

## PROPOSED CHANGES TO THE CLASSIFICATION SYSTEM OF LIVING COCCOLITHOPHORIDS. III.

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The classification of living coccolithophorids is presently under further scrutiny following the recent review by Jordan & Kleijne (in press). This has been initiated, in particular, by the needs of two ambitious projects, *The Encyclopedia of Algal Genera* (ed. B.C. Parker) and the Expert-Centre for Taxonomic Identification (ETI). As a consequence of their requests for information it has been necessary to re-examine, and in some cases revise, the generic concepts of a number of taxa, and to provide an up-to-date list of all known species (Jordan & Green, 1993). In this paper we discuss the new combinations of several species previously assigned to *Cricosphaera*, a genus regarded as a junior synonym of *Pleurochrysis*.

Also we propose that, where holococcolith and heterococcolith bearing species are shown to be alternate phases of a single life-cycle, the two phases should be recombined as one species, but with each phase assigned *forma* status.

### TAXONOMIC RECOMMENDATIONS

*Calyptrolithina divergens* var. *tuberosa* (Heimdal, in Heimdal & Gaarder 1980) *stat. nov.* (Note 1)

Basionym: *Zygosphaera divergens* f. *tuberosa* Heimdal, in Heimdal & Gaarder, 1980, p.12, pl.3, fig.25.

Synonym: *Calyptrolithina divergens* f. *tuberosa* (Heimdal, in Heimdal & Gaarder) Heimdal, 1982, p.54.

*Papposphaera borealis* f. *sagittifera* (Manton et al 1976) *comb. & stat. nov.* (Note 2)

Basionym: *Papposphaera sagittifera* Manton., Sutherland, & McCully 1976, pp.228-229, figs 1-4.

Synonym: *Papposphaera borealis* (Manton, Sutherland & Oates 1976) Thomsen, Østergaard & Hansen, 1991, p.641, figs 2-4, 9 (in part).

*Papposphaera arctica* f. *sarion* (Thomsen 1981) *comb. & stat. nov.* (Note 2)

Basionym: *Papposphaera sarion* Thomsen, 1981, p.79, figs 5-8.

Synonym: *Papposphaera arctica* (Manton, Sutherland & Oates) Thomsen, Østergaard & Hansen, 1991, pp.640-641, figs 5-8 (in part).

*Pleurochrysis elongata* (Droop 1955) *comb. nov.* (Note 3)

Basionym: *Syracosphaera (Hymenomonas) elongata* Droop, 1955, p.240, figs 12-14.

Synonyms: *Cricosphaera elongata* (Droop) Braarud, 1960, p.212.

*Hymenomonas elongata* (Droop) Parke & Green, 1976, pp.552 and 554.

*Pleurochrysis gayraliae* (Beuffe 1978) *comb. nov.* (Note 3)

Basionym: *Cricosphaera gayraliae* Beuffe, 1978, p.458, figs 1-13.

*Scyphosphaera apsteinii* var. *dilatata* (Gaarder 1970) *stat. nov.* (Note 1)

Basionym: *Scyphosphaera apsteinii* f. *dilatata* Gaarder, 1970, p.119, figs 4-6.

*Syracosphaera dilatata* (Heimdal, in Heimdal & Gaarder 1981) *stat. nov.* (Note 4)

Basionym: *Caneosphaera halldalii* f. *dilatata* Heimdal, in Heimdal & Gaarder, 1981, p.44, pl.2, fig.9.

Synonym: *Syracosphaera halldalii* f. *dilatata* (Heimdal, in Heimdal & Gaarder) Jordan & Young, 1990, pp.15-16.

***Tetralithoides* Theodoridis 1984 emend.**

Type species: *Tetralithoides quadrilaminata* (Okada & McIntyre) comb. nov.

Emended description: Coccusphere shape unknown, but with monomorphic oval coccoliths. Each coccolith rim bearing both a proximal and distal flange of equal size. Rim surrounding a large central area, with calcified plates covering the proximal part of the coccolith.

Type species: *Tetralithoides quadrilaminata* (Okada & McIntyre) comb. nov.

***Tetralithoides quadrilaminata* (Okada & McIntyre 1977) comb. nov. (Note 5 & Figs 1-2)**

Basionym: *Cricosphaera quadrilaminata* Okada & McIntyre 1977, p.15, pl.6, figs 5-6.

Synonym: *Tetralithoides symeonidesii* Theodoridis, 1984, p.88, pl.9, figs 5-12.

