



## ***Cocconeis pinnata* W. Gregory ex Greville (Bacillariophyta): Lectotypification and an emended description after examination of type material and South Pacific specimens**

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### **Abstract**

A marine species of *Cocconeis* (Bacillariophyta) from coral reef lagoon of Tahiti Island (Society Archipelago, South Pacific) was identified as *Cocconeis pinnata* W. Gregory ex Greville. Neither drawings nor micrographs of the raphe valve (RV) of *C. pinnata* are available in the literature. The examination of Gregory's type material (several slides annotated 'Arran 57' from Greville's collection housed in BM, British Museum, London, U.K.) allowed us to complete and emend the *C. pinnata* description. Lectotypification of *C. pinnata* is proposed. Since the raw material used by Gregory was not found, no scanning electron microscope (SEM) observation of type material can be provided. Except for Hustedt (1933) and a few later reports, all descriptions and illustrations agree with the original description. LM and SEM observations demonstrate that the sternum valve (SV) stria arrangement of specimens from Tahiti match those of the type. The description of the RV by Grunow in Van Heurck (1880) refers to a stria pattern very similar to that of *C. pseudomarginata* W. Gregory. The RV of *C. pinnata*, as revealed in LM and SEM, has a dense striation and no internal marginal rim. Both valves of *C. pinnata* have areolae with remarkable arborescent volae, which is a new feature for *Cocconeis*. *Cocconeis pinnata* is cosmopolitan, from cold-temperate to tropical areas. Several taxa have been formerly assigned to *C. pinnata*, though they are probably varieties of *C. costata*.

**Key words:** *Cocconeidaceae*, coral reefs, Tahiti Island

### **Introduction**

In his researches into the taxonomy of diatoms, William Gregory (1803–1858) contributed extensively to the knowledge of the genus *Cocconeis* Ehrenberg (1837: 173) describing 15 new taxa (Gregory 1855, 1857a, b). Two species of *Cocconeis* Gregory named but never described, *Cocconeis pinnata* W. Gregory ex Greville (1859: 79) and '*Cocconeis crassa*' nom. nud., were both dealt with in a paper written by Greville shortly after Gregory's death; Greville described only the former, as he was unable to find any specimens of '*Cocconeis crassa*' (Greville 1859: 79).

Discovery of specimens of a marine benthic diatom from the South Pacific, identified as *C. pinnata*, motivated our focus on this poorly known taxon. *Cocconeis pinnata* has relatively large valves (Greville 1859: 79), its sternum valve (SV) having a typical and easily recognizable morphology, while its raphe valve (RV) has yet to be illustrated, either in the type description or any subsequent studies, and has been described only briefly (see Taxonomic History).

In a previous contribution about *Cocconeis costata* W. Gregory and *C. pinnata*, Romero & Rivera (1996) noted of *C. pinnata* that 'revision of the type material still is needed' (Romero & Rivera 1996: 336). At that

time they were unable to study Greville's specimens but instead examined several slides from Frenguelli's diatom collection (LPC, for details of this collection see Sar *et al.* 2009). Unfortunately, the identification of Frenguelli's specimens as *C. pinnata*, following Frenguelli & Orlando (1958: 82, pl. 1, figs 12, 14, 15), is now considered erroneous but led to some misunderstandings (Romero & Rivera 1996). As such, examination of Gregory's types has become even more important.

This study provides an emended description of *Cocconeis pinnata* based on light microscope (LM) examination of Gregory's type material and scanning electron microscope (SEM) and LM examination of a marine sample recently collected from Tahiti Island (South Pacific, Society Archipelago). Lectotypification of *C. pinnata* is proposed.

## Material & methods

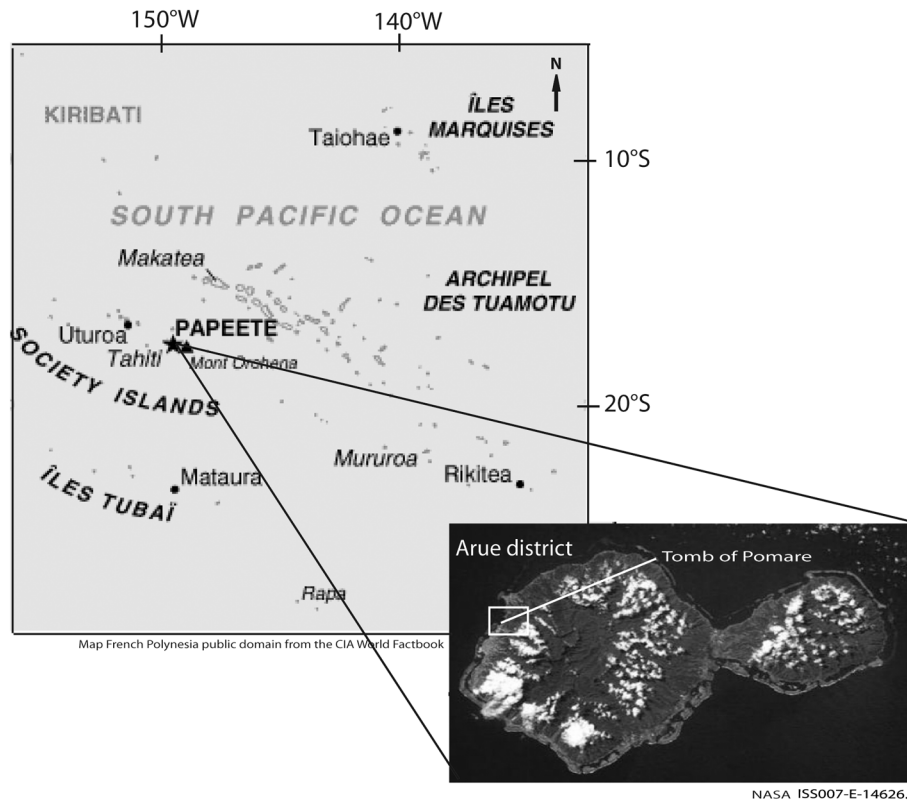
Material used in this study is derived from two sources: Gregory's type material and a marine sample from Tahiti Island, South Pacific, Society Archipelago.

*Gregory's type material:* Gregory's slides are housed in BM (the Natural History Museum, London). There is no collated index and the Gregory's notebooks are the only definitive index to the species present on each of the slides; the collection is difficult to work with. Examination of the six Gregory notebooks yielded no relevant information concerning either *Cocconeis pinnata* or the ever elusive '*Cocconeis crassa*' *nom. nud.* As a consequence, no slide of Gregory's could be identified as having specimens of either. Nevertheless, *Cocconeis pinnata* was actually described by Greville and it is his collection in BM that is a more appropriate source of type specimens. From the numerous Greville's collection slides marked from 'Arran 57' (collector John Hutton Balfour, Greville 1859: 79) only 7 can be considered syntypes for *C. pinnata*: BM 1465, BM 1467, BM 1468, BM 4985, BM 4986, BM 4997 and BM 4998. These are discussed in more detail below but briefly all 7 are labelled by Greville with species names and numbered diamond circles marked their whereabouts. Among the species names on these 7 slides is *C. pinnata*. For coordinate assignment/location of specimens, a benchmark now indicates the 'x, y' origin on each slide examined following the protocol outlined in Sterrenburg *et al.* (2012). Since the raw material used by Gregory was not found, no scanning electron microscope (SEM) observation of the type material is provided.

*Tahiti Island (South Pacific, Society Archipelago):* Several marine to brackish sites of the Arué District (Tahiti, Windward Society Islands, 1042 km<sup>2</sup>, Fig. 1) were sampled during October 23<sup>rd</sup>–24<sup>th</sup>, 2010. In particular, intertidal coral sediments from the coral reef lagoon and a scrape of a large specimen of *Holothuria atra* Jaeger were collected (black sea cucumber, sample 'Papeete 4', 17° 31.431'S; 149° 31.233'W; marine environment of Pointe Honu, near 'Pomare Tomb', collection C. R.-G., USR 3278, CRIOBE, Perpignan, France). Specimens illustrated on Figs (13–18, 21–43). The Tahiti samples were preserved in formalin (10% final dilution).

*Tahiti Island material preparation:* Samples were repeatedly rinsed with distilled water, treated with concentrated H<sub>2</sub>O<sub>2</sub> to remove organic matter, then rinsed again in distilled water, alcohol-desiccated and mounted in Naphrax<sup>®</sup> to make permanent slides. The slides were observed using a Zeiss Axiophot 200 microscope with differential interference contrast (DIC) and photographed with a Canon PowerShot G6 digital camera (CRIOBE-Perpignan University, France).

If the SV features are easily observed, the characteristics of the RV are more difficult to discern in specimens preserved on permanent slides in refractive mounting media (Figs 8–12, 13). Hence, SEM is essential to describe their morphology. For SEM examination, preserved field samples were collected on 1 µm Nuclepore filters and rinsed twice with deionised water (milliQ) to remove salt. The filters were air-dried and mounted onto aluminum stubs before coating with gold palladium alloy (EMSCOP SC 500 apparatus) and examined with a SEM Hitachi S-4500 operated at 5 to 10 kV (Perpignan University Via Domitia, France).



