithophores, as suggested by Jordan *et al.* (2004). To make things even more complex, apart from life-cycle pairing, the holococcoliths are a taxonomic challenge in themselves, due to the fact that their morphology is less stable, therefore allowing intraspecific variation, but normally not preventing a solid morphological distinction (Geisen *et al*., 2002).

Here, we aim to further our understanding of holococcolithophores by describing two more taxa belonging to this group.

2. Material and methods

In general, the Aegean Sea (eastern Mediterranean) surface-water circulation during spring and summer is incorporated into an anticlockwise gyre system, similar to that in operation in the Adriatic, Ionian, Tyrrhenian and Alboran Seas (see Triantaphyllou *et al.,* 2002 for a brief description of the study area). Water samples were collected for coccolithophore analysis, in August, 2001, from eight stations in the coastal environment of the Gulf of Korthi (Andros Island, middle Aegean Sea). The samples were collected from depths up to 120m, using a single oceanographic Hydro-bios bottle. For each sampling depth, 1.5l of sea-water was filtered through a Millipore cellulose nitrate filter (47mm diameter, 0.45μm pore-size). The filters were examined in a Jeol JSM5600 Scanning Electron Microscope (SEM) and all the individual coccolithophore specimens on the examined filter piece (approximately 8x8mm^2) were identified and counted following the methodology of Jordan & Winter (2000).

3. Observations and discussion

Up to now, over 50 extant holococcolithophore species have been recorded from the Mediterranean Sea (Knappertsbusch, 1990; Kleijne, 1993; Cros, 2001; Cros & Fortuño, 2002; Triantaphyllou *et al*., 2002). The derived distribution patterns in the middle Aegean Sea indicate that holococcolithophores may constitute a significant part of the summer nannoflora in the upper photic zone of the coastal waters of Andros Island (Triantaphyllou *et al.,* 2002). The holococcolithophore diversity in August, 2001 yielded 39 species. The assemblages were characterised by high species diversity, and absolute abundances usually ranged between 7.3x10^3 cells/l and 0.1x10^3 cells/l.

The genus *Sphaerocalyptra* is relatively well represented, contributing several species. *S. quadridentata* is one of the most common components of the summer holococcolithophore assemblages. It is dominant in the uppermost layers of the photic zone, especially at 5m depth, persisting in high frequencies

down to 15m, and it appears to increase in abundance towards shallower environments (Triantaphyllou *et al*., 2002; Triantaphyllou & Dimiza, 2003). The rest of the identified *Sphaerocalyptra* species in the Aegean Sea (*S.* cf. *S. adenensis, Sphaerocalyptra* sp.1 of Cros & Fortuño (2002), *Sphaerocalyptra* sp.4 of Cros & Fortuño (2002), *S. dermitzakii* sp. nov. and *S. youngii* sp. nov.) were very rare (<0.2x10^3 cells/l) in the studied water-samples.

4. Taxonomic remarks

Schiller (1913) first described *Calyptrosphaera quadridentata* from the Mediterranean Sea, but it was then transferred by Deflandre (1952) to become the type species of his new genus *Sphaerocalyptra*. The genus *Sphaerocalyptra* is characterised by a dimorphic coccosphere, bearing body and circumflagellar coccoliths that are campanulate calyptroliths, without a tube. The circumflagellar coccoliths are distinctly higher than the body coccoliths. In 1991, Kleijne described the species *S. adenensis* from the Indian Ocean, Gulf of Aden and the Red Sea. In a detailed study of the genus *Sphaerocalyptra* in samples from the western Mediterranean, Cros (2001) and Cros & Fortuño (2002) added six more unnamed species. Recently, Young *et al*. (2003) included *Sphaerocalyptra* in a broad morphological group, the members of which are characterised by tubeless, conical coccoliths bearing a simple base-plate with a central, more-or-less conical, protrusion, spine or mound of crystallites. They subdivided *Sphaerocalyptra* species into two groups, based on the morphology of the calyptrolith cone, that is, with and without openings in the cone.

