

## ***Picarola margalefii*, gen. et sp. nov., a new planktonic coccolithophore from NW Mediterranean waters\***

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**SUMMARY:** A coccolithophore which is referred to a new genus *Picarola* gen. nov. and described as a new species *Picarola margalefii* sp. nov., has been observed from the NW Mediterranean. The description of the new species is based on Scanning Electronic Microscopy (SEM) observations. The coccoliths of *Picarola margalefii* sp. nov. are muroliths that have a narrow high rim and a central area with a cross and an elongate four-sided central process. Energy dispersive X-ray microanalyses confirmed their calcareous nature. The relation between the new genus and the genera *Papposphaera* Tangen, *Vexillarius* Jordan et Chamberlain, and *Turrilithus* Jordan et al., is discussed. The coccolithophore *Picarola margalefii* gen. et sp. nov., is dedicated to Dr. Ramon Margalef.

**Key words:** *Picarola margalefii*, coccolithophore, Haptophyta, taxonomy, calcareous nannoplankton, living, Western Mediterranean.

**RESUMEN:** *PICAROLA MARGALEFII*, GEN. ET SP. NOV., UN NUEVO COCOLITÓFORO PLANCTÓNICO DEL MEDITERRÁNEO NOROCCIDENTAL. – Un coccolitóforo atribuido a un género nuevo, *Picarola* gen. nov., y descrito como una especie nueva, *Picarola margalefii* sp. nov., ha sido hallado en el Mediterráneo noroccidental. La descripción de la nueva especie se basa en observaciones realizadas con Microscopía Electrónica de Barrido. Los coccolitos de *Picarola margalefii* sp. nov. son murolitos que tienen un margen alto y estrecho y un área central que presenta una cruz con un largo proceso central de cuatro caras. Se confirmó su naturaleza calcárea mediante microanálisis basados en energía dispersiva de rayos X. Se discute la relación morfológica entre el género nuevo y los géneros *Papposphaera* Tangen, *Vexillarius* Jordan et Chamberlain, y *Turrilithus* Jordan et al. El nuevo coccolitóforo *Picarola margalefii*, gen et sp. nov., se dedica al Dr. Ramon Margalef.

**Palabras clave:** *Picarola margalefii*, coccolitóforo, Haptophyta, taxonomía, nanoplancton calcáreo, viviente, Mediterráneo occidental.

### INTRODUCTION

Coccolithophores, a group of calcifying phytoplankton, represent a significant component of the marine ecosystem. They are major producers of biogenic calcite in the open ocean and important agents in the global carbon cycle (Honjo, 1976; Westbroek et al., 1994). In recent years, the knowl-

edge of coccolithophores has improved due, mainly, to an increase in detailed studies on these organisms using electron microscopy. The description of a number of holo- and heterococcolithophore combination coccospheres has suggested that the holo- and heterococcolithophore forms involved were part of the life cycle of the same species (Parke and Adams, 1960; Kleijne, 1991; Cros et al., 2000). In spite of this fact, the number of recognized species has increased. Most of the newly described species have

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been recovered from surface waters (Sánchez-Suárez, 1990; Kleijne, 1991; Kleijne *et al.*, 1991, 2002; Knappertsbusch, 1993; Thomsen *et al.*, 1995) but a few come from the lower euphotic zone (Jordan *et al.*, 1991; Jordan and Chamberlain, 1993; Hagino and Okada, 1998). Despite awareness of the limitations involved, coccolith morphology remains the most important character in the classification of the coccolithophores. At present, their systematics adheres (Perch-Nielsen, 1985; van Heck, 1990; Jordan *et al.*, 1995) to the ruling of the International Code of Botanical Nomenclature (ICBN, Greuter *et al.*, 2000).

While studying the coccolithophores of the Catalano-Balearic Sea (NW Mediterranean), five specimens of a coccolithophore form, which had been neither described, photographed, nor drawn in the literature, were found in waters from 50 to 70 m depth. This new form, with coccoliths having a characteristic elongated and curved process, differs greatly from all other known coccolithophores, but bears some resemblance to the genera *Papposphaera* Tangen (Tangen, 1972), *Vexillarius* Jordan *et al.* Chamberlain (Jordan and Chamberlain, 1993), and *Turrilithus* Jordan, Knappertsbusch, Simpson *et al.* Chamberlain (Jordan *et al.*, 1991).

