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***Turrilithus latericioides* gen. et sp. nov., a New Coccolithophorid from the Deep Photoc Zone**

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Turrilithus latericioides gen. et sp. nov. (Prymnesiophyceae) is described from scanning electron microscopy studies of filtered water samples collected from the Atlantic Ocean (June 1982) and the Mediterranean Sea (September 1986 and February 1988). The coccolith of this new species is characterized by the possession of a four-sided, tower-shaped appendix constructed from quadrangular plates, and was confirmed as calcium carbonate by energy-dispersive X-ray analysis. The taxonomic position of this species is considered and its affinity to other living and fossil forms discussed.

In the last two decades extensive sampling programmes in several of the world's oceans have resulted in numerous new species of coccolithophorid being reported, although relatively few have been formally described. The increasing dependence on scanning electron microscopy for routine examination and enumeration of coccolithophorids in marine community studies has led to even greater reliance on coccolith morphology for distinguishing species at the ultrastructural level. For logistic reasons, most workers have only been able to collect shallow water samples, so deep photic-zone (120–220 m) species have not been recorded very frequently. However, Okada & Honjo (1973), working in the Pacific, have shown that several species are strictly confined to these depths. In this paper a new species is described from the deep photic waters of the North Atlantic (over the Cape Verde Abyssal Plain) and from the Mediterranean Sea (off the southern coast of France), which has been referred to previously as species 10552A (Jordan, Chamberlain & Simpson, 1987).

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MATERIALS AND METHODS

Water samples were collected from Station 10552 (19° 21'N, 29° 52'W; 14 June 1982) on Cruise 129 of the R.R.S. *Discovery* during a geochemical sampling programme in the tropical and subtropical north-east Atlantic. The samples were procured using a Neil-Brown Conductivity, Temperature, Depth (C.T.D.) rig carrying up to 12 2.5 l water bottles. The C.T.D. sensor relayed physical data back to the ship in real time throughout the cast. When the sampler had reached the lower limit of the cast, sampling points were decided upon from temperature, salinity and pressure data. The rig was then raised and at each selected depth a bottle was closed electronically. After all the bottles had been fired the sampler was hauled back on to the ship, and the water bottles transferred to a rack. A nitrogen line was attached to the upper spigot of each bottle and a filter holder (containing a 47 mm diameter, 0.4 µm porosity Nuclepore polycarbonate membrane) was attached to the sample port of the lower portion. Nitrogen gas was then supplied to the bottle at 2.5–10 p.s.i., forcing the water (approximately 1 l in each case) through the filter. The filter was then washed several times in distilled water to remove salt, air-dried and placed in a plastic case for storage. A portion (c. 8 × 8 mm) of each filter was removed and immediately mounted onto an aluminium electron microscope stub using double-sided adhesive tape. The samples were subsequently coated with gold in a Nanotech or Edwards (S150B) sputter coating device for 1–2 min. The stub was then

outlined with a colloidal silver suspension (Electrodag 915) and examined with a Cambridge S100, S200 or S250 scanning electron microscope (SEM). Energy-dispersive X-ray microanalysis was conducted using a Jeol 35CF Scanning Microprobe equipped with a Link Systems 860 Series 1 analyser.

Samples were also collected off the south coast of France (42° 47'N, 4° 37'E; 17 September 1986) during the French project VICOMED 1 and further Mediterranean specimens were obtained in mid-February 1988 (Station MIN, 39° 39'99"N, 4° 38'13'E) also from a depth of 100 m. Fifteen litres of sea-water were taken with a 30 l Niskin bottle, filtered on board with a Millipore filter system (0.45 µm porosity) and rinsed with an ammonia solution (pH 9) to remove salt. After air drying, 1 cm² of filter was mounted on to a coverslip, coated with gold (15 nm) and examined using a Jeol 2000 or an Hitachi 2300 SEM.

OBSERVATIONS

Turrilithus gen. nov. (from Latin, *turris* = tower; from Greek, *lithos* = stone).

