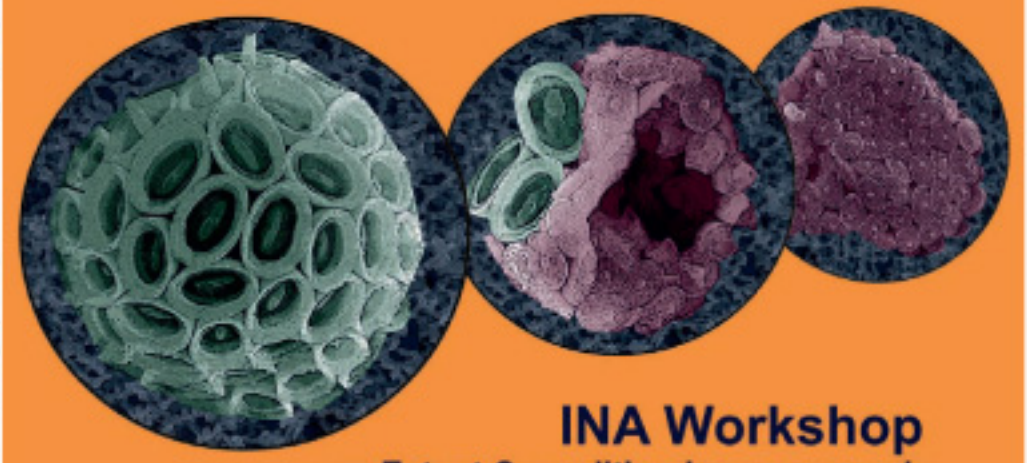
Journal of Nannoplankton Research

volume 34 | special issue | october 2014

COCCOLITHOPHORES 2014



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Observation of an exothecal coccolith associated with *Syracosphaera halldalii:* evidence for dithecatism?

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Abstract: A specimen of the coccolithophore *Syracosphaera halldalii* collected in Irish Shelf Waters is observed in Scanning Electron Micrographs (SEM) associated with a single exothecal coccolith. The exothecal coccolith is situated in the circum-flagellar area of a collapsed coccosphere and is a thick, elliptical, planolith, concavely bent and with an open centre. *S. halldalii* has been regarded as monothecate although this single observation may indicate dithecatism in the species and with further observations, could necessitate reclassification within *Syracosphaera*.

Keywords: *Syracosphaera*, exothecal coccoliths, taxonomy

1. Introduction

Syracosphaera halldalii is a common coccolithophore species that has been widely observed in the plankton and previously recorded in the eastern North Atlantic Ocean and equatorial Pacific Ocean (Okada and McIntyre, 1977), the Mediterranean Sea (Cros and Fortuño, 2002; Triantaphyllou *et al*., 2004) and the northern Red Sea (Kleijne, 1991; Kleijne 1993; Young et al. 2003). The species differs from most of the *Syracosphaeraceae* in that exothecal coccoliths are absent and it is therefore considered monothecate (Young et al. 2003). Water samples collected for coccolithophore analysis in Irish shelf waters in 2002 revealed relatively high abundances (>9 x 10^3 cells l^{-1}) of *S. halldalii*, a single specimen of which was associated with a previously undescribed, morphologically distinct exothecal coccolith (Figs 1-2).

2. Materials and methods

The specimen figured was collected as part of the CV3600 survey of the biogeographic distribution of planktonic coccolithophores in Irish Shelf Seas aboard the RV Celtic Voyager on 28th July 2002 at station 3601 (55°49.98 N, -7°51.27 W) from 30m depth (Raine and McGrane, 2002).

Discrete water samples were collected using a 5 ltr Niskin water sampling bottle mounted on a Sea-Bird SBE 9-11 CTD rosette. Up to 1 ltr of sample was filtered onto 25 mm diameter polycarbonate membrane filters with a pore size of 0.8 μm using a vacuum pump and according to the methodology outlined in McGrane, 2007. Filters were mounted with carbon tape onto a 25 mm aluminium stub aluminium stubs and placed in a Emitech K550 sputter coater and coated with a gold/palladium film of 20 nm thick at 25 mA for 2 minutes. Coccolithophore examination was carried out using a Hitachi s-4700 cold field emission Scanning Electron Microscope equipped with a computer-controlled stage.

3. Results and discussion

Amongst coccolithophores, the development of a discrete outer layer of coccoliths or exotheca, morphology different to the coccoliths of the inner layer or endotheca, is exclusively the preserve of the Syracosphaeraceae (Cros 2000; Cros and Fortuno 2002; Young *et al*. 2003). Dithecatisim, the possession of both an endotheca and an exothecal layer, has been observed in all *Syracosphaera* species with the exception of *S, halldalii* and *S. protrudens* (Kleijne and Cros, 2009).