Emended description: Oval caneolith-like coccoliths with a very large central area covered by three or four angular plates forming a solid bottom. Central plates interlock in a complicated manner in distal view. In proximal view plates appear fused giving X- or Y-shaped suture lines. Distal and proximal flanges similar in size. Proximal part of rim with a short oblique continuation directed into the central area and overlying the central area plates. Coccoliths 3.9 to 7.5 µm long and 2.9 to 5.2 µm wide.

## EXPLANATORY NOTES

1) **Use of varieties.** In a previous paper the use of subspecies in coccolithophorid taxonomy was discussed and it was proposed that use of variety was generally preferable (Jordan & Young, 1990). At that time taxa of *forma* status were not mentioned. Since then there has been a proposal to adopt *forma* status exclusively for the use of life cycle stages (Kleijne, 1991). This proposal is supported and continued below (see Note 2). However, within the classification scheme there are two taxa with *forma* status which are not alternate life cycle stages of the type form. To avoid future confusion it is proposed here to change their status to variety.

2) **Heterococcolithophorid/holococcolithophorid combinations within the Papposphaeraceae.** Recently, it has been reported that cells of *Papposphaera* and *Pappomonas* spp. were seen to combine consistently with cells of *Turrisphaera* and *Trigonaspis* spp. (Thomsen *et al.*, 1991). This association, called a "combination cell" (see Thomsen *et al.*, 1991, figs 8 & 9), only occurs between discrete pairs of species. For instance, *Papposphaera sagittifera* and *Turrisphaera borealis*, *Papposphaera sarion* and *Turrisphaera arctica*, *Papposphaera* sp. and *Turrisphaera polybotrys*, and *Pappomonas flabellifera* var. *borealis* and *Trigonaspis* cf. *diskoensis*. The authors believed that these associations were part of the life histories of these species. To emphasise this they transferred the *Turrisphaera* species to their *Papposphaera* counterparts. As the latter genus has priority *Turrisphaera* has now become superfluous and a junior synonym of *Papposphaera*. However, in the case of two species the new combinations took the specific epithet of the holococcolithophorid stage (*Turrisphaera* phase), as they were described prior to, or at the same time as, their respective heterococcolithophorid stage. Thus the combinations *P. arctica* and *P. borealis* were created.

In the literature there are only two other examples of heterococcolithophorid-holococcolithophorid alternate life cycles. These are *Coccolithus pelagicus* and '*Crystallolithus*' *hyalinus*/*C. braarudii* (Parke & Adams, 1960; Rowson *et al.*, 1986), and *Calcidiscus leptoporus* and '*Crystallolithus*' *rigidus* (Kleijne, 1991). However, they do not form combination cells like those above, instead one stage is produced and subsequently released from inside the cell of the other stage. Furthermore, as recommended by Kleijne (1991) the stages in the life cycle of coccolithophorids should be retained as separate taxonomic units with *forma* status. Thus in accordance with this recommendation the combinations proposed by Thomsen *et al.* (1991) should be further subdivided to this level (see the section on taxonomic recommendations).

3) **Assignment of species of *Cricosphaera*.** Braarud (1960) described this genus for monomorphic cricolith-bearing coccolithophores Braarud (1960) transferred two *Syracosphaera* species into his new genus; *S. carterae* and *S. elongata*. The former was designated as the type species and two further species were later added to the genus; *C. quadrilaminata* (Okada & McIntyre, 1977) and *C. gayraliae* (Beuffe, 1978). However, several years earlier *Pleurochrysis* had been described by Pringsheim (1955) on the basis of its flagellar morphology and life

history, but without any knowledge of its coccoliths. These coccoliths were recognised later as cricoliths. At that time the two genera were separated by life history. Species were only retained in *Cricosphaera* if a benthic stage had not been recognised. However, Christensen (1978) transferred *C. carterae* to *Pleurochrysis* on the grounds that it possessed a benthic stage. By transferring the type species of *Cricosphaera* to *Pleurochrysis* the former became superfluous and a junior synonym of the latter. Thus the species of *Cricosphaera* should be transferred to *Pleurochrysis* or to another genus (see Note 5).