## MATERIALS AND METHODS

The five specimens studied were found in four samples collected in the Northwestern Mediterranean, at station 25W (41°02.3'N, 2°14.7'E) of the cruise FRONTS-95 (17-23 June, 1995) and stations I2 (41°13.9'N, 2°20.7'E) and I6 (40°49.3'N, 2°43.7'E) of cruise MESO-96 (18 June - 3 July, 1996) on board the R/V *García del Cid*.

The water samples were obtained at selected depths using a rosette with Niskin bottles attached to a conductivity, temperature and depth (CTD) probe. About 200 ml of sea water were filtered, using a vacuum pump, onto polycarbonate Nuclepore filters of 0.8 µm pore size and 25 mm diameter. Another filter (MF-Millipore, cellulose acetate, of 3 µm pore) was placed below the Nuclepore, to obtain an even distribution of filtered particles. Salt was removed by rinsing the filters with about 2 ml of bottled drinking water. The filters were air dried (about 5 min) and stored in hermetically closed boxes under partial vacuum made with a hand pump. A part of the filter was glued with silver colloidal suspension on a SEM stub, coated with gold to avoid electric charges, and

examined using an Hitachi S-570 Scanning Electron Microscope. Energy-dispersive X-ray microanalyses were conducted with a Kevex Delta III Energy Dispersive Spectrometer.

The coccolith counts and the coccosphere and coccolith measurements were made on micrographs taken during sample examination. In the description, the lengths (in µm) quoted in parentheses represent minimum (left) and maximum values (right); the two numbers in the middle indicate the minimum and maximum of the interval containing 50% of the values. Only minimum and maximum values are given when few measurements were available. The terminology follows the guidelines given in Young *et al.* (1997).

## RESULTS

### Observations

Two coccospheres which were neither described nor figured in the literature were found at station 25W of cruise Fronts-95, one at 50 m depth and another at 70 m depth. Three more coccospheres were found at 70 m depth, during cruise Meso-96, two at station I2 and another at station I6. The calcareous composition of the coccoliths (see the spectrum of X-ray microanalysis in Fig. 1) was corroborated on the holotype specimen, which is represented in Figure 2A-C. Three more specimens are shown in Figures 2D-3.

The coccospheres appear sub-spherical to ellipsoidal and have numerous circum-flagellar coccol-

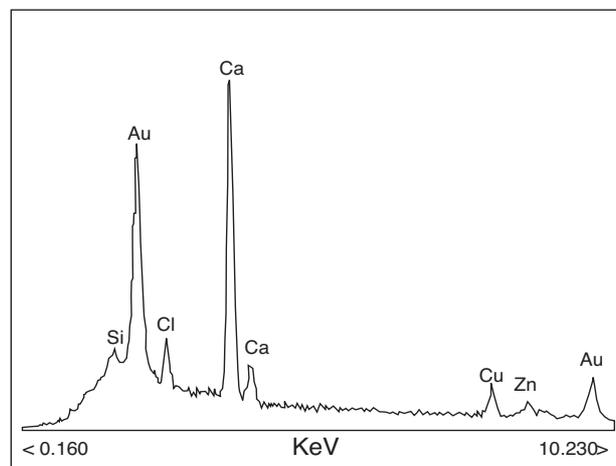


FIG. 1. – Spectrum of energy-dispersive X-ray microanalysis from the holotype specimen (specifically of circum-flagellar coccoliths). The high calcium peaks corroborate the abundance of this element; the high gold signals arise from the sample coating.