Coccosphaera monomorpha, coccolithos turri-formes, unumquemque appendice quadrilatera erecta ex bracteis quadrangularibus constanti, ferens.

Species typifica: Turrilithus latericioides sp. nov.

Coccosphere monomorphic, bearing tower-shaped coccoliths, each with a four-sided, erect appendix composed of quad-

rangular plates. Type species: *Turrilithus latericioides* sp. nov.

Turrilithus latericioides sp. nov. (from Latin, *latericium*-brickwork).

Coccosphaera 100–200 coccolithos monomorphos turri-formes ferens. Coccosphaera, ut videtur ab speciminibus incompletis, sphaerica ad sub-sphaerica, diam. circa 5–10 µm.

Coccolithi elliptici, bractea basali tenui perforatione proximali centrali subtenti. Ex peripheria bractee basalis murus humilis distaliter expansus oriens. In axem curtum bractee basalis transtrum appendicem erectam cavam quadrilateram ferens. Appendix distaliter dilatata. Unaquaque superficies appendicis ex 11 bracteis inaequalibus quadrangularibus in seriebus duabus verticalibus dispositis constans. Summum tubi appendicis 8 bracteis pluribus ad bracteam basalem parallelis partialiter oclusum. Ex his 8 bracteis, quatuor in angulos majores, unaquaque spinam curtam ad angulum extremum ferens. Bractee minores interjacentes spinas duas in peripheria externa ferentes. Apertura ad summum appendicis "Iron-Cross" ad instar. Coccolithi 0.8–0.9 × 0.45–0.55 µm, altitudine 1.1–1.4 µm.

Coccosphere bearing between 100 and 200 monomorphic, tower-shaped coccoliths. From incomplete specimens, the coccosphere shape appearing spherical to subspherical and measuring approximately 5–10 µm in diameter.

Coccoliths elliptical, subtended by a thin base plate with a proximal, central perfora-