**FIGURE 1:** Location of the Society Archipelago in the South Pacific and map of Tahiti Island showing the sampling site (north of 'Tombeau du Roi', 17° 31.405' S; 149° 31.106' W).

*Terminology and abbreviations:* For the description of the frustule and its parts, terminology follows Anonymous (1975), Ross *et al.* (1979) and Round *et al.* (1990).

Various terminologies have been proposed for the Achnanthes Silva order. Round (1990) uses P-valve for the valve without a raphe and R-valve for the valve with a raphe, while Mizuno (1987) uses araphid valve (AV) and raphid valve (RV), and De Stefano *et al.* (2008) use sternum valve (SV) and raphe-sternum valve (RSV). As previously proposed by Riaux-Gobin *et al.* (2013, in press), and following the Greek origin of the word 'sternum', it is proposed to designate the valve with a raphe as the raphe valve (RV) and the valve without a raphe as the sternum valve (SV).

Herbaria are abbreviated according to *Index Herbariorum* (<http://sciweb.nybg.org/science2/IndexHerbariorum.asp>) and authors according to the *International Plant Names Index* (<http://www.ipni.org/>).

## Taxonomic History

As reported by Greville (1859: 79), *Cocconeis pinnata* was first observed on samples dredged by Professor John Hutton Balfour in 1857 from 'Lamlash Bay' in Arran (Island of Arran), in the Firth of Clyde, Scotland, and provisionally named as *C. pinnata* by Gregory, who died before he could publish his account. Greville was able to examine Gregory's material and provide in his account of this 'beautiful little species' a brief description and one drawing: 'valve oval, well distinguished by the short, strong, moniliform and distant striae, and by the narrow-elliptical blank space which longitudinally occupies the middle of the valve...length 14  $\mu$ m, and 11 striae in 10  $\mu$ m' (Greville 1859: 79, fig. 1, reproduced here as Fig. 4). The Latin epithet *pinnata* (from *pinna* and *pinnatus*) refers to the structure of a feather, to leaflets arranged on each side of a common petiole, or to crenels of a fortification. The adjective 'moniliform' used by Greville (from Latin 'monilia': string of beads, necklace, antenna of some insects) refers to the remarkably sturdy structure of the sternum valve (SV) striae.

Since its original description, a number of observations, interpretations and drawings have been published (Table 1). Grunow in Van Heurck (1880: pl. 30, figs 6, 7; reproduced here as Figs 3a, b) included an illustration of what they called *C. pinnata* with its SV striae clearly biseriate near the valve margin. Grunow illustrates a complete frustule (in Van Heurck 1880: pl. 30, fig. 7, reproduced here as Fig. 3b, 'frustule entire' from figure caption) with the raphe visible via the SV. No detail of the RV stria is given, except in the caption: 'la valve inférieure est analogue à celle de *C. pseudomarginata* W. Gregory mais plus petite et à stries formées par des ponctuations plus rapprochées' [the inferior valve (RV) is similar to that of *C. pseudomarginata* but smaller and with striae composed of denser areolae] (Van Heurck 1880: pl. 30, fig. 7).

Cleve (1895: 181) created a number of new subgenera placing *Cocconeis pinnata* in *Disconeis* (Cleve 1895: 180) describing the species thus: 'Elliptical. L [= length] 0.024 to 0.04 [=24–40 µm length]; B [= breadth, width] 0.019 to 0.03 [= 9–30 µm width]. Upper V [=SV] with broad, axial area and strong, slightly radiate costae, 4 to 5 in 0.01 mm [=10µm]. Intercostal spaces with double rows of puncta, arranged in oblique lines. Lower V [RV] as in *Cocconeis pseudomarginata*, but smaller and with closer striation (according to Grunow)'; Cleve appended a wide and varied distribution ('Spitsbergen! Finmark! [= part of Norway] North Sea! Mediterranean Sea! Adriatic! Seychelles! Island of Rhea near Singapore!', Cleve 1895: 181). Cleve also provided 3 possible synonyms, each appended with a question mark suggesting these were simply suggestions: '*C. lorenziana* Perag...*C. denticulate* Leuduger-Fortmorel ... *Rhaphoneis archeri* O'Meara... ' (Cleve 1895: 181). These are known today as: *Cocconeis lorenziana* (Grunow) H. Peragallo (1888: 37, pl. 5, fig. 38, basionym: *Rhaphoneis lorenziana* Grunow 1862 : 381, pl. 4/7, fig. 5) = *Achnanthes baldjickii* subsp. *lorenziana* (Grunow) R. Ross (1963: 82, figs 30-31); *Cocconeis denticula* Leuduger-Fortmorel (1879: 11, pl. 1, fig. 2), probably an independent species; and *Rhaphoneis archeri* O'Meara (1867: 247, pl. 7, fig. 12, the locality is 'Arran [= Aran] Island, Co. Galway', which is not to be confused with the Island of Arran, Scotland, Gregory's site), which is probably *Cocconeis costata* W. Gregory (1855: 39). All 3 of these species above are worth further investigation.

H. & M. Peragallo present four SVs but no RVs (1897: pl. 2, figs 11–14, reproduced here as our Fig. 5a–d). Their figure 15 (reproduced here as Fig. 5d) is named as *Cocconeis pinnata* forma *major* (Peragallo & Peragallo 1897: pl. 2, fig. 15).

Schmidt illustrates 5 SVs (Schmidt 1894: pl. 189, figs 1–5; reproduced here as our Fig. 6a–f) and a complete frustule (Schmidt 1894: pl. 189, fig. 1, reproduced here as our Fig. 6a) though only the coarse striae of the SV can be seen through the RV and no detail of the RV striation is offered. Schmidt offers the following distribution list: 'Sölsvig, Grip (Brun), Bergen (Brun), Cap (as quoted in Cleve)'.

Jørgensen described the RV of *C. pinnata* [as *Pleuroneis pinnata* (Gregory) E. Jørgensen (homotypic synonym), without drawings, nor micrographs] as 'RV, raphe fine, straight, stretching to the ends of the valve, in the middle with clavate ends, somewhat separated from each other. Axial area not visible, central one very small, roundish. Striae very faint, not distinctly seen on my specimens. A marginal rim with rudimentary loculi (4 in 10 µm). A distinct hyaline border. This species seems on the whole to be closely related to *Cocconeis* (*Pleuroneis*) *costata* though undoubtedly a separate species' (Jørgensen 1905: 208).

The illustrations and interpretation of Hustedt (1933: 331, fig. 783) largely differ from the previous ones in having the SV and RV with similar stria pattern and a largely lanceolate axial area.

Frenguelli & Orlando (1958) illustrate three SVs and no RV (pl. 1, figs 12, 14, 15), of which two specimens have a narrow axial area (figs 14, 15) and one has a dense striation (fig. 15) and Foged (1975) provides an illustration of an SV *C. pinnata* (pl. 11, fig. 16) which corresponds to the original description, although with a lower stria density.

Several recent descriptions of *Cocconeis pinnata*, and some of its varieties (i.e., Riaux-Gobin 1991, Romero & Rivera 1996, Riaux-Gobin & Romero 2003, Al-Handal *et al.* 2010, Leterme *et al.* 2012) are addressed in the Discussion.

**TABLE 1:** *Cocconeis pinnata* taxonomic history, from 1859 to 1975.

Reference	Year	Name	Comment	Original figure quotation	reproduced here as	SV striae in 10 µm	RV
Greville	1859	<i>Cocconeis pinnata</i> W. Gregory ex Greville	original description	fig. 1	Fig. 4	moniliform, large sternum 4.3 str.	no description, no illustration
Grunow in Van Heurck	1880	<i>Cocconeis pinnata</i> W. Gregory ex Greville	conform to original description	pl. 30, figs 6, 7	Fig. 3	raphe seen through the SV no data	no illustration similar to <i>Cocconeis pseudomarginata</i>
Cleve	1895	<i>Cocconeis pinnata</i> W. Gregory ex Greville	homotypic synonym, conform to original description	no illustration	-	broad axial area, 4 to 5 str.	no illustration RV as in <i>C.</i> <i>pseudomarginata</i>
Peragallo and Peragallo	1897	<i>Cocconeis pinnata</i> W. Gregory	conform to original description	figs 11–14	Fig. 5	large elliptic axial area 4 to 5 str.	no illustration follows Grunow, similar to <i>Cocconeis</i> <i>pseudomarginata</i>
Schmidt	1894	<i>Cocconeis pinnata</i> W. Gregory	conform to original description	pl. 189, figs 1–5	Fig. 6	raphe seen through the SV, in fig. 1 no data	no illustration, <i>pseudomarginata</i>
Jørgensen	1905	<i>Pleuroneis pinnata</i> (W. Gregory) E. Jørgensen	homotypic synonym, conform to original description	no illustration	-	marginal rim with udimentary loculi 4 str.	no illustration, striae very faint
Hustedt	1933	<i>Cocconeis pinnata</i> W. Gregory	erroneous description	fig. 7, 8, 3	-	largely lanceolate axial area 4–5 str.	RV with similar stria pattern as the SV 4–5 str.
Freguelli and Orlando	1958	<i>Cocconeis pinnata</i> W. Gregory	erroneous determination	pl. 1, figs 12, 14, 15	-	axial area straight and narrow no stria number	no stria number
Foged	1975	<i>Cocconeis pinnata</i> W. Gregory	Conform to original description	pl. 11, fig. 16	-	largely lanceolate axial area 4 str.	no illustration no stria number

## Taxonomic Treatment

### *Cocconeis pinnata* W. Gregory ex Greville 1859

*Cocconeis pinnata* W. Gregory ex Greville (1859: 79; pl. 6, fig. 1) emend Riaux-Gobin, Compère & Romero (Figs 7-43)

non *Cocconeis pinnata* (Hustedt) Cleve-Euler (1934: 43, illegitimate homonym [basonym: *Achnanthes pinnata* Hustedt 1922: 123, pl. 9, figs 15–18] = *Planothidium conspicuum* (Mayer) Aboal in Aboal *et al.* (2003: 163) [basonym: *Achnanthes conspicua* Mayer 1919: 198, pl. 6, figs 9, 10].