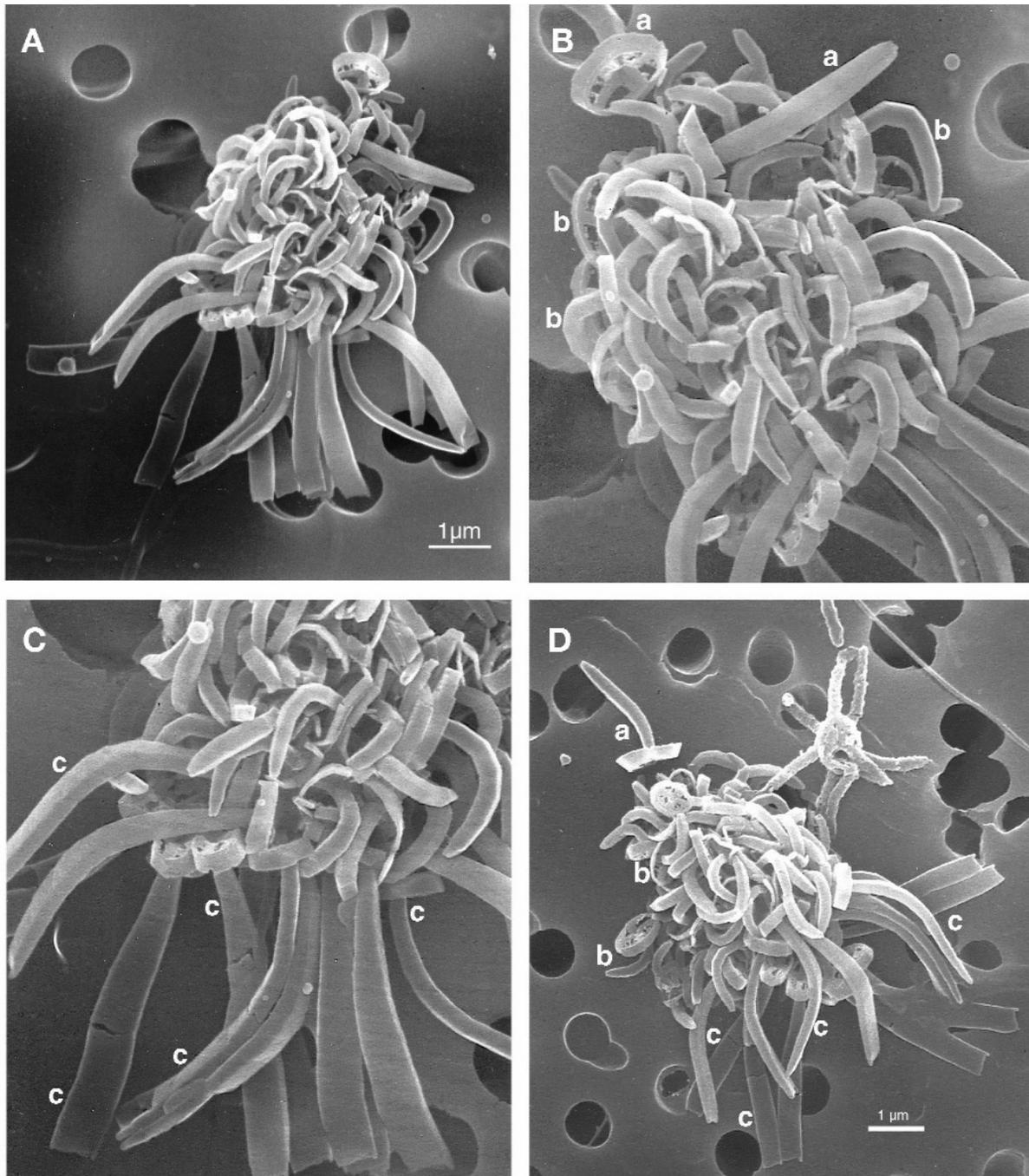


FIG. 2. – Scanning electron micrographs of *Picarola margalefii* sp. nov. **A:** whole coccosphere with body cocoliths, circum-flagellar cocoliths and two antapical cocoliths (upper right). Notice the remains of the two hardly visible flagella (lower left). Holotype. Fronts-95, 25W (41°02.3'N, 2°14.7'E), 70 m. **B:** detail of the holotype showing body cocoliths (b) with the central process curved around 90°; at upper left two antapical cocoliths (a) with flaring wall and nearly straight process. **C:** detail of the holotype illustrating the circum-flagellar cocoliths (c); the long process, which is slightly curved, has a distal rectangular section and finishes abruptly in a truncated ending. **D:** whole coccosphere presenting one detached antapical cocolith (a), body cocoliths (b) and circum-flagellar cocoliths (c). The star-like object at the upper-middle right part of the micrograph does not belong to the coccosphere. Fronts-95, 25W (41°02.3'N, 2°14.7'E), 50 m.

iths with an elongated and slightly curved process. All the cocoliths of the coccosphere (70 to 107) are muroliths presenting a narrow high rim and a central area with a cross and a long four-sided process. The rim consists of a wall of quadrilateral elements and, possibly (this is not clarified so far), by a narrow

proximal part that forms a tiny external connecting ring in the central area. The four arms of the cross, in the central area, connect the rim with the four sides of the central process. On the coccosphere, three different types of muroliths can be distinguished: body cocoliths (54 to 80), circum-flagellar