Below, we present the systematic taxonomy of the representatives of the genus *Sphaerocalyptra* that are found in the Aegean Sea and describe two new species, *S. dermitzakii* sp. nov. and *S. youngii* sp. nov.

Family **CALYPTROSPHAERACEAE** Boudreaux & Hay, 1969

Sphaerocalyptra dermitzakii Triantaphyllou, Dimiza & Theodoridis sp. nov.
Pl.1, Fig.1

Derivatio nominis: After Prof. Michael Dermitzakis (National and Kapodistrian University of Athens, Department of Historical Geology-Paleontology, Greece) for his extensive and multidisciplinary contributions to palaeontology and micropalaeontology in Greece and internationally, who was instrumental in directing us towards the study of calcareous nannoplankton.

Diagnosis: Dimorphic holococcosphere. Holococcoliths bear a basal ring, a cone of obliquely-arranged crystallites and have a perforate appearance. [*Holococcosphaera dimorpha. Holococcolithi habent annulum basalem, unum conum de crystallitis oblique ordinatis et facie perforata*.]

Description: Dimorphic holococcospheres with two kinds of conical calyptrolith. Body calyptroliths consist of a basal ring constructed of one or more rows of crystallites and a cone sharply elevated from the basal ring, with characteristically very thin, pointed endings. The wall of the cone is composed of crystallites arranged in a linear manner, with each line arising from the basal plate obliquely and spiralling towards the apex of the cone. The crystallites of the wall are characteristically loosely packed, which in effect gives the wall a perforate appearance. The proximal side of each holococcolith is concave.

Remarks: This species differs from *Sphaerocalyptra* sp.2 of Cros & Fortuño (2002) in the more linear organisation of the wall and the distinctively concave proximal surface of the basal ring. Additionally, the circumflagellar calyptroliths have a solid conical shape, not possessing any distal projection.

Type specimen: Plate 1, Figure 1.

Type material: University of Athens, Faculty of Geology Stub 12/X (filter sample), Station T3-7 (37˚46.67'N, 24˚57.73'E), 5m water-depth; Cruise 01ED100, 21st August, 2001, Gulf of Korthi, Andros Island, middle Aegean Sea, eastern Mediterranean.

Type repository: Museum of Paleontology & Geology, Department of Historical Geology-Paleontology, University of Athens, Greece.

Number of specimens studied: Two.

Dimensions: Body holococcolith length = 0.8-1.2μm; circumflagellar holococcolith length = 1.4-1.6μm.

Distribution: Aegean Sea, eastern Mediterranean.

Sphaerocalyptra youngii Triantaphyllou, Dimiza & Theodoridis sp. nov.
Pl.1, Fig.2

Derivatio nominis: After Dr. Jeremy Young (The Natural History Museum, London, UK), eminent nannoplankton researcher, whose scientific contribution has largely defined our concepts in coccolithophore research.

Diagnosis: Dimorphic holococcosphere with irregularly-perforated, hollow holococcoliths, lacking a basal ring. [*Coccosphaera dimorphica cum coccolitho vacuo inordinate perforato sine annulo basali*.]

Description: Dimorphic holococcosphere with two kinds of open calyptrolith. Body holococcoliths are small calyptroliths with no basal ring. They consist of a high base with a central, conical protrusion that is characterised by several irregular, large openings. Circumflagellar calyptroliths are notably higher than body calyptroliths, having tall cones with acute endings.

Remarks: It differs from *S. quadridentata* in bearing several irregular, large openings on the campanulate calyptroliths. An intraspecific variation could be predicted, as it has already been demonstrated for solid and perforate holococcoliths of *Helicosphaera carteri* (Cros *et al*., 2000; Geisen *et al*., 2002). However we have

found no combination coccospheres, nor intermediate stages between the two morphologies, therefore we suggest that *S. youngii* is a real new species.
Type specimen: Plate 1, Figure 2.
Type material: University of Athens, Faculty of Geology Stub 7/N (filter sample), Station T3-3 (37˚48.77'N, 24˚59.97'E), 5m water-depth; Cruise 01ED100, 21st August, 2001, Gulf of Korthi, Andros Island, middle Aegean Sea, eastern Mediterranean.
Type repository: Museum of Paleontology & Geology, Department of Historical Geology-Paleontology, University of Athens, Greece.
Number of specimens studied: One.
Dimensions: Body holococcolith length = 0.8-0.9μm; circumflagellar holococcolith length = 2.0-2.5μm.
Distribution: Aegean Sea, eastern Mediterranean.