Synonyms: *Disconeis pinnata* (W. Gregory ex Greville) Cleve 1895: 181

*Pleuroneis pinnata* (W. Gregory ex Greville) E. G. Jørgensen 1905: 208

Valves elliptical to ovoid, slightly tapering toward apices (Figs 13, 21). *Dimensions of type specimens*: Valve dimensions 26.9–36.9  $\mu\text{m}$  length, 16.5–27.2  $\mu\text{m}$  width. SV:  $5.0 \pm 0.3$  striae in 10  $\mu\text{m}$ . RV:  $21.9 \pm 1.1$  striae in 10  $\mu\text{m}$ , observed specimens  $n = 21$  (Table 1). *Dimensions of specimens from Tahiti*: 22.2–36.5  $\mu\text{m}$  length, 14.1–22.4  $\mu\text{m}$  width. SV:  $6.3 \pm 0.6$  striae in 10  $\mu\text{m}$ . RV:  $26.5 \pm 1.7$  striae in 10  $\mu\text{m}$  (SEM specimens  $n = 14$ ; LM specimens  $n = 13$ , Table 1).

*Sternum valve* with relatively wide elliptical axial area (Fig. 19), marginal area lacking areolae and externally depressed along inter costae (Figs 19, 21, 24). Striae robust, raised, and radiate, biseriate near margin,  $6.3 \pm 0.6$  striae in 10  $\mu\text{m}$ . Areolae in centre part of valve slightly trans-axially elongated (Figs 19, 24, 27), while elsewhere  $\pm$  rounded (Fig. 26). Areolae externally ornamented by complex arborescent volae (Figs 26–29), internally occluded by hymen with radial slits (Fig. 31). Small ‘pearls’ or spherical corpuscles spread over entire valve (Figs 19, 20, 21), sometimes randomly, but often aggregated i.e., along sternum. SV valvocopula visible in LM (Figs 14, 18), wide, flat and thick, open at one apex (Fig. 30, arrows; Fig. 32), bordered by large and  $\pm$  regular fimbriae, overlapping each intercosta (Fig. 30; Figs 34–35, arrows). In internal view, wide fimbriate of SV valvocopula cover marginal ends of striae, creating loculi with rounded ends (Fig. 32, arrow; Figs 34, 35).

*Raphe valve* flat to slightly concave. Raphe straight, filiform, with simple distal raphe endings very close to margin (Fig. 37). Central raphe endings close to each other and coaxial (Fig. 38). Axial area narrow and straight. Central area very small and oblong (Fig. 38). Striae dense and radiate ( $26.5 \pm 1.7$  in 10  $\mu\text{m}$ ), composed of small, round areolae with one marginal row of ‘flame’-like areolae (Figs 42–43). Shorter intercalary striae present (Fig. 42, arrows). Areolae slightly transversely elongated at valve centre (Fig. 37), internally closed by hymenate occlusions (Fig. 43), externally ornamented by 2 (4 near margin) short-branched volae (Figs 37, 39). Helictoglossae non-protruding, straight (Fig. 43). RV valvocopula opened at one apex (Fig. 36, arrow). In addition to valvocopulae, cingulum consisting of at least one flat copula (Fig. 40, arrow).

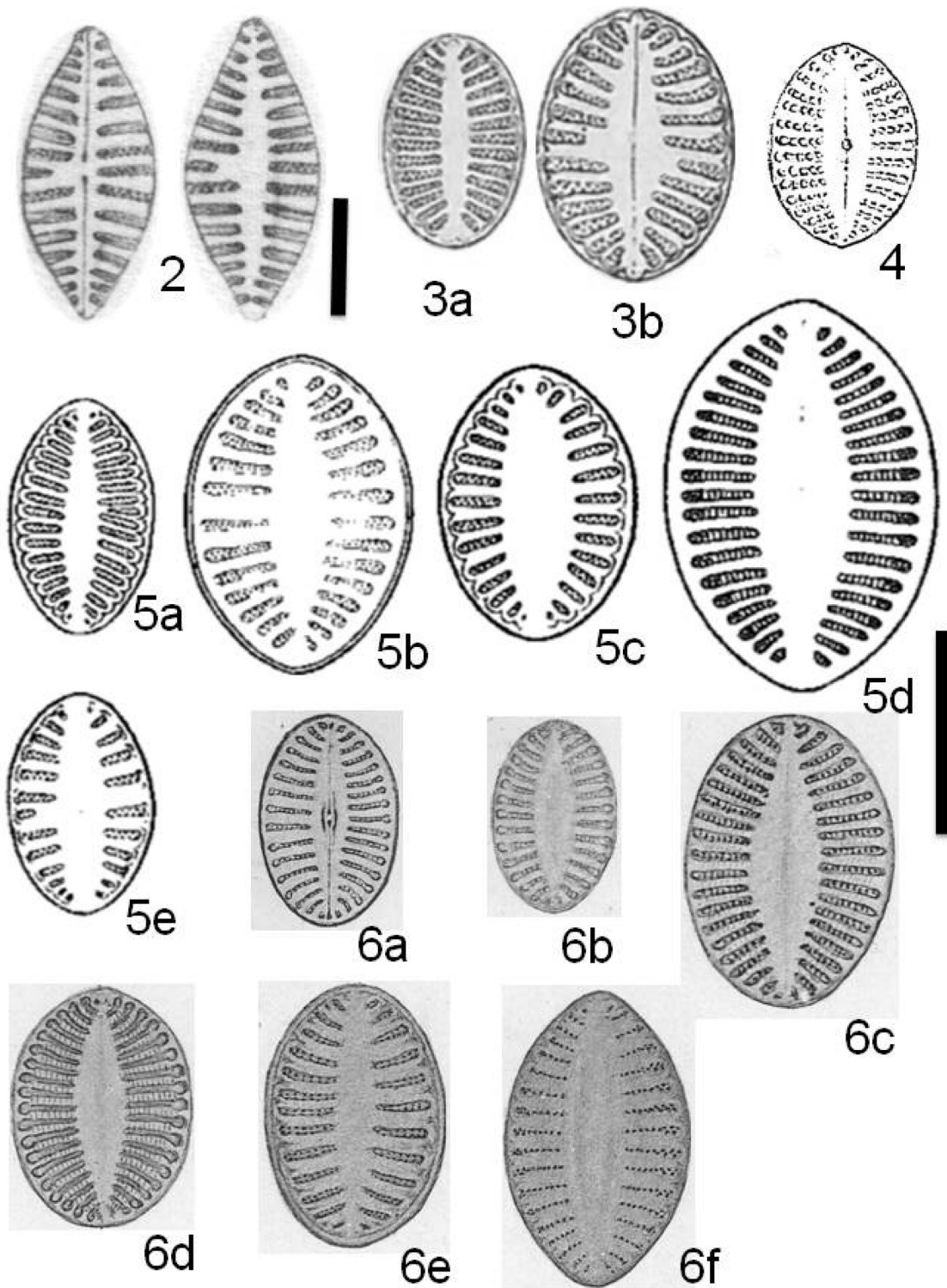
**Type:**–SCOTLAND, UK. Arran (Arran Island), Firth of Clyde, ‘Lamlash Bay, in the island of Arran. Dredged by Professor Balfour 1857’, Greville (1859: 79) (lectotypus **hic designatus**, BM 4986, specimen located at sector 5, position 4 S, 14.5 E, see Figs 9, 10; BM 1465, BM 1467, BM 1468, BM 4985, BM 4997, BM 4998, syntypes).

Greville (1859) provided a description of only the SV, illustrated with a single line drawing (pl. 6, fig. 1 reproduced here as Fig. 4). He did not refer to any particular specimen and although a great many of Greville’s original pencil drawings are extant in BM (these drawings are usually annotated with slides numbers, specimens locations, etc.), this particular drawing is not among them.