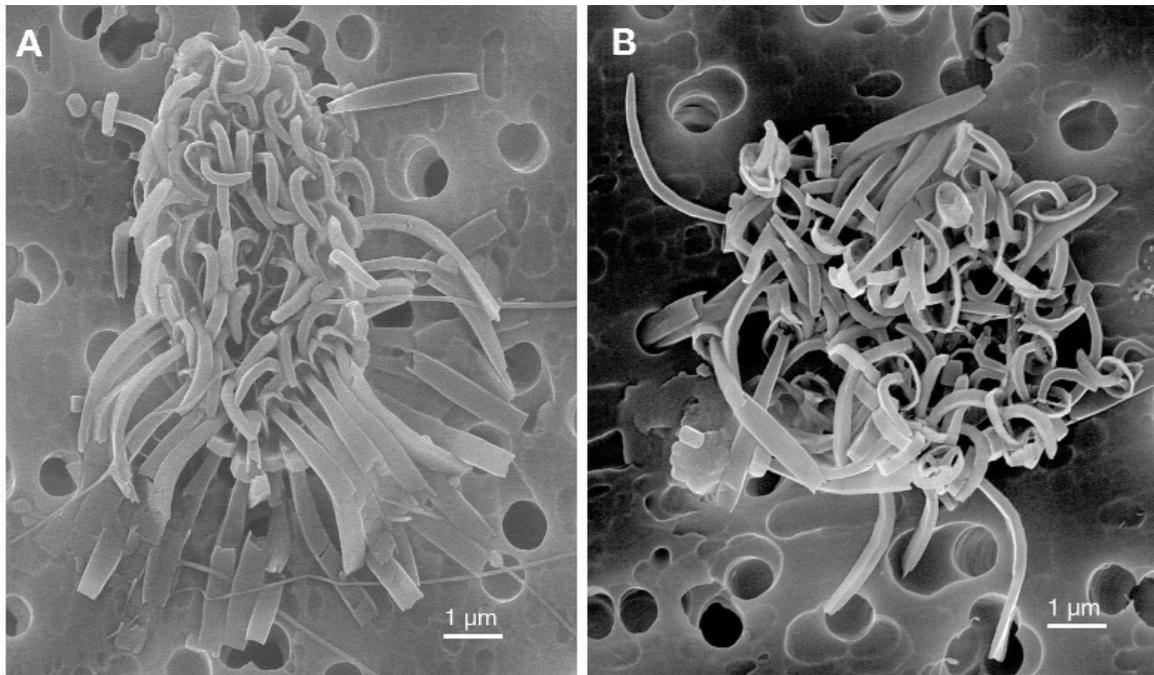


FIG. 3. – Scanning electron micrographs of *Picarola margalefi* sp. nov. **A:** Large coccosphere presenting numerous body and circum-flagellar coccoliths. Meso-96, I6 (40°49.3'N, 2°43.7'E), 70 m. **B:** collapsed coccosphere in apical view. Meso-96, I2 (41°13.9'N, 2°20.7'E), 70 m.

coccoliths (14 to 28) and antapical coccoliths (0 to 2, only present in some coccospheres). These three types of muroliths differ in their proximal parts and, particularly, by the architecture of their central structures.

The body coccoliths (b; see Figs. 2B and 2D) have an elliptical base with a long axis (0.65-) 0.80-1.00 (-1.22)  $\mu\text{m}$  long and a short axis ca. 0.5-0.6  $\mu\text{m}$  long. The wall is straight sided, without flanges, and it is 0.05 to 0.15  $\mu\text{m}$  high. It has not been clarified whether the cross of the central area is axial or nearly axial. The central process is (0.9-) 1.1-1.4 (-1.8)  $\mu\text{m}$  long and has a squared section of ca. 0.2  $\mu\text{m}$  side; these processes, which are robust and possess pointed endings, are perpendicular to the base in their proximal part but they bend suddenly, with a blunt angle of around 90°, towards the apical pole of the coccosphere.

The circum-flagellar coccoliths (c; see Figs. 2C and 2D) have a narrowly elliptical to oblong base, with a long axis of ca. 0.8-0.9  $\mu\text{m}$  and a short axis of ca. 0.4-0.5  $\mu\text{m}$ . The wall is straight and approximately 0.15 to 0.20  $\mu\text{m}$  high. It has not been clarified whether the cross of the central area is axial or nearly axial. The central process is (2.1-) 2.9-3.1 (-3.6)  $\mu\text{m}$  long and has a proximal squared section of around 0.2  $\mu\text{m}$  side, and a distal rectangular section of around 0.4  $\mu\text{m}$  x 0.1  $\mu\text{m}$  (the longer side runs parallel to the short axis of the coccolith base); these

processes are slightly curved and finish abruptly in truncated endings.