Sphaerocalyptra quadridentata (Schiller, 1913) Deflandre, 1952
Pl.1, Fig.3

1913 *Calyptrosphaera quadridentata* Schiller: p.607, pl.3, figs 20, 21.
1952 *Sphaerocalyptra quadridentata* (Schiller) Deflandre: p.452, fig.350b.
1972 *Sphaerocalyptra quadridentata* (Schiller) Deflandre: Borsetti & Cati, p.398, pl.41, fig.1.
1979 *Sphaerocalyptra quadridentata* (Schiller) Deflandre: Winter *et al*., pl.5, fig.9.
1991 *Sphaerocalyptra quadridentata* (Schiller) Deflandre: Kleijne, p.65, pl.17, fig.3.
2002 *Sphaerocalyptra quadridentata* (Schiller) Deflandre: Cros & Fortuño, p.67, figs 103A, B.
2003 *Sphaerocalyptra quadridentata* (Schiller) Deflandre: Young *et al*., p.93, pl.43, figs 1-4.

Remarks: *S. quadridentata* has been shown to form combination coccospheres with *Algirosphaera robusta* by Kamptner (1941) and Triantaphyllou & Dimiza (2003). However, Cros & Fortuño (2002) illustrated two less conclusive combination coccospheres of *S. quadridentata* and *Rhabdosphaera clavigera*. Given this ambiguity, the traditional name, *S. quadridentata*, is retained (Young *et al*., 2003; Jordan *et al*., 2004).
Distribution: Mediterranean Sea, Atlantic Ocean, Red Sea.

Sphaerocalyptra cf. *S. adenensis* Kleijne, 1991, Cros & Fortuño, 2002
Pl.1, Fig.5

1991 *Sphaerocalyptra adenensis* Kleijne: p.65, pl.17, figs 4-6.
2002 *Sphaerocalyptra* cf. *S. adenensis* Kleijne: Cros & Fortuño, p.67, figs 103C, D.
2003 *Sphaerocalyptra* cf. *S. adenensis* Kleijne: Young *et al*., p.93, pl.43, fig.6.

Remarks: The body and circumflagellar calyptroliths lack a basal flange but are constructed of closely-packed crystallites that appear arranged in concentric rows. According to Cros & Fortuño (2002) and our own observations, the specimens studied have smaller coccoliths than those of *S. adenensis*.
Dimensions: Body holococcolith length = 0.7-0.9μm; circumflagellar holococcolith length = ~1.6μm.
Distribution: Mediterranean Sea, Indian Ocean, Red Sea, Gulf of Aden.

Sphaerocalyptra sp.1 Cros & Fortuño, 2002
Pl.1, Fig.4

2002 *Sphaerocalyptra* sp.1 Cros & Fortuño: p.67, figs 104A, B.
2003 *Sphaerocalyptra* sp.1 Cros & Fortuño: Young *et al*., p.93, pl.43, figs 7-9.

Remarks: Body holococcoliths characterised by small, sharp cones. Circumflagellar calyptroliths notably higher and tipped by thin, acute protrusions. Both kinds of calyptrolith bear a basal flange and are formed of radiating rows of crystallites, from the tip of the cone to the base.
Dimensions: Body holococcolith length = 0.6-0.7μm; circumflagellar coccolith length = ~1.5μm.
Distribution: Mediterranean Sea.