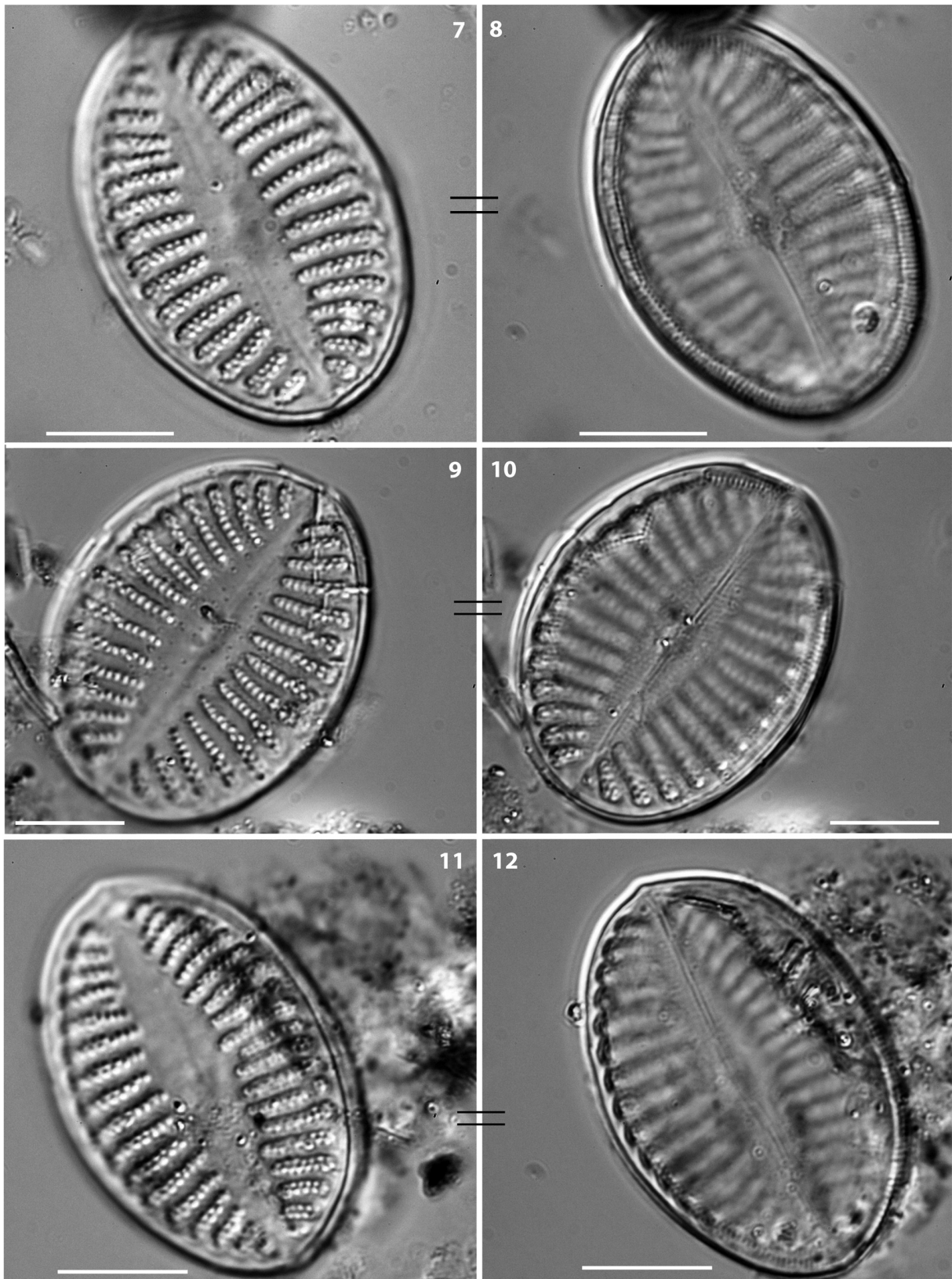
Of the numerous slides in BM labelled ‘Arran 57’, 7 may be considered syntypes since they have one or more specimens of *Cocconeis pinnata* labelled and circled on the coverslip by Greville. These are as follows: BM 1465, one specimen (labelled as circle number 2); BM 1467, four specimens (labelled as circle numbers 2, 4, 7, 8); BM 1468, three specimens (labelled as circle numbers 1, 2, 5); BM 4985, two specimens (labelled as circle numbers 2, 3); BM 4986, one specimen (labelled as circle number 5); BM 4997, four specimens (labelled as circle numbers 2, 5, 7, 8); and BM 4998, two specimens (labelled as circle numbers 2, 7), yielding a total of 17 specimens. All the slides are in relatively good condition, to a certain degree darkened, with some having several specimens of *C. pinnata* not circled or named by Greville (see Figs 7, 8, from slide BM 4986, close to sector 6). Among these specimens, several complete frustules and detached SV were found, no detached RV was encountered. Micrographs (Figs 7–12) of complete frustules shown at two different foci have been taken from slides BM 4986 and BM 1467.

**Observations:**–*Type specimens*: The SV axial area is largely elliptical and its striae strongly moniliform, uniseriate near the sternum, bi- to tri-seriate near the margin. As observed in the LM, the SV structure of type material specimens conforms to the original description except for its larger dimensions, which are 2.5 times

larger than reported by Greville (1859). . With a modern LM it is relatively easy to resolve the fine striation on the RV ( $22.2 \pm 2.3$  striae in  $10 \mu\text{m}$ , Table 1, Figs 8, 10, 12). The RV striae are radiate and regularly spaced throughout. The raphe is straight and the central raphe endings are clearly close to each other (Fig. 8).



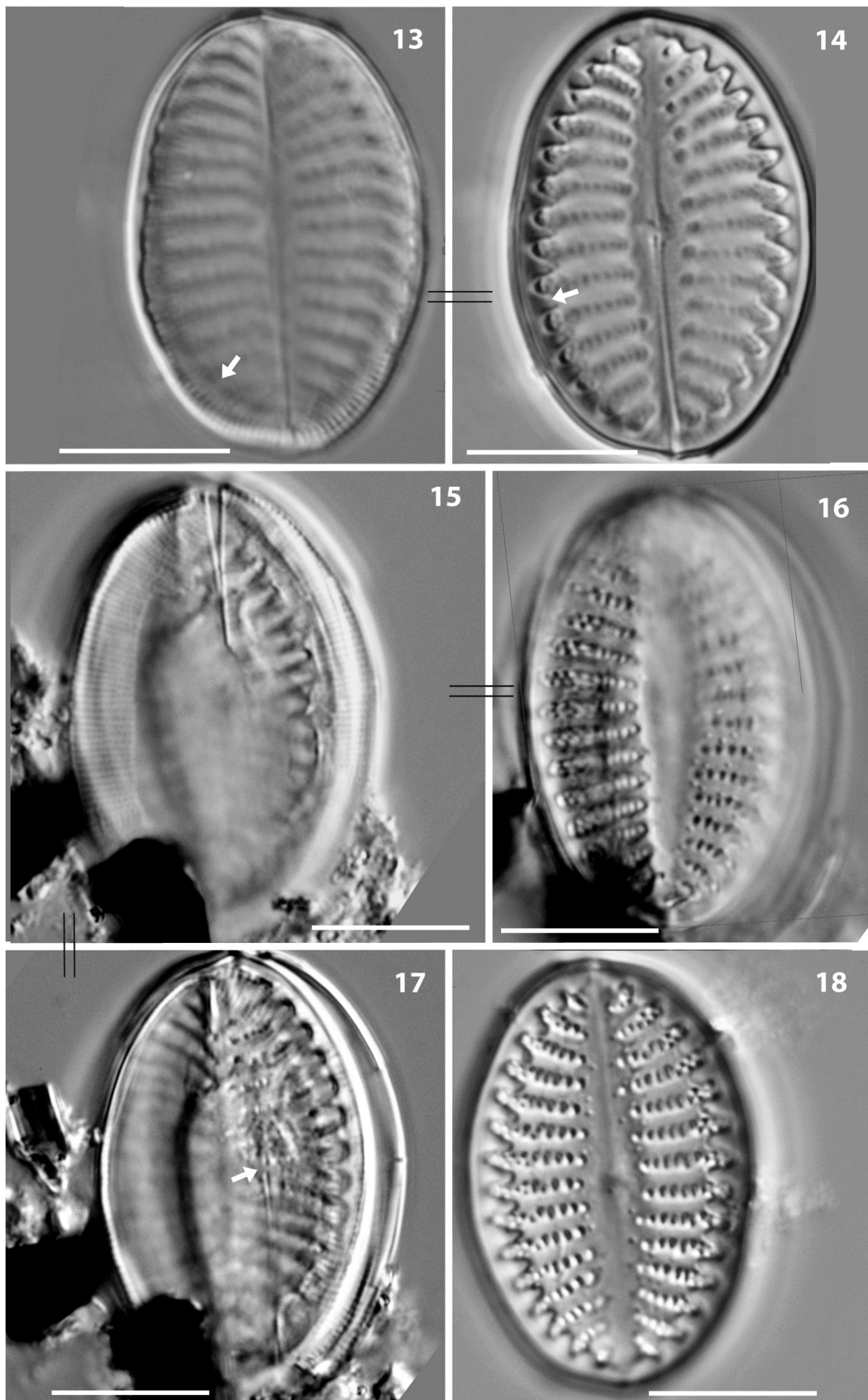
**FIGURE 2–6:** Fig. 3: *Cocconeis pinnata* var. *artica* Østrup (1910, pl. 13, fig. 13); Fig. 3a,b: *C. pinnata* illustrated by Grunow in Van Heurck (1880–1885, figs 6, 7); Fig. 4: *C. pinnata* Gregory ex Greville (Greville 1859, fig. 1); Fig. 5a,b,c,d,e: *C. pinnata* illustrated by Peragallo & Peragallo (1897–1908, pl. II, figs 11–14); Fig. 6a,b,c,d,e,f: *C. pinnata* illustrated by Schmidt (1877–1958, pl. 189, figs 1–5). LM, scale bars:  $10 \mu\text{m}$ .