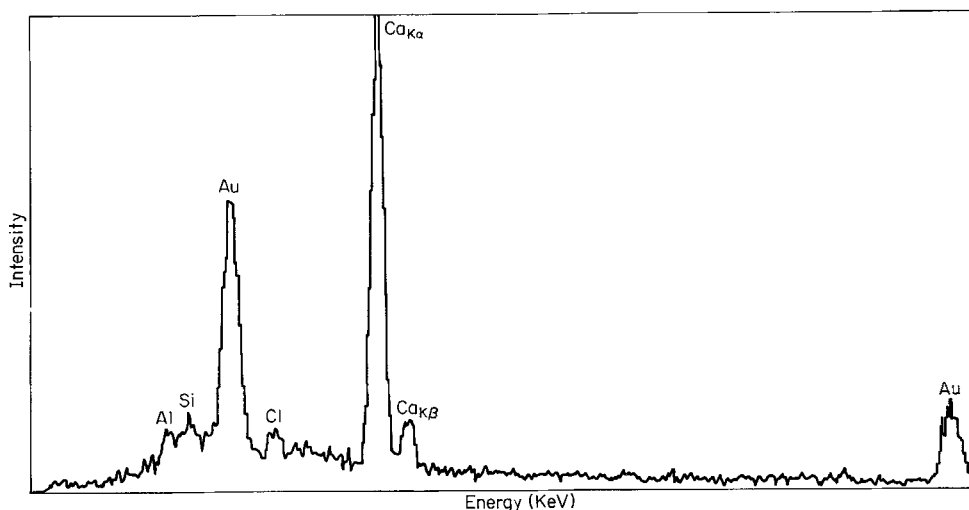
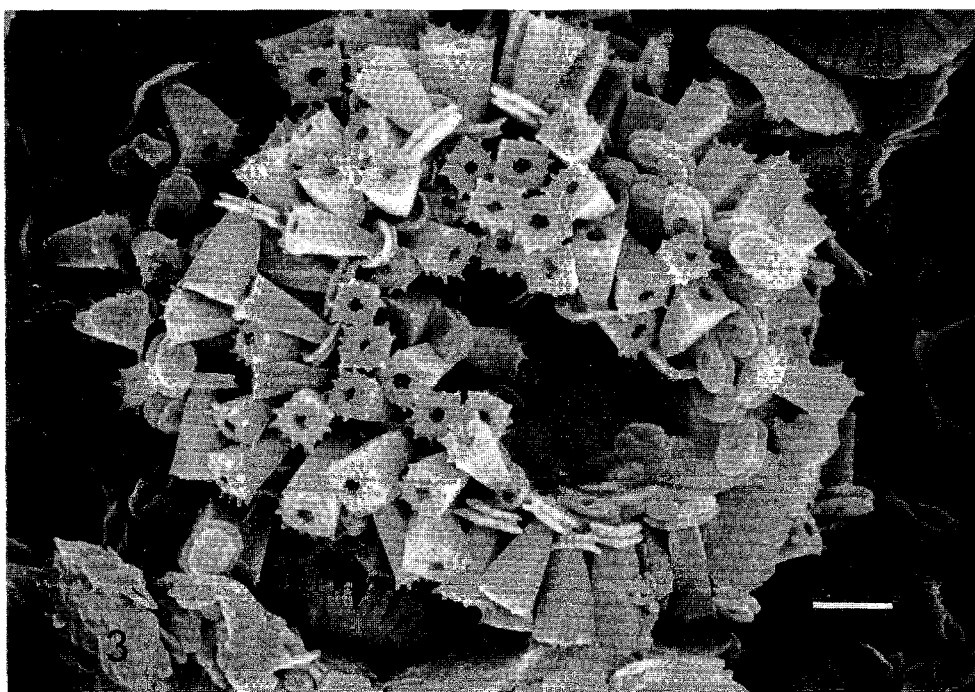