Sphaerocalyptra aff. *S.* sp.1 Cros & Fortuño, 2002
Pl.1, Fig.6

Remarks: This species differs from *Sphaerocalyptra* sp.1 Cros & Fortuño, 2002 (p.67, figs 104A, B) in having a more distinctively radiating arrangement of crystallite rows on the cones of the body calyptroliths.
Dimensions: Body holococcolith length = 1.1-1.2μm; circumflagellar holococcolith length = 1.9-2.3μm.
Distribution: Aegean Sea, eastern Mediterranean.

Sphaerocalyptra aff. *S.* sp.2 Cros & Fortuño, 2002
Pl.1, Fig.7

Remarks: The crystallite arrangement of the steep holococcolith cones is similar to that of *Sphaerocalyptra* sp.2 Cros & Fortuño, 2002 (p.67, fig.105A), but the circumflagellar calyptroliths do not possess any projection.
Dimensions: Body holococcolith length = 1.0-1.3μm; circumflagellar holococcolith length = 1.6-1.7μm.
Distribution: Aegean Sea, eastern Mediterranean.

Sphaerocalyptra sp.4 Cros & Fortuño, 2002
Pl.1, Fig.8

2002 *Sphaerocalyptra* sp.4 Cros & Fortuño: p.68, figs 104C, D.

2003 *Sphaerocalyptra* sp.4 Cros & Fortuño: Young *et al.,* p.93, pl.43, fig.12.

Dimensions: Body holococcolith length = 1.1-1.2μm; circumflagellar holococcolith length = 1.9-2.3μm.
Distribution: Mediterranean Sea.

Acknowledgements

The valuable criticisms of R. Jordan, M. Geisen and the Editor, J. Lees, are warmly acknowledged. Dr. M. Dimaki-Zora is thanked for her contribution to the Latin diagnoses. Financial support for this study was provided by Research Project 70/4/3385 of the University of Athens, and the 01ED100/PENED Project of the European Union, the General Secretariat for Research & Technology/Greek Ministry of Development and the Municipality of Chora, Andros Island.

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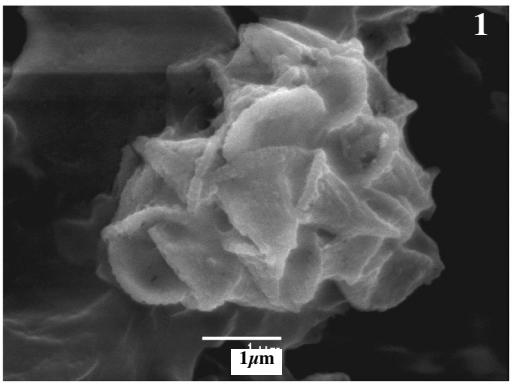
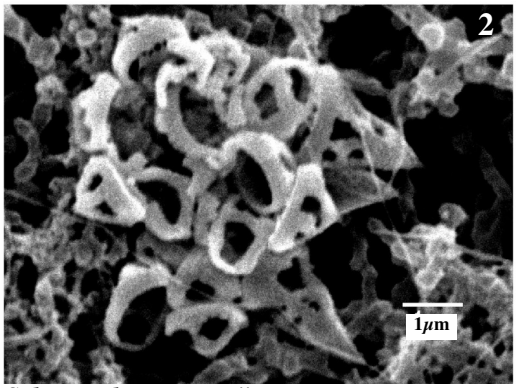
Plate 1