The few antapical coccoliths (a; see Figs. 2B and 2D) have a broadly elliptical base, with a long axis of ca. 0.9-1.2  $\mu\text{m}$  and a short axis of ca. 0.8-1.0  $\mu\text{m}$ . The wall is flaring and approximately 0.15  $\mu\text{m}$  high. The cross of the central area is nearly axial. The central process is ca. 2.10  $\mu\text{m}$  long and has a squared section of around 0.25  $\mu\text{m}$  side in its wider central part; the processes are robust, nearly straight and finish in rounded tips.

### *Picarola* gen. nov.

*Etymology:* *Picarol* is catalan for a small bell or cowbell; *a*, for feminine form. This name was suggested by a comment from Dr. R. Margalef.

*Diagnosis:* *Coccosphaera* habens coccolithos angusti marginis constantis ex muro et area centrali formata cruce et processu in centro. Murus compositus quadrilateralibus elementis non imbricatis. Processus elongatus et curvatus quadrilateralis. Singula processus latera singula brachia crucis conectunt basi.

Coccosphere having coccoliths that possess a narrow rim consisting of a wall, and a central area with a cross and a centrally placed process. The wall is composed of non-overlapping quadrilateral elements. The process is long, curved and four-sided,

with each of the sides connecting, in the base, with one of the cross arms.

*Type species: Picarola margalefii* sp. nov.

***Picarola margalefii* sp. nov.**

*Holotype:* Figure 2A. Negative 138910. Deposited in the ICM (CSIC) Barcelona.

*Type locality:* 41°02.3N, 2°14.7E. Station 25WT, at 70 m depth, during the cruise Fronts-95 (NW Mediterranean).

*Etymology:* The new species *Picarola margalefii* sp. nov., is dedicated to Dr. Ramon Margalef, who studied the phytoplankton of the NW Mediterranean and encouraged our coccolithophore studies in these waters.

*Diagnosis:* *Coccosphaera cum longitudine circiter 6 ad 12 µm per axem longiorem, habens circiter 54-80 coccolithos usitatos, circiter 14-28 coccolithos circumflagellares et 0-2 coccolithos antapicales. Coccolithi usitati compositi muro recto et processu quadrato, admodum curvato (circa 90°) et acuto. Coccolithi circumflagellares compositi muro alto et recto et processu longo, leviter curvato et quadrato ad partem proximalem, rectangulari distaliter, desinenti truncate. Coccolithi antapicales compositi muro campaniformi et processu satis recto desinenti in punctum rotundatum.*

Coccosphere size ranges around 6 to 12 µm along the longer axis, having approximately 54 to 80 body coccoliths, 14 to 28 circum-flagellar coccoliths and 0 to 2 antapical coccoliths. Body coccoliths have a straight wall and a pointed process, which is squared in section and highly curved (around 90°). Circum-flagellar coccoliths have a straight and high wall and a large and slightly curved process, which has a squared proximal section, a rectangular distal section and finishes abruptly in a truncated end. Antapical coccoliths have a flaring wall and a nearly straight process, which finishes in a rounded tip.

## DISCUSSION

*Picarola* gen. nov. resembles the genus *Papposphaera* (Tangen, 1972) in having coccoliths with a similar disposition of rim elements, a central area filled with a cross and an elongated central process, but it differs from the latter genus, mainly, in having quadrilateral elements in the rim, instead of mostly pentagonal ones (Manton and Oates, 1975; Thomson, 1981), and in having a process without the differentiated distal calyx structure found in *Pap-*

*posphaera* coccoliths. The new genus resembles the genus *Vexillarius* (Jordan and Chamberlain, 1993) in having the coccolith rim formed by quadrilateral elements but differs from the latter because the process of the *Picarola* coccoliths lack the differentiated distal part present in the equatorial *Vexillarius* coccoliths. The new genus resembles *Turrilithus* (Jordan *et al.*, 1991), in having a four-sided central process without distal differentiated structure, but differs in having coccoliths with a murolith instead of a placolith base (see Young and Bown, 1997). Moreover neither *Vexillarius* nor *Turrilithus* possess a cross in the central area in contrast with *Papposphaera* and *Picarola* gen. nov., in which it is clearly visible. Due to the affinities with the genus *Papposphaera*, we tentatively propose the inclusion of the new genus within the family Papposphaeraceae Jordan *et* Young (Jordan and Young, 1990).

The known species of the genera *Turrilithus* and *Vexillarius* inhabit lower euphotic zone depths (Jordan *et al.*, 1991; Jordan and Chamberlain, 1993). In the NW Mediterranean, the maximum densities of *Papposphaera* specimens have been found at around 70 m depth (Cros, 2002). Therefore, the new genus appears to be related with *Papposphaera*, *Turrilithus* and *Vexillarius*, not only in coccolithophore morphology but also with respect to habitat preferences.

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