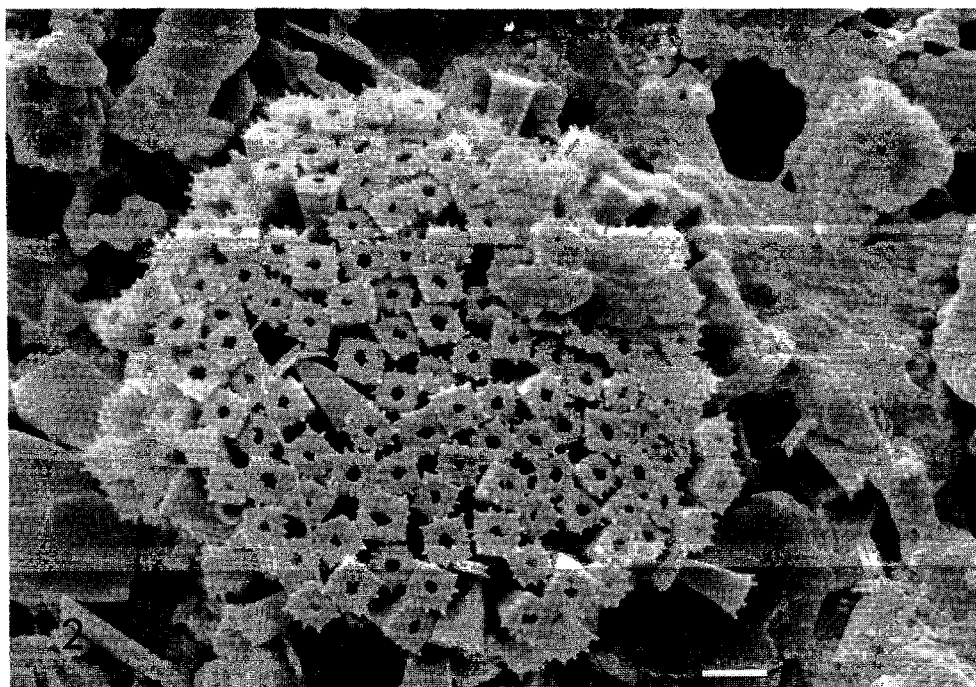
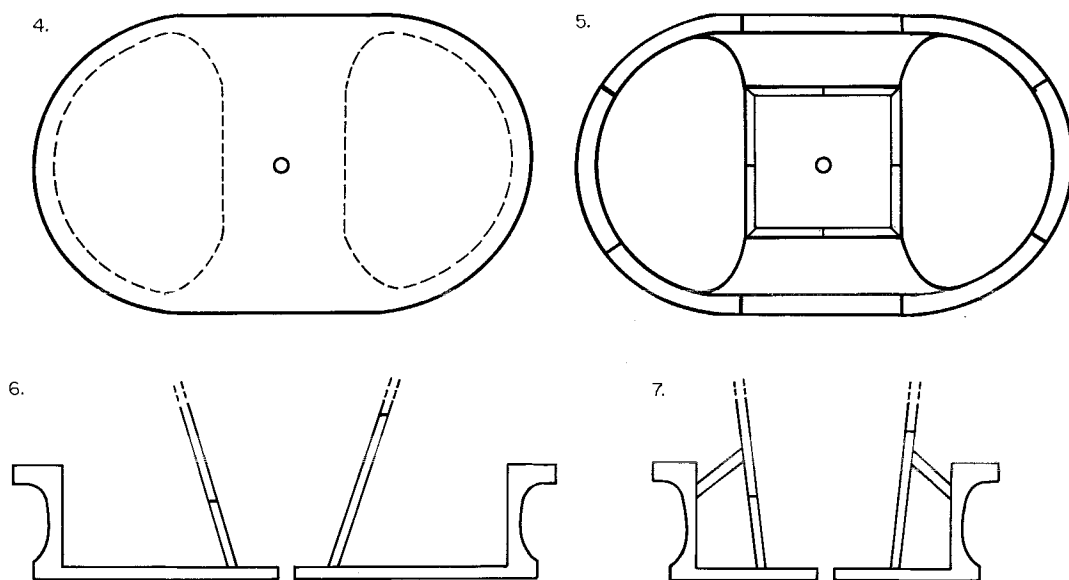