Sphaerocalyptra dermitzakii sp. nov. Sample T3-7, 5m



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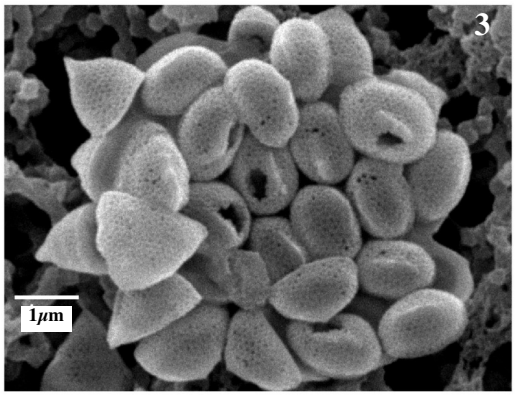
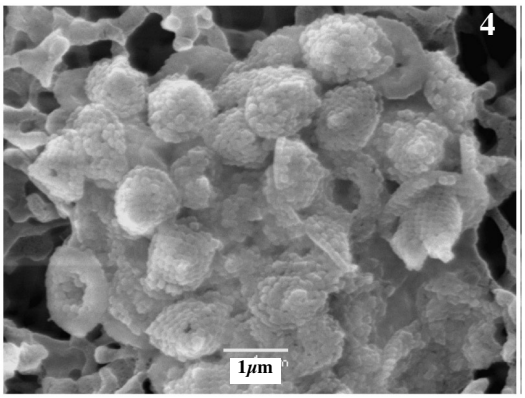
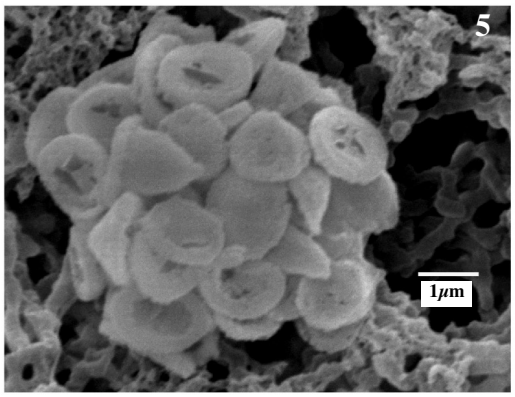


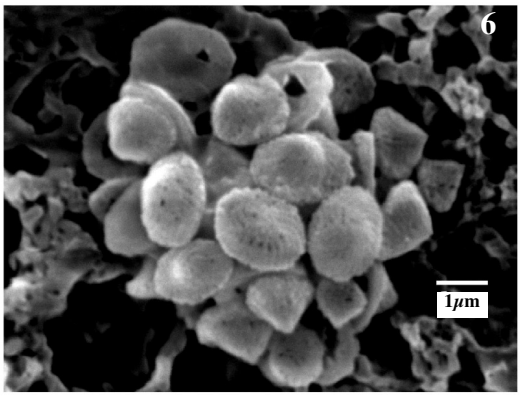
Sphaerocalyptra quadridentata Sample T3-6, 45m



***Sphaerocalyptra* sp.1** Sample T3-4, 45m



Sphaerocalyptra* cf. *S. adenensis Sample T3-8, 7m



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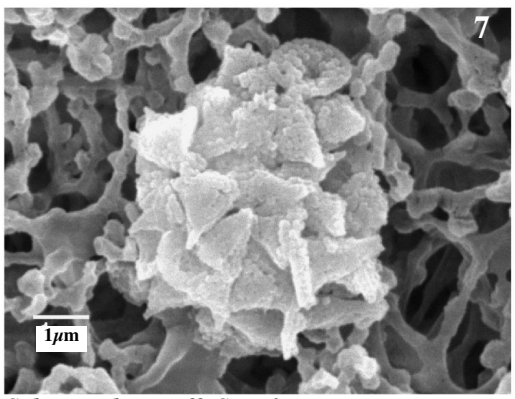
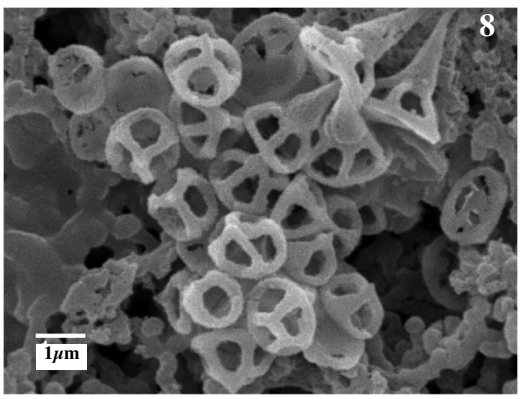


***Sphaerocalyptra* aff. *S.* sp.2** Sample T3-5, 15m



***Sphaerocalyptra* sp.4** Sample T3-5, 45m