**FIGURE 7–12.** *Cocconeis pinnata* from type slides (LM). On the cover slip of each slide, numbered diamond circled sectors localise specimens labelled on the slide margin. A rough benchmark gives now origin on each slide. Fig. 7, SV; Fig. 8, RV: from slide BM 4986, a specimen not circled by Greville, close to sector 6, coordinates 9 S, 19.5 E. Fig. 9, SV; Fig. 10, RV: Lectotype from slide BM 4986, circled specimen, sector 5, coordinates 4 S, 14.5 E. Fig. 11, SV; Fig. 12, RV: from slide BM 1467, circled specimen, sector 3, coordinates 2 S, 12.5 E.

LM, scale bars: Figs 7–12: 10  $\mu$ m.





**FIGURE 13–18.** *Cocconeis pinnata* from Tahiti Island (LM). Fig. 13, RV striae (arrow). Fig. 14, RV showing the central raphe endings, and SV valvocopula (arrow). Fig. 15, RV, Fig. 16, SV, Fig. 17, RV with central raphe endings (arrow). Fig. 18, SV showing the digitate SV valvocopula.

LM, scale bars: Figs 13–18: 10  $\mu$ m.

*Tahiti Specimens*: The specimens found on Tahiti Island are very similar to the type specimens, although there are some differences such as the slightly smaller valve dimensions and a SV axial area slightly smaller than in the type (Table 1) that may be due to morphological plasticity.

The specimen of *Cocconeis pinnata* illustrated by Witkowski *et al.* (2000, pl. 37, fig. 14; no RV illustrated) also has a narrower axial area than in the type. Contrary to the assumption of Grunow and several later authors, it can be noted that the RV of *C. pinnata*, even if densely striated, is very different to that of *C. pseudomarginata* (illustrated as *Cocconeis major* W. Gregory 1857b: fig. 28; Hustedt 1933: fig. 813b; De Stefano & Romero 2005: pls 30, 31). Furthermore, there is no evident affiliation of *C. pinnata* with *C. costata* W. Gregory (Gregory 1855, 1857a), as stated by Jørgensen (1905: 208), since the RV of *C. pinnata* does not have a marginal rim, externally or internally. The central raphe endings are very close to each other (Figs 8, 38) and not 'somewhat separated' or 'clavate', as stated by Jørgensen (1905: 208), who does, however, note the presence of loculi, also observed in our specimens (Figs 32, 34, 35).

## Discussion

Type material of *Cocconeis pinnata* conforms to its original description with the exception of the valve dimensions that have now been corrected (Table 2). Observation of the RV confirms the dense striation reported, but not illustrated, by Grunow (in Van Heurck (1880: pl. 30, fig. 7) and Cleve (1895: 181) and the SEM observations show important differences to the RV structure of *C. pseudomarginata*. Furthermore, SEM internal views of the RV of *C. pinnata* show the absence of a marginal elevated internal rim, which definitively separates *C. pinnata* from *C. costata*. The external ornamentation of the areolae on both valves, particularly the arborescent volae on the SV, are unique to *Cocconeis*.

*Classification of Cocconeis pinnata, varieties and doubtful allied taxa*:—At present there are five varieties and one form named under *Cocconeis pinnata*. In chronological sequence, in 1897, H. & M. Peragallo illustrated, but did not describe, *Cocconeis pinnata* f. *major* in the Atlas of their *Diatomées marines de France et des districts maritimes voisins* (Peragallo & Peragallo 1897: pl. 2, fig. 15). In all, they presented 4 illustrations of SVs but no RVs of *Cocconeis pinnata* (Peragallo & Peragallo 1897: pl. 2, figs 11–14, reproduced here as our Fig. 5a–d) and just the one of *Cocconeis pinnata* f. *major* (Peragallo & Peragallo 1897: pl. 2, fig. 15, reproduced here as our Fig. 5e). In the text accompanying the Atlas, they refer to all the illustrations under the name *Cocconeis pinnata* not mentioning the forma name for figure 15 (Peragallo & Peragallo 1897: 11). They do, however, provide a reference to some specimens, 'T. et P. n<sup>os</sup> 86, 194' (Peragallo & Peragallo 1897: 11), meaning slides numbered 86 and 194 of the second edition of Tempère and Peragallo's *Diatomées du monde entier* (Tempère & Peragallo 1915). Slide number 86 is from 'Expédition du Challenger. Sondage no. 151 Sud de Kerquelen, Océan Antarctique' and has *Cocconeis pinnata* listed (Tempère & Peragallo 1915: 45); slide number 194 is from 'Rendondo beach (Californie), dépôt fossile marin' and has *Cocconeis pinnata* Greg. var. listed (Tempère & Peragallo 1915: 96). Neither of these slides is of type material: *Cocconeis pinnata* f. *major* is from Villefranche (Peragallo & Peragallo 1897: pl. 2, fig. 15, legend; all other specimens, figs 11–14, are from 'Barcelone', figure legend). *C. pinnata* f. *major* is not mentioned in any of the modern nomenclatural sources nor any of the older printed versions.

Inspection of the illustration for *Cocconeis pinnata* var. *arctica* Østrup (1910 [1917]: 213, pl. 13, fig. 13) suggests it is a species of *Achnanthes* sensu stricto, of which it has relevant characters, for example, the distal raphe endings strongly curve in opposite directions (Fig. 3).

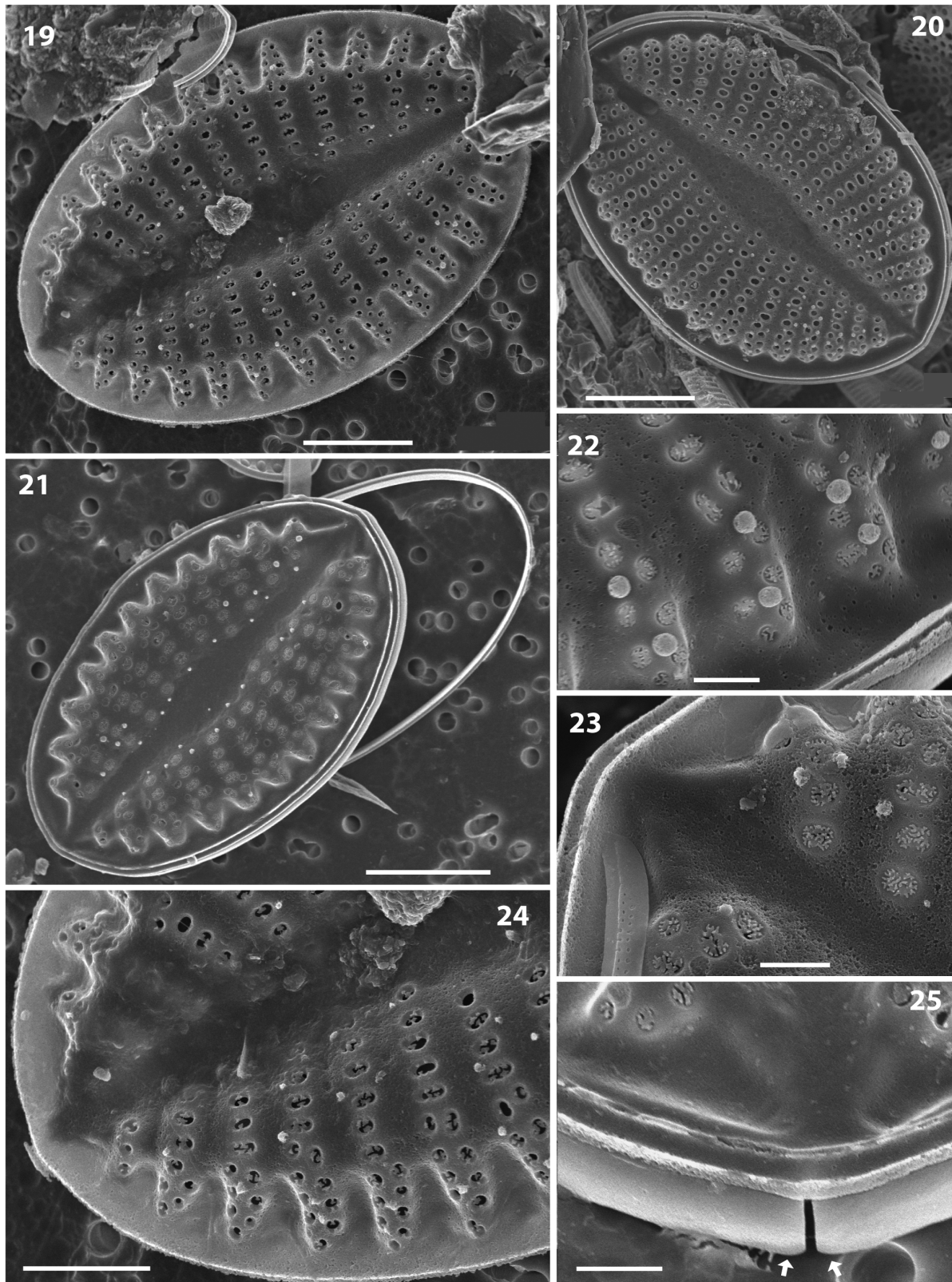
*Cocconeis pinnata* var. *plena* M. Peragallo (1921, p. 53, pl. II, fig 4) is usually considered to be *C. imperatrix* f. *plena* (M. Peragallo) Frenguelli (1943: 230) (see, e.g. VanLandingham 1968: 809).