FIG 1. Energy-dispersive X-ray spectrum from the coccoliths of *Turrilithus latericioides*.



FIGS 2-3. Scanning electron micrographs of collapsed coccospheres of *Turrilithus latericioides*. Scale bars 1 μ m. Fig. 2. Coccolith appendices, the natural, outward-facing arrangement. Fig. 3. A partially disrupted coccosphere showing the imbrication of the basal portions of the coccoliths.



FIGS 4–7. Diagrammatic representations of the basal portion of a coccolith. Fig. 4. Proximal view; dashed line represents position of D-shaped, thin regions between peripheral wall and central, transapical bar. Note position of proximal pore. Fig. 5. Distal view with appendix removed but showing its position on the transapical axis. Fig. 6. Apical section. Fig. 7. Transapical section showing apparent arrangement of the two wall projections.

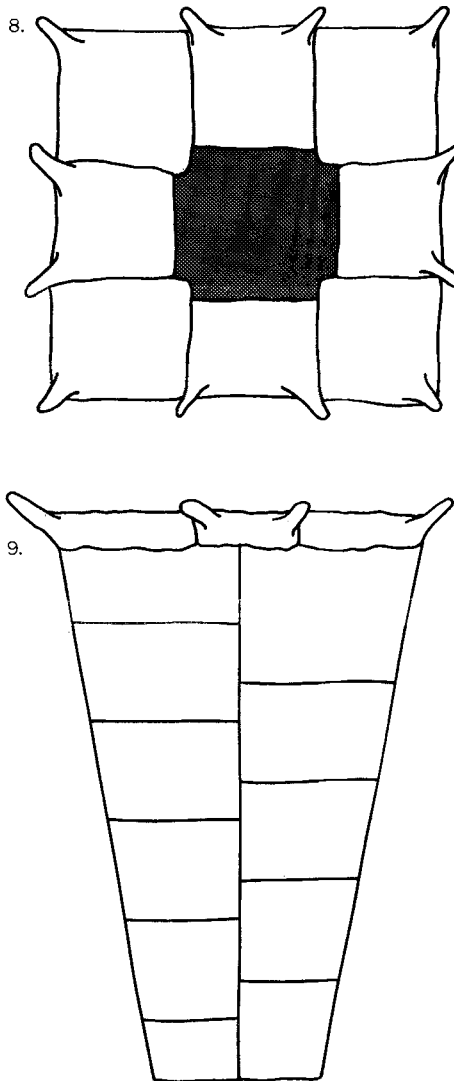
tion; a low wall arising from the periphery of the base plate and flaring outwards distally. The short axis of the base plate traversed by a bar supporting an upright, hollow, four-sided appendix, the latter widening distally and each face comprising 11 unequally sized, quadrangular plates arranged in two vertical rows. The top of the appendix tube partially occluded by eight further plates, arranged parallel to the base plate. Of these additional plates, those at the corner being the larger and bearing a short spine at the outermost corner, the smaller intervening plates bearing two spines, both situated on the outer periphery. The “roof” aperture appearing “Iron Cross”-shaped. Coccoliths measuring $0.8\text{--}0.9\text{ }\mu\text{m} \times 0.45\text{--}0.55\text{ }\mu\text{m}$ by $1.1\text{--}1.4\text{ }\mu\text{m}$ in height.

Type location: subtropical north Atlantic Ocean ($19^{\circ} 21'N$, $29^{\circ} 52'W$) at a depth of 140 m on 14 June, 1982.

Holotype: micrograph in Fig. 11, from material found at the type location. Negative RWJ.10552/0005 held in Department of Microbiology, University of Surrey.

Turrilithus latericioides is described above as a new species of marine coccolithophorid. The presence of calcium was confirmed by energy-dispersive X-ray analysis of its coccoliths (Fig. 1). The diagnosis was based solely on SEM observations made during routine examination of filtered material for the compilation of coccolithophorid community structures. Although a description including light microscopy would be considered more acceptable, the extremely diminutive size of the organism, and especially its coccoliths, makes light microscope observations of limited value. Detailed studies must await isolation of specimens into pure culture, which may be problematic due to both the small size and apparent paucity of specimens in any one sample. However, we believe that the observations presented here warrant the establishment of a new species.

The coccosphere is monothecate and bears approximately 100–200 monomorphic coccoliths (Figs 2, 3) which appear to interlock weakly at their bases (Fig. 3). The coccolith essentially comprises two parts, the base (Figs 4–7) and the appendix (Figs 8, 9).