**4) *Syracosphaera dilatata*.** The taxon was first described as a form of *Caneosphaera halldalii* by Heimdal and Gaarder (1981) and later transferred to *Syracosphaera* (Jordan & Young, 1990). The coccoliths of this form are, however, significantly different from the type, *S. halldalii* f. *halldalii*. The type possesses a distinct, wide distal flange (see Gaarder & Heimdal, 1977, pl.6), whilst f. *dilatata* has merely a flared rim (see Heimdal & Gaarder, 1981, pl.2, fig.9). In addition, the presence of a beaded mid-wall flange on the circum-flagellar coccoliths of f. *dilatata*, which is mentioned but not figured by the authors (Heimdal & Gaarder, 1981, p.44), is a significant difference between this form and the type. Neither *S. halldalii* or its close relative, *S. molischii*, have a mid-wall flange. It is therefore proposed to elevate *S. halldalii* f. *dilatata* to species level.

**5) *Tetralithoides quadrilaminata*.** *Cricosphaera quadrilaminata* was first described from the deep photic zone of subtropical/tropical waters of both the Atlantic and Pacific Oceans (Okada & McIntyre, 1977). Since then it has only been recorded a few times: in deep photic waters of the subtropical N.E. Atlantic (Jordan & Kleijne, unpubl. obs); in Miocene sediments of the Mediterranean, the Atlantic and the Indian Ocean (Theodoridis, 1984); and in Quaternary sediments of the Philippine Sea (Matsuoka & Okada, 1989) and off the coast of Japan (Okada, 1992).

Its coccoliths were described as cricolith-like, however, the possession of calcareous elements associated with the proximal part of the tube and of other elements filling the central area (Fig.1), is not characteristic of members of the Pleurochrysidaceae. In our opinion these calcified plates may be homologous to the flattened plates of *Alisphaera* or the radial laths of *Syracosphaera* spp. In addition, the oblique continuation of the rim into the central area (Fig.2), is also a character of both *Alisphaera* and *Syracosphaera* spp. (Jordan *et al.*, in prep.). Thus transfer of this species to *Pleurochrysis* would not be as satisfactory as for the other *Cricosphaera* species (see Note 3). Its taxonomic position would be more closely associated with the Syracosphaeraceae. Placement in *Alisphaera* would not be satisfactory, because the development of the central area in *C. quadrilaminata* is significantly different.

Theodoridis (1984) described a new genus and species, *Tetralithoides symeonidesii*, from the Miocene of the western Mediterranean (DSDP Site 372). He recorded occurrences from zones NN2 to NN11. The polarised light micrographs closely resemble the one featured later in Okada (1992), however, Theodoridis did not realise that his new species was identical to *Cricosphaera quadrilaminata* (Okada & McIntyre, 1977) described seven years earlier. We therefore propose the new combination *Tetralithoides quadrilaminata*.