*Cocconeis pinnata* var. *orbicularis* Frenguelli & Orlando (1958: 28) is unusual, in that it is named as a variety in an earlier part of Frenguelli & Orlando (1958: 28) but later named as a species *Cocconeis orbicularis* Frenguelli & Orlando (1958: 83 and in the index Frenguelli & Orlando 1958: 149 and plate legend

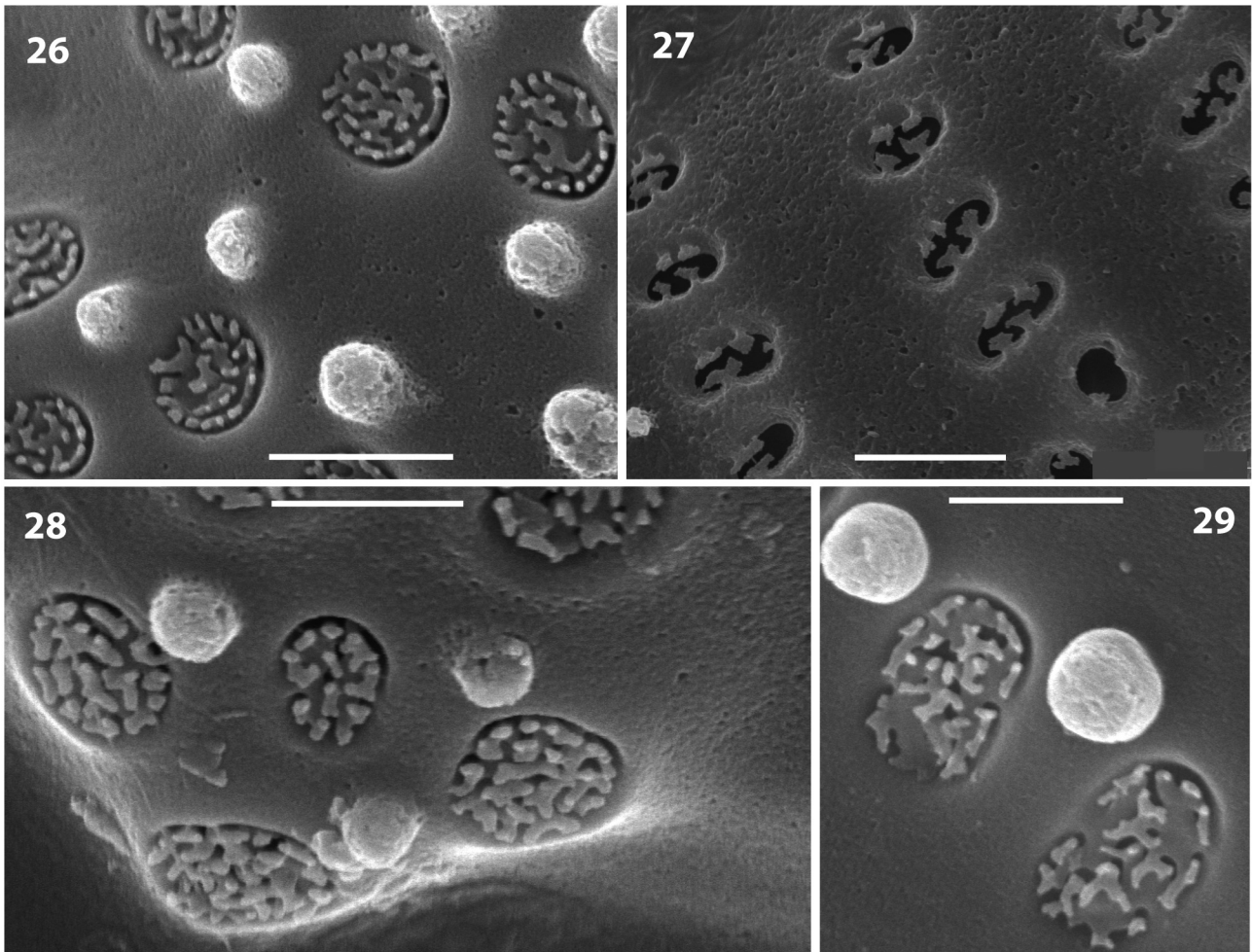
Frenguelli & Orlando 1958: 158). *Cocconeis pinnata* var. *orbicularis* Frenguelli & Orlando *nom. nud.* is, however, invalid as it has no Latin diagnosis and no type is specified in the original publication; Sar et al. (2009) state that the new names in Frenguelli & Orlando (1958) are invalidly published.

**TABLE 2:** Main features of *Cocconeis pinnata* Gregory ex Greville, after observation of Gregory's type material (Greville's slides in BM collection) annotated 'Arran 57' (BM 1465, BM 1467, BM 1468, BM 4985, BM 4986, BM 4997 and BM 4998) and of a taxon from the South Pacific.

	valve shape	length (µm)	width (µm)	SV striae in 10 µm	SV areola occlusion density	RV striae in 10 µm	RV areola occlusion density	central raphe endings	SVVC	RVVC	cingulum
<i>Cocconeis pinnata</i> Gregory ex Greville Type 'Arran 57' LM, n = 21	oval	26.9–36.9 (33.7 ± 2.4)	16.5–27.2 (22.2 ± 2.3)	5.0 ± 0.3		21.9 ± 1.1					
<i>Cocconeis pinnata</i> Gregory ex Greville Present study (South Pacific) LM, n = 13 SEM, n = 14	elliptic to ovoid, apices slightly acuminate	22.2–33.5 (27.2 ± 4.1)	14.1–22.4 (17.7 ± 3.2)	6.3 ± 0.6	internal hymen with radial slits, external complex arborescent volae	26.5 ± 1.7	internal hymen with radial slits, external branched volae	close to each other, opposed	fimbriate, open, presence of loculi		one supplementary band
					areolae axially oblong in middle valve		areolae radially oblong 20–35	close to margin, not enlarged, direct	open, not observed in detail		



**FIGURE 19–25:** *Cocconeis pinnata* from Tahiti Island (SEM). External views of the SV. Fig. 19, 20, 21: complete valve. Fig. 22: detail of the margin, with pearls-globular corpuscles spread on the striae. Figs 23, 24: apex and detail of the apically/axially elongated areolae in mid-valve. Fig. 25: open SV valvocopula (arrows). SEM, scale bars: Fig. 20: 8  $\mu\text{m}$ ; Fig. 21: 6  $\mu\text{m}$ ; Fig. 19: 5  $\mu\text{m}$ ; Fig. 24: 3  $\mu\text{m}$ ; Figs 22, 23, 25: 1  $\mu\text{m}$ .