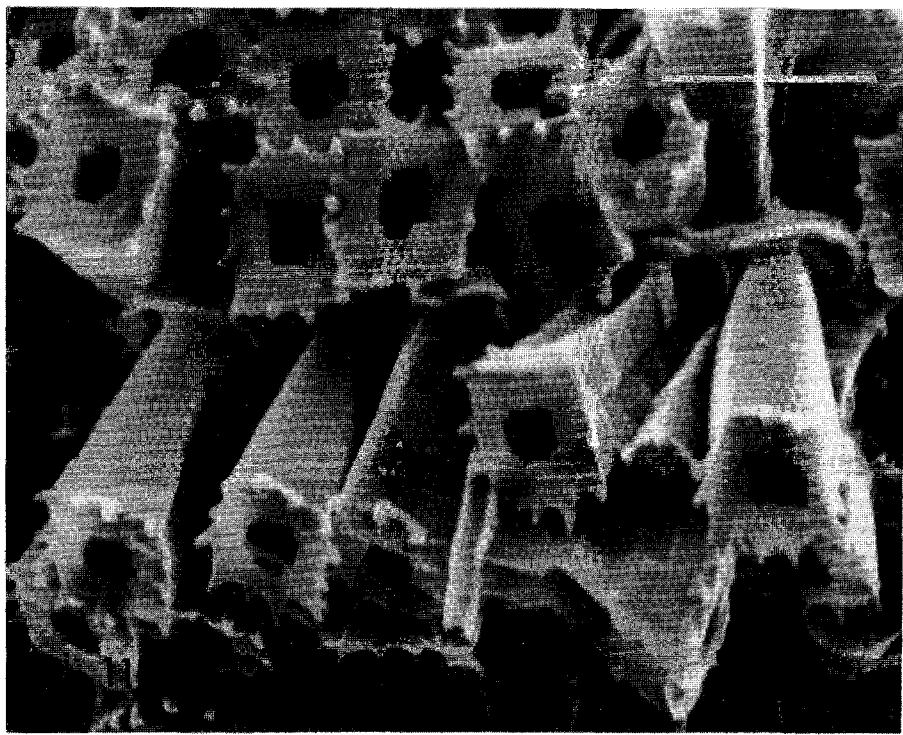
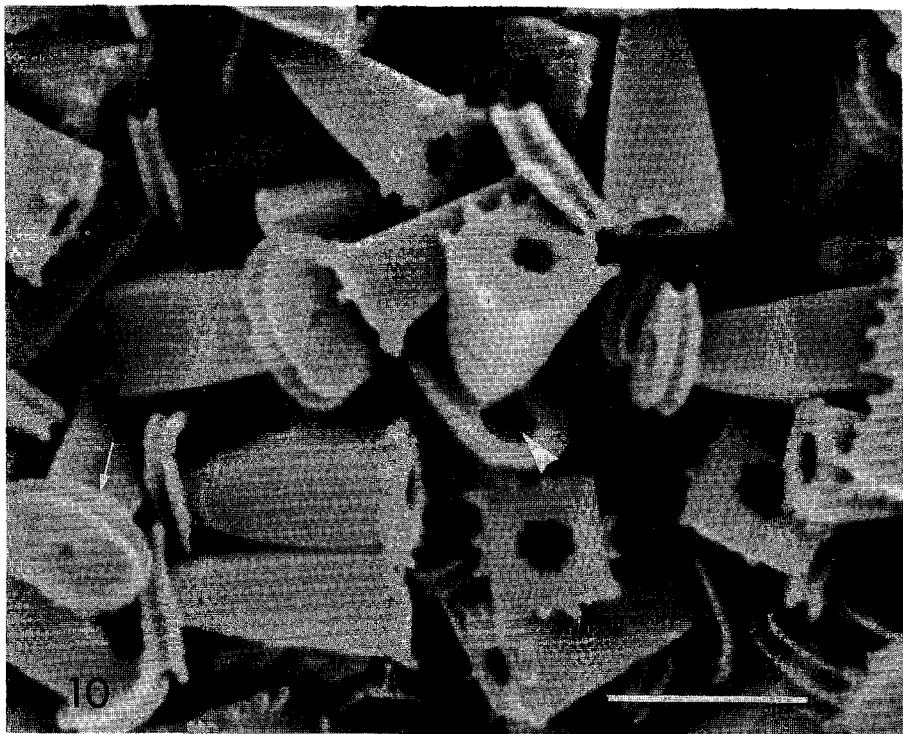