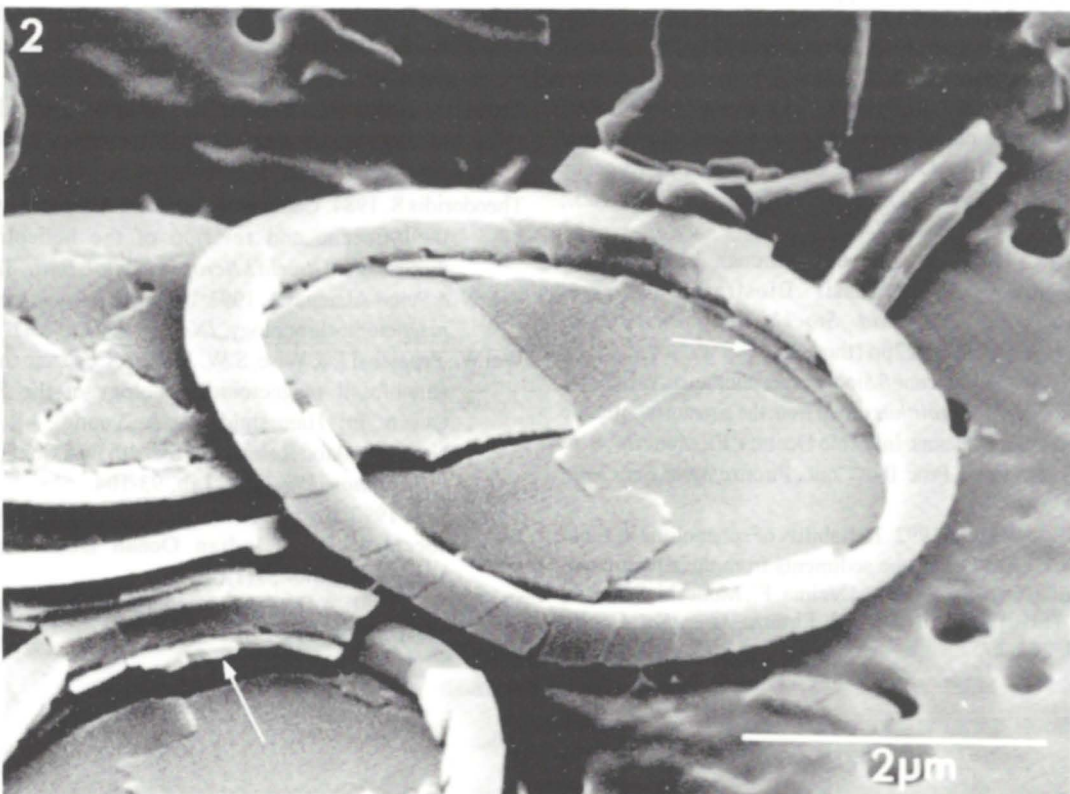
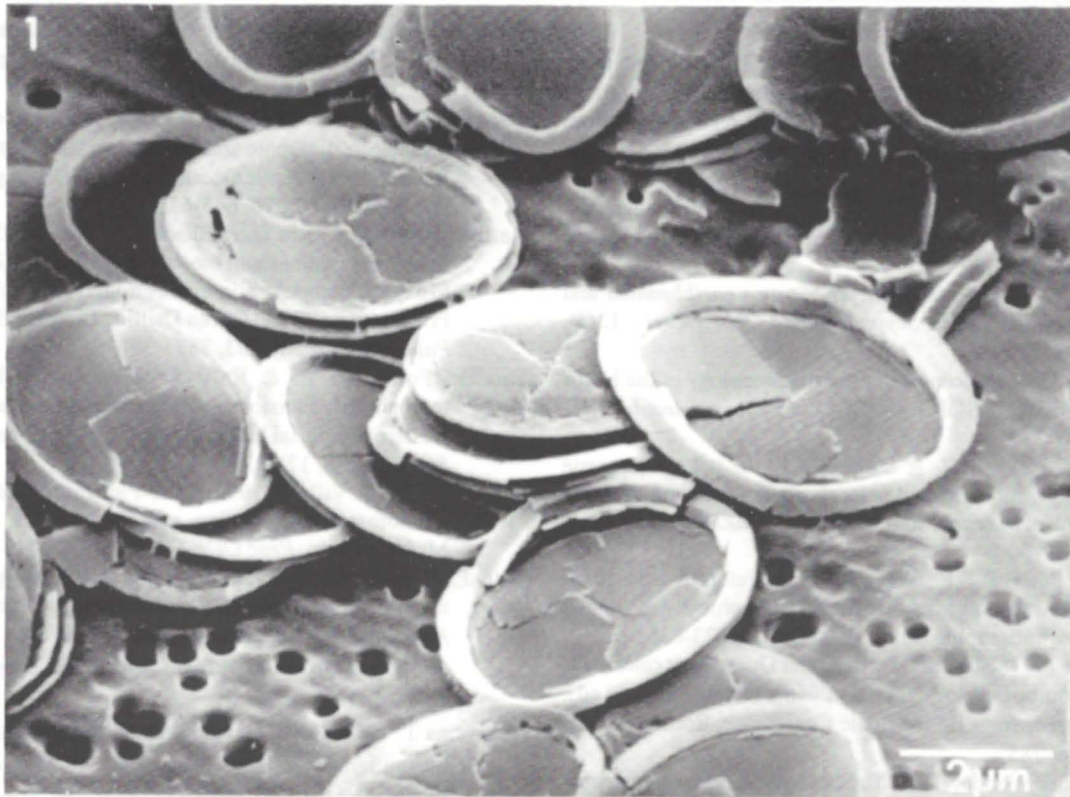
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## \*PLATE:

Figure 1: Coccoliths of *Tetralithoides quadrilaminata* showing both distal and proximal views. In distal view the 3 or 4 central area plates are shown to be overlapping, whilst in proximal view they appear fused in X- or Y- shaped suture lines. Specimen from 160m at St. 11311 (26°11'N 44°53'W). Bar = 2  $\mu$ m.

Figure 2: Coccoliths of *Tetralithoides quadrilaminata* showing both distal and proximal views at higher magnification. Note also the smaller oblique continuations of the rim at the proximal end of the tube (arrowed). Bar = 2  $\mu$ m.

\*These photographs were published in the article by R. W. Jordan, A. Kleijne & B. R. Heimdal: Proposed changes to the classification system of living coccolithophorids III., *INA Newsletter*, 15/1, 1993, p. 18 - 22. Due to the bad quality of printing, we reproduce them again.