In addition to the morphological characteristics of coccospheres and coccoliths, the diverse morphology of exothecal coccoliths and the degrees of differentiation between species, are an important diagnostic tool used to

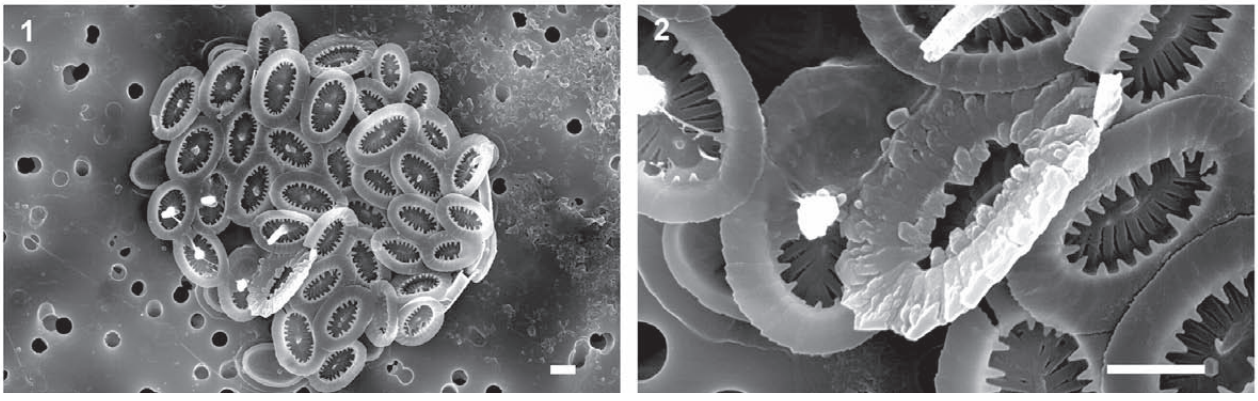

Figure 1-2: *Syracosphaera halldalii* Gaarder, in Gaarder & Hasle 1971 ex. Jordan and Green, 1994. Scale bar = 1 μm.
Fig. 1: Collapsed coccosphere of *S. halldalii* with a single exothecal coccolith situated at the flagellar opening alongside 5 circum-flagellar caneoliths displaying a tall blunt spine. Body coccoliths show variation in size (length 2.2-3.2 μm, width 1.5-2.0 μm) with wide, smooth distal flange and tooth-like projections horizontally towards the lath-filled central-area.
Fig. 2: Distal view of exothecal coccolith showing robust, elliptical, concave planolith with serrated distal flange margin; exothecal coccolith length 3.2 μm; exothecal coccolith width ~2 μm; central open area ~1.6 μm;

classify and group *Syracosphaera* species (Kleijne and Cros, 2009).. In a revised classification system for the genus Kleijne and Cros (2009) distinguished four main groups and 15 subgroups of *Syracosphaera* and placed the two monothecate, dimorphic species in the *halldalii* subgroup, of the *S. molischii* group, characterised by vertical coccolith walls, a flat distal flange in addition to a proximal flange and spine-bearing circum-flagellar coccoliths,

The exothecal coccolith observed in association with a specimen of *S. halldalii* is a thick, elliptical, concavely bent planolith (3.2 μm in length) with a wide distal flange bearing a serrated margin and a relatively large open central area (1.6 μm in length) which has a tooth-like structure similar to the central area of the *halldalii* muroliths. It is possible that some corrosion of the coccolith has taken place, or that it may be allochthonous in origin, i.e. it might be a coccolith of another species which has accidently fallen on the coccosphere. Alternatively it may represent evidence for dithecatism in *S. halldalii*.

The dithecatism interpretation is supported by a number of factors. First, the position of the exothecal coccolith, situated in the circum-flagellar area of the coccosphere is similar to that of other members of the *S. molischii* group. Second, the exothecal coccolith figured is a thick elliptical planolith, concavely bent and with an open central area. These characteristics resemble those of *S. andruleitii* (Kleijne and Cros, 2009) but it is larger in size (3.2 μm length), presents a wider distal flange with a serrated margin and a larger central opening (1.6 μm width), and therefore appears morphologically distinct from other exothecal coccoliths recorded previously (Cros, 2000; Young et al. 2003; Kleijne and Cros, 2009). Third, it does not obviously resemble any other known heterococcolith although this might be partially due to corrosion. So we suspect it is an exothecal coccolith but a single observation is inconclusive and further observations are required before we can conclude that *S. halldalii* has exothecal coccoliths and exhibits dithecatism.

Acknowledgements

I would like to thank J. Young, M. Triantaphylou, K. Hagino and L. Cros who kindly reviewed this manuscript and A. McGrane for processing of images. This research was supported by the Higher Education Authority of Ireland under PRTLI Cycle II with shiptime provided by the Marine Institute of Ireland. Access to the SEM was provided by the Centre for Microscopy and Imaging, NUI Galway.

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