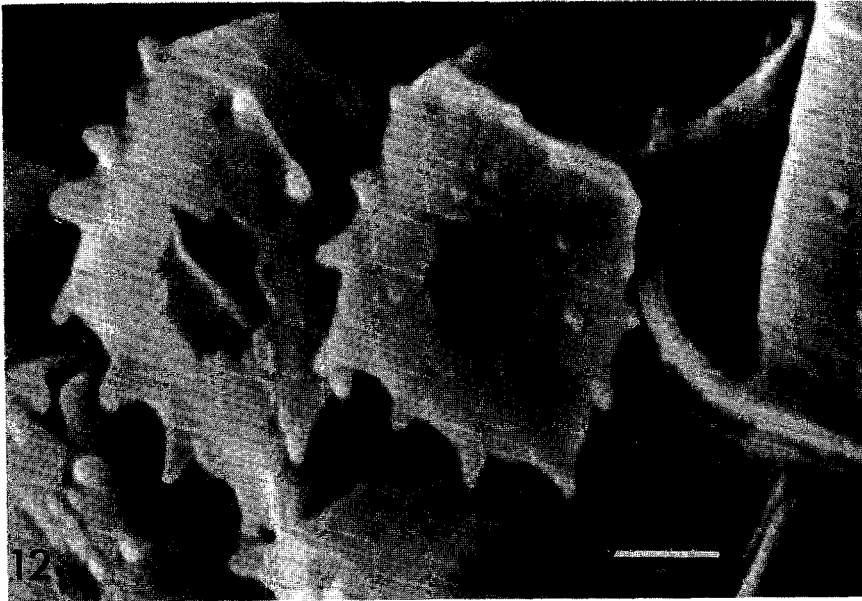
FIGS 8–9. Diagrammatic representations of the appendix. Fig. 8. Top view showing the arrangement of roof plates, spines and the central aperture. Fig. 9. Side view showing the arrangement of the wall plates and the overlapping region of roof plates.

The base is elliptical in shape and, with the exception of a centrally placed pore, is usually almost plane in proximal view (Fig. 10). However, due to the thinness of the bottom plate, two “D”-shaped patches can be discerned lying back to back and separated by a bar traversing the short axis of the base (Fig. 10). Extensive examination of the basal portion shows that these D-shaped areas may become perforated and torn due to damage, leaving rather ill-

defined holes, or series of holes, which show no regular pattern. These features suggest that this is an organic base plate covering an elliptical, bridge-bearing, calcified structure. There is no sign whatsoever of any radial elements crossing the D-shaped areas from the central bridge to the rim.

In the distal view a low, slightly flaring wall can be seen around the periphery of the base, which finally terminates in a short, out-turned, horizontal rim. This elliptical wall is





FIGS 10–12. Scanning electron micrographs. Scale bars 1 μm in Figs 10 and 11. Fig. 10. Distal and proximal views of coccoliths. Note D-shaped areas either side of appendix of central coccolith (thick arrow), and proximal view of base plate showing faint lobes at wall edges (thin arrow). Fig. 11. Side view of coccoliths showing the arrangement of wall plates. Fig. 12. Top view of roof plates. Scale bar = 250 nm.

constructed from eight variously curved plates, each approximately 300 nm long. These elements may give the wall a somewhat lobed appearance when viewed either distally or proximally, but these features are only obvious in slightly damaged specimens. The appendix is fixed across the short axis, supposedly lying on the bar (as determined from proximal view). In addition, an inward extension of the rim projects across the short axis of the base from one wall plate on each side, although only as far as the appendix (Fig. 7). The D-shaped patches seen in proximal view are equivalent to the depressions either side of the appendix, but again no substructure is present.

The appendix resembles a four-sided tower, in which each face is identical and composed of 11 unequally sized, brick-like quadrangular plates arranged in two vertical rows, the left-hand one composed of six plates and the right of five. The plates are all unequal as the rows are vertically off-set and the appendix outwardly widens from the base; hence the wall plates increase in width

with the height of the tube (Fig. 11). At the top of the tubular appendix, partially occluding the opening, is a “roof” of another eight quadrangular plates, consisting of four larger corner plates and four smaller intervening ones (Fig. 12). The “roof” appears to sit on the appendix rim somewhat like the lid of a box, with each “roof” plate possessing its own rim which overlaps the underlying wall plates. Each corner plate bears a single, protruding, short blunt spine at its outermost point, whilst the intervening plates bear two, one at each of the outwardly directed corners. The aperture is centrally placed and shaped like an Iron Cross, a feature caused by the disparity in size of the corner and intervening plates. This shape is not always consistent, though, and overgrowth often results in slight distortions.