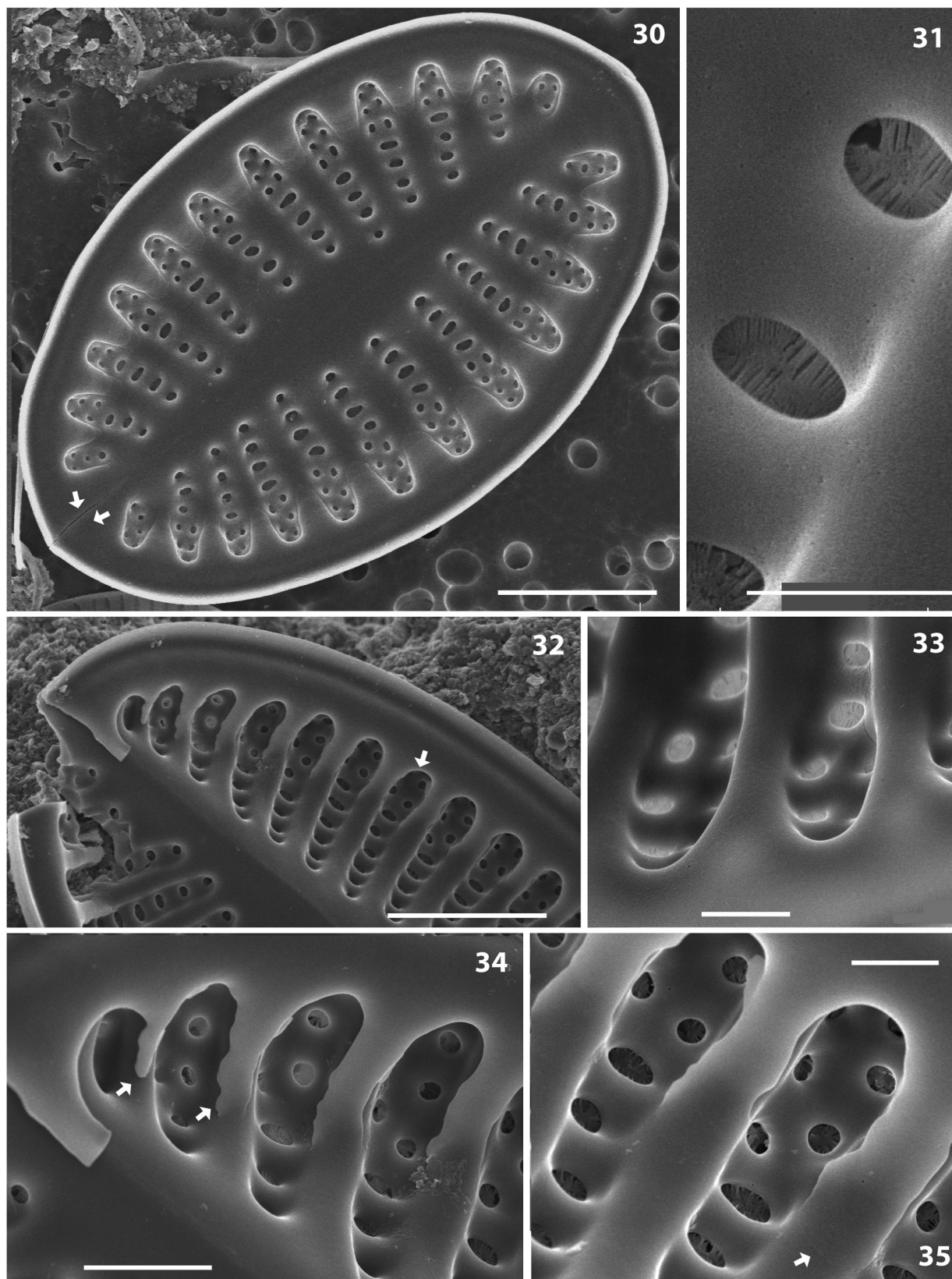
**FIGURE 26–29:** *Cocconeis pinnata* from Tahiti Island (SEM). External views of the SV. Figs 26, 28, 29: details of the areolae from the margin of the valve, with complex arborescent volae and pearls-globular corpuscles in between. Fig. 27: detail of the axially elongated areolae in the middle valve. SEM, scale bars: Fig. 27: 1  $\mu\text{m}$ ; Fig. 26: 0.7  $\mu\text{m}$ ; Figs 28, 29: 0.5  $\mu\text{m}$ .

*Cocconeis pinnata* var *matsii* Al-Handal, Riaux-Gobin & Wulff is now best considered a distinctive species. Although at first it was distinguished from its nominate species, the valve measurements (striae, 12–13 in 10  $\mu\text{m}$ , 3–5 in 10  $\mu\text{m}$  for *C. pinnata*), greater number of areolae suggest it is better considered as a species. Finally, no specimens of *C. pinnata* var. *cipollae* Zanon (1933: 28, pl. 1, fig. 20) have been examined and it is known only from the single illustration in Zanon (1933: pl. 1, fig. 20) which may well be a specimen of *Tryblionella cocconeiformis* (Grunow) Mann.

In summary:

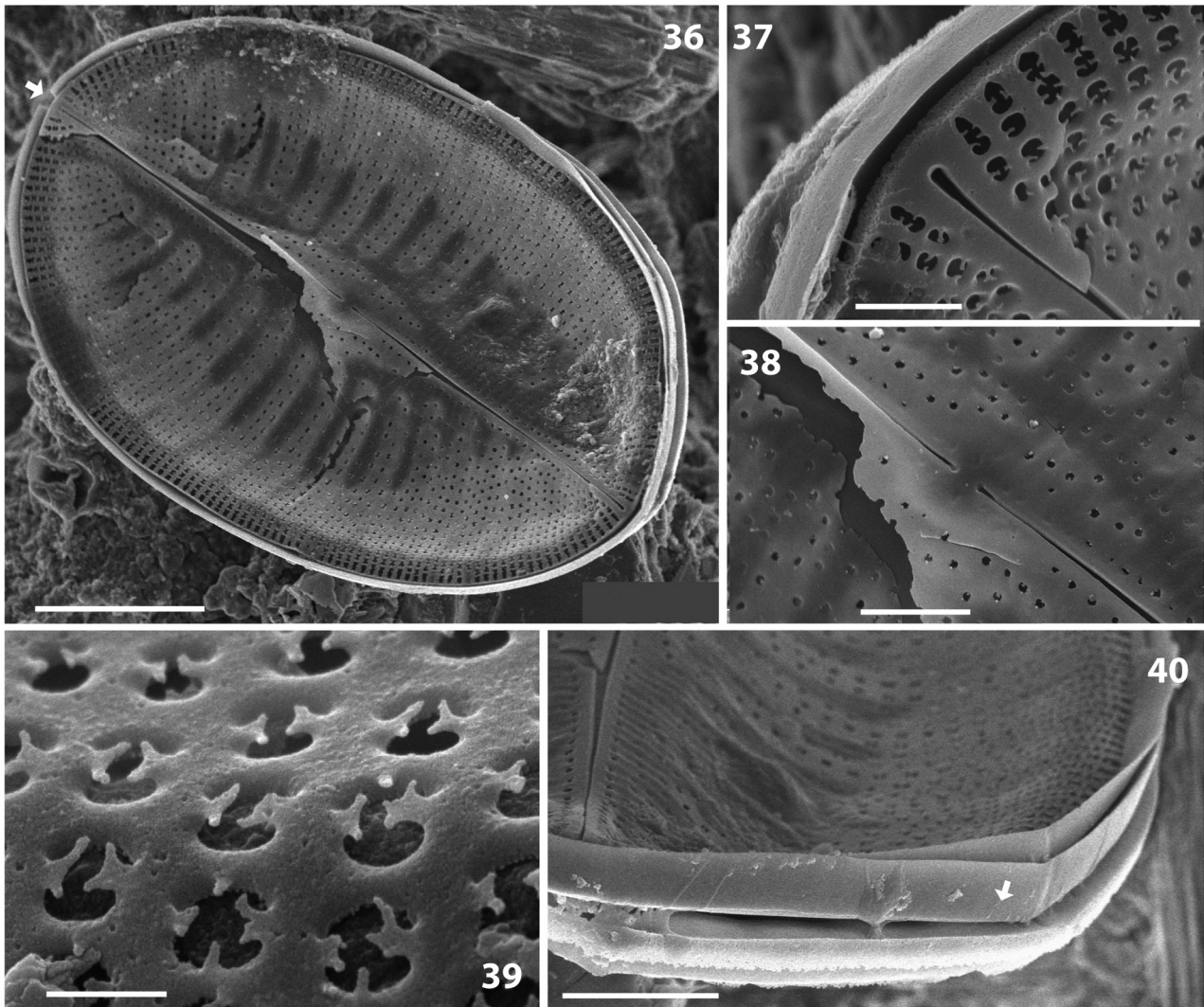
- 1 *Cocconeis pinnata* f. *major* = *Cocconeis pinnata*?
- 2 *Cocconeis pinnata* var. *plena* = *C. imperatrix* forma *plena*
- 3 *Cocconeis pinnata* var. *orbicularis* nom. inval. = *Cocconeis orbicularis* nom. inval.
- 4 *Cocconeis pinnata* var. *matsii* = ***Cocconeis matsii* (Al-Handal, Riaux-Gobin & Wulff) comb. nov.**  
 Basionym: *Cocconeis pinnata* var. *matsii* Al-Handal, Riaux-Gobin & Wulff 2010: 6, figs 13–18, 25–34.  
 Type: Antarctica, King George Island, Potter Cove, 62°14'S, 58°41'W (BM 11346 ! holotype)
- 5 *Cocconeis pinnata* var. *cipollae* = [? *Tryblionella cocconeiformis* (Grunow) Mann].

*Recent reports of Cocconeis pinnata and several invalid descriptions:*—Riaux-Gobin (1991, pl. 1, fig. 13) illustrated a specimen of *C. pinnata* (around 35  $\mu\text{m}$  long) with strongly raised and moniliform costae and a widely elliptic sternum, whereas figure 12 is probably *C. costata*.



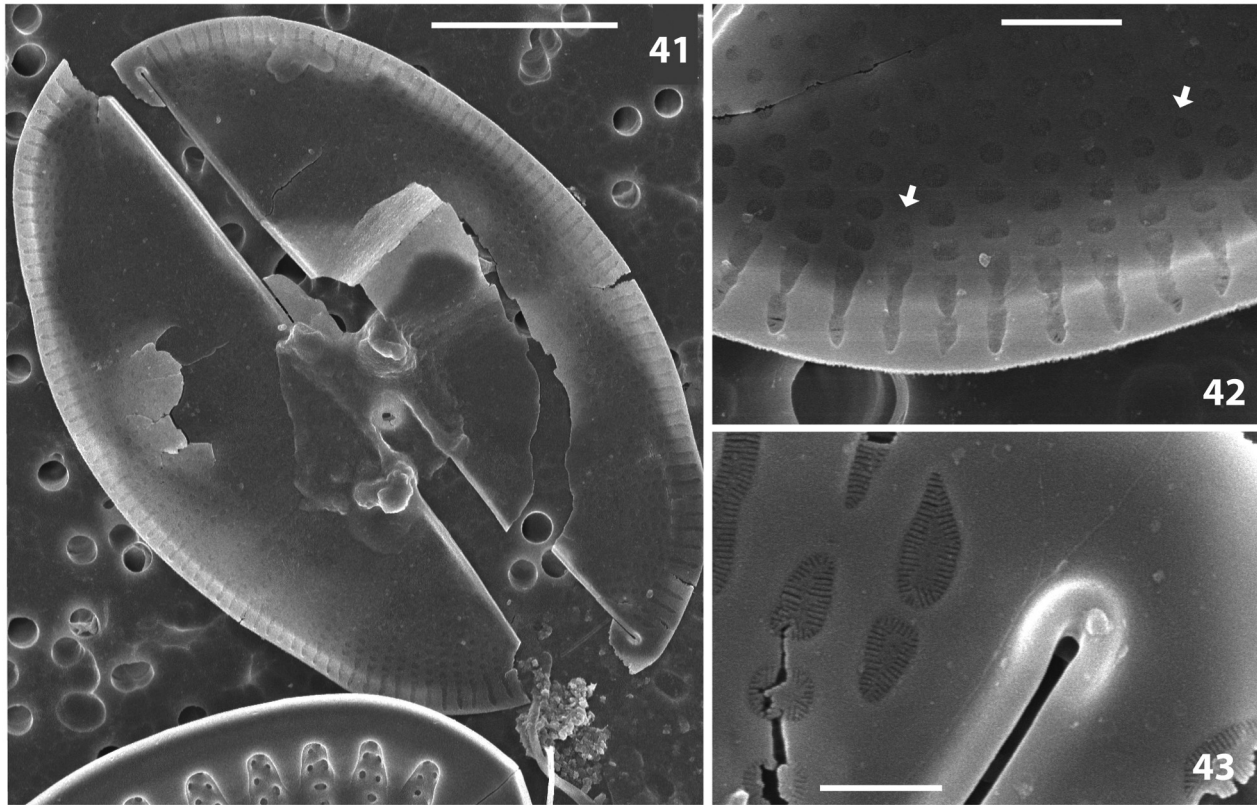
**FIGURE 30–35:** *Cocconeis pinnata* from Tahiti Island (SEM). Internal views of the SV. Fig. 30: complete valve, with the SV valvocopula open at one apex (arrows). Fig. 31: detail of the areolae hymen with radial long slits. Fig. 32: SV valvocopula expanding on the margin, with digitate long fimbriae taking place on the interstriae. The valvocopula manages a space between the valve and the copula (visible on the broken apex) and creates loculi (arrow). Figs 33, 34, 35, detail of the loculi and digitate fimbriae endings (arrows).

SEM, scale bars: Fig. 32: 6  $\mu$ m; Fig. 30: 5  $\mu$ m; Fig. 34: 2  $\mu$ m; Figs 33, 35: 1  $\mu$ m; Fig. 31: 0.7  $\mu$ m.



**FIGURE 36–40:** *Cocconeis pinnata* from Tahiti Island (SEM). External views of the RV. Fig. 36: complete valve, with the RV valvocopula open at one apex (arrows). Fig. 37: detail of the areolae on apex, and distal raphe ending close to the margin. Fig. 38: central area restricted and central raphe endings opposed and close to each other. Fig. 39: detail of the arborescent volae closing the areolae (most often two per areolae). Fig. 40: relatively narrow cingulum with a supplementary cingular band/copula (arrow). SEM, scale bars: Fig. 36: 7  $\mu$ m; Fig. 40: 3  $\mu$ m; Fig. 38: 2  $\mu$ m; Fig. 37: 1  $\mu$ m; Fig. 39: 0.3  $\mu$ m.

Romero and Rivera examined several slides from LPC, ‘Serie 46 N° 1’ (‘Bahia Esperanza...latitude 63° 23’S., longitude 56° 58’W., [*Cocconeis*] *pinnata* Greg. escasa’, Frenguelli & Orlando 1958: 57) and Serie 28 N° 2 (‘Isla Laurie, en Bahía Uruguay...[*Cocconeis*] *pinnata* Greg. rara’, Frenguelli & Orlando 1958: 41–42) (Romero & Rivera, 1996). Unfortunately, identification of these specimens as *Cocconeis pinnata* by Romero & Rivera (1996) perpetuated the initial misidentification by Frenguelli & Orlando (1958). This study allows those previous identifications to be corrected: Riaux-Gobin & Romero (2003, pl. 7) illustrate ‘*Cocconeis* cf. *pinnata* Gregory (sensu Romero & Rivera 1996)’, which is better named as *C. costata*; Al-Handal *et al.* (2010) described and named *Cocconeis pinnata* var. *matsii* which although bears some resemblance to *C. costata* may best be considered distinct; Leterme *et al.* named one of their specimens *C. pinnata* (Leterme *et al.* 2012: fig. 2), which also better matches *C. costata*; Romero & Rivera (1996, figs 56–59) illustrated the SV of *C. pinnata* as having striae composed of small areolae in quincunx and triseriate near the sternum (Romero & Rivera 1996: fig. 56), which does not match the ‘moniliform’ striae as illustrated in Greville (1859) or subsequent authors. Moreover, the RV illustrated by Romero & Rivera (1996: figs 60–64) has a marginal rim suggesting these too are probably *C. costata* and its allies.



**FIGURE 41–43:** *Cocconeis pinnata* from Tahiti Island (SEM). Internal views of the RV. Fig. 41: complete valve, without the RV valvocopula. Note the fine radiate striation and absence of marginal rim. The helictoglossae are very close to the margin. Fig. 42: detail of the marginal oblong flame-like areolae and rounded areolae structured on a hexagonal pattern. Note the presence of short intercalary marginal striae (arrows). Fig. 43: detail of the simple and straight low raised helictogloss. Note the internal hymenate pore occlusion of the areolae.

SEM, scale bars: Fig. 41: 5  $\mu\text{m}$ ; Fig. 42: 1  $\mu\text{m}$ ; Fig. 43: 0.4  $\mu\text{m}$ .

*Internet illustrations under the name Cocconeis pinnata:*—There are several illustrations of *Cocconeis pinnata* available on the internet. For example, *PlanktonNet* (<http://planktonnet.awi.de/>) has two images both from the Cape Verde Islands, Sao Vicente coast) and *Le plancton marin. Découvrir les organismes du phytoplancton et du zooplancton* (Loir 2011, <http://www.diatomloir.eu/Siteplancton/Index.html>) has one, from the Infralittoral de Bretagne Sud (Sub-littoral zone of southern Brittany). On the other hand, the LM illustration of *C. pinnata* presented in the AlgaeBase under Image ID No. 43221 (Guiry & Guiry 2013) [http://www.seaweedafrica.org/search/images/view/?img\\_id=43221](http://www.seaweedafrica.org/search/images/view/?img_id=43221) from Bainbridge Island, Washington, USA, Point blanc, does not match the original description of *C. pinnata* since the SV axial area of the illustrated taxon is narrow and straight and the bi- to triseriate striae (even close to the sternum) are composed of very fine areolae. The latter might be close to *C. costata*. The same is applicable to the image on micro\*scope (Bertoglio A., <http://starcentral.mbl.edu/microscope/portal.php>).

*Fossil or rare related taxa:*—Several taxa have SV morphology similar to that of *Cocconeis pinnata*: *Cocconeis oamaruensis* Schrader (1969: 33; illustrated in Desikachary & Sreelatha 1989: pl. 50, figs 4-5) has a ring-like marginal chamber but the areolae are described as fine; *Cocconeis schleinitzii* Janisch (in Schmidt 1894: pl. 190, figs 5, 6); *Cocconeis versicolor* Brun (1891: 19, pl. 18, fig. 1), which although poorly illustrated, the RV appears biseriate; surprisingly it is described as having a stauros, although that appears doubtful on the illustration (Brun 1891: 19, pl. 18, fig. 1a); *Cocconeis formosa* Brun (1891: 16, pl. 18, 6c) is similar to *C. pinnata*, but it too appears to have a small stauros.



*Geography of Cocconeis pinnata*:—First described from Northern Europe (United Kingdom, Greville 1859), *C. pinnata* is widespread from cold temperate to tropical marine environments (Grunow in Van Heurck 1880, Cleve 1895, Peragallo & Peragallo 1897, Schmidt 1894, Jørgensen 1905). Its Antarctic distribution remains questionable (see remarks above about the taxa described in Frenguelli & Orlando 1958). Hällfors (2004) recently cites (without illustration) this taxon as planktonic in the Baltic Sea, probably after sediment resuspension. It is not surprising to find *C. pinnata* in the French Polynesia (South Pacific) since it was previously recorded from tropical sites such as Seychelles and Rhea Island near Singapore (Cleve 1895).

## Conclusion

*Cocconeis pinnata* has been lectotypified from Gregory's material acquired by Greville and now located in BM. Recently collected material from epizoic specimens living on a holothurian from Tahiti reef lagoon allowed further comparison and SEM examination. An emended description has been supplied.

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