DISCUSSION

T. latericioides is described here from the deep photic zone of the subtropical north

Atlantic, where it was found at depths of 140 and 180 m. To date it has been recorded from only a single Atlantic station, situated at 20°N over the Cape Verde Abyssal Plain. However, recently it has been recorded twice (by M.K.) from the Mediterranean Sea at a depth of 100 m and from the surface waters of the south-west Indian ocean (in January 1983; pers. comm. Amos Winter). Its absence from the surface sediments suggests that either this species is relatively rare, despite its wide distribution, or its coccoliths disintegrate or partially dissolve into unrecognizable fragments before they can be preserved. The absence of this species from previous reports probably reflects the paucity of samples recovered from the deep photic zone in the past and the difficulty of discerning the structure of these tiny coccoliths with the light microscope. The temperature range for this species from the first two sites is 13–20°C, suggesting a similar temperature tolerance to other deep photic-zone species (e.g. *Florisphaera profunda* Okada and Honjo and *Thorosphaera flabel-lata* Halldal and Markali).

T. latericioides has an unusual four-sided appendix, which is constructed of individual plates arranged in an orderly manner and fixed to a simple dish-like base. Together with the presence of a centrally placed proximal pore, these features are slightly reminiscent of the Rhabdosphaeraceae. In a recent review of this family, Norris (1984) removed all those species which did not possess the classical cyrtolith-type coccolith and stated that the family was defined by (1) cells bearing one or two types of cyrtolith; (2) the presence of a rhabdosphaerid-type rim (one or two cycles of radial elements around the periphery of the cyrtolith); and (3) if a central process was present, there was a centrally placed proximal pore (except in *Algirosphaera* Schlauder). Appendix shape was limited to styliform, salpingiform and sacculiform types. In defining the family in this way Norris (1984) omitted two genera, *Neosphaera* Lecal-Schlauder and *Umbello-sphaera* Paasche, which are normally considered to be members. Both these genera

lack the rhabdosphaerid-type rim (= podorhabdid rim of Norris, 1984) and a central process, and as such there may be good grounds for their removal from the family. *T. latericioides* also lacks this type of rim but does possess a proximal pore. The shape and construction of the appendix of this species is rather unusual and obviously Norris (1984) made no allowance for it in his family definition. If one considers the construction of the cyrtolith appendices it can be seen that the styliform types are produced from the upward growth of elements present in the disorganized central portion of the coccolith, whereas in the salpingiform and sacculiform types the appendix is built up from a mosaic of short strips of which only the bottom row originates from the central portion. These latter types resemble to some extent the apparent formation of the appendix of *Turrilithus*, in which the bottom row of brick-like quadrangular plates appear to rise from a central position.

However, the basal structure of *Turrilithus* is not composed of radial elements and there is no rhabdosphaerid-type rim, hence its inclusion in the Rhabdosphaeraceae seems very doubtful. In the fossil record there is a number of taxa whose overall basal appearance resembles that of *T. latericioides*. In particular, one genus, *Zeughrabdotos* Reinhardt (Zygodiscaceae; Eiffellithales), possesses elliptical coccoliths with a well defined bar traversing the short axis, perforated by a centrally placed pore and in some species with a short circular stem. The two D-shaped openings either side of the bar are spanned by a delicate perforate sheet (Rood, Hay & Barnard, 1971), although no mention was made of whether the sheet was proximal or distal; we suspect that it is proximal. The main difference between species of *Zeughrabdotos* and *Turrilithus* lies in the composition and thickness of the wall, with the former having a wall built up of a distinct double cycle of elements (= podorhabdid rim), whilst the latter has a very thin wall comprising a single layer of individual elements. The arrangement of the wall elements in *T. latericioides* is similar to

those found in living genera, notably the caneloliths of *Syracosphaera* and the cricoliths of *Cricosphaera*. However, since cricoliths lack a proximal pore and caneloliths bear radial lamellae, the inclusion of *T. latericioides* into either genus would be inappropriate at present.

In considering the present living and fossil taxonomic systems it appears that *T. latericioides* bears some resemblances to a variety of genera, although some differences also occur. It is therefore suggested that for the present this new species should remain unaffiliated until further observations make the situation clearer.

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