

Re-description of *Cymopolia miocenica* (Karrer) (Chlorophyta, Dasycladales) from the Late Miocene of Sicily (Italy) and the Middle Miocene of Banat (Romania)

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ABSTRACT - Professor Giuliano Ruggieri found a rich dasyclad flora in siliciclastic sediments of a Late Miocene (lower Messinian) succession from Sicily (Petràlia Sottana, Palermo). The algal remains belong to the genus *Cymopolia* Lamouroux (Cretaceous-Recent). Morphological and biometrical characters allow the Sicilian taxon to be attributed to *Cymopolia miocenica*, a species formerly described by Karrer in 1868 as *Dactylopora miocenica*, and known only in the Middle Miocene of the Paratethys area (Romania and Hungary). A lectotype, chosen among Karrer's material housed in the Naturwissenschaften Museum of Vienna, is here indicated.

The remains of *Cymopolia miocenica* consist of sterile and fertile calcareous articles. The sterile bodies are usually cylindrical, while the fertile ones are elongated to short barrel-shaped. All the articles are strongly calcified except around the outer swollen part of primary laterals of fertile whorls. The original aragonitic calcification looks still preserved, a fact probably related to the conservation in clay. The calcified structure exhibits the same pattern as in the extant species. A reconstruction of the alga is supplied.

RIASSUNTO - [*Cymopolia miocenica* (Karrer) (Chlorophyta, Dasycladales) del Miocene Superiore della Sicilia, con osservazioni sul materiale tipo (Miocene Medio del Banato, Romania)] - Durante le sue ricerche paleontologiche e geologiche in Sicilia il professor Giuliano Ruggieri rinvenne presso Contrada Abbazia a sud di Petràlia Sottana (Palermo) numerosi resti di alghe fossili in sedimenti silicoclastici di una successione riferibile al Miocene superiore che inviò allo scrivente nel 1982. Alcuni anni dopo ulteriori due campioni (BA.100 e BA.100.a) vennero raccolti dall'autore due chilometri più a sud della località sopraccitata. I resti algali appartengono in massima parte ad un'alga verde dasicladale del genere *Cymopolia* Lamouroux (Cretaceo-Attuale). I caratteri morfologici e biometrici permettono di attribuire il taxon siciliano a *Cymopolia miocenica*, una specie descritta da Karrer nel 1868 come *Dactylopora miocenica* e conosciuta esclusivamente nel Miocene Medio della Paratetide (Romania ed Ungheria). L'osservazione e la misurazione del materiale tipo conservato presso il Naturwissenschaften Museum di Vienna conferma l'attribuzione a questa specie. L'analisi del materiale viennese ha permesso anche di indicare un lectotipo, regolarizzando così il suo status tassonomico.

L'orizzonte a *Cymopolia* della zona di Petràlia Sottana proviene da una successione di argille e marne grigio-azzurre di oltre 100 metri di spessore riferibile al Messiniano inferiore. I macrofossili sono costituiti in genere da molluschi sia gasteropodi che bivalvi mentre i microfossili algali sono rappresentati principalmente da *Cymopolia miocenica* (Karrer) ed in misura minore da *Halimeda* sp. Sono presenti anche foraminiferi (*Dendritina* sp., *Borelis* sp.) ed ostracodi con la specie *Heliocythere vehjehonensis* (Pochaczka).

Gli articoli calcarei di *Cymopolia miocenica* siciliani sono sia sterili sia fertili, così come quelli conservati a Vienna. Gli articoli sterili sono prevalentemente cilindrici mentre quelli fertili hanno la forma di un barilotto tozzo o variamente allungato. Tutti gli articoli sono fortemente calcificati ad eccezione della parte esterna rigonfia dei laterali primari; in questa zona si può venire a creare infatti una sorta di cavità anulare. Gli articoli verosimilmente mostrano ancora l'originaria calcificazione aragonitica, ciò sembra essere legato alla conservazione in argilla. La struttura della calcificazione ricalca l'organizzazione osservabile nelle *cymopolie* viventi. Viene fornita infine una ricostruzione dell'alga.

INTRODUCTION

During paleontological and geological studies, Professor Giuliano Ruggieri found a rich algal flora, in siliciclastic sediments of a Late Miocene succession from Sicily, that he sent in 1982 to the author. The algal remains belong to the genus *Cymopolia* Lamouroux, 1816 (Cretaceous-Recent). Ruggieri's material consists of about 180 free specimens. In addition to this material, two further samples were collected by the present author (BA.100 and BA.100.a) about 6 km South of Petràlia Sottana (central-northern Sicily), two kilometers farther South of Contrada Abbazia, the source of Ruggieri's material.

Morphological and biometrical characters allow the Sicilian taxon to be attributed to *Cymopolia miocenica*,

a species described by Karrer (1868) as *Dactylopora miocenica*, and known only in the Middle Miocene of the Paratethys (Romania and Hungary). The observation of type material housed in the Naturwissenschaften Museum of Vienna confirms the attribution. The Petràlia Sottana outcrop thus constitutes the first occurrence of this taxon outside the Paratethyan area.

Miocene Dasycladaceans of the Paratethyan area have been recorded for a long time (e.g. Reuss, 1848; Karrer, 1868). They occur mainly in the middle part of the epoch (Badenian and Sarmatian). Acetabulariaceans are the best represented with several species of *Acicularia* (see Deloffre & Granier, 1992; Szczechura, 2006) and the widespread taxon *Halicoryne morelleti* (Pokorny) (see Bucur et al., 1993; Rákosi, 1989, Pl. 4, figs. 2-6, sub *Acicularia transsylvana*). Dasycladaceans

have been recorded with *Cymopolia miocenica* and *Neomeris ignota* Morellet & Morellet (see Deloffre & Génot, 1982).

All Miocene genera have extant representatives. More than 13 species of *Cymopolia* are known starting from the Early Cretaceous; a great amount of them occur in the Paleocene-Eocene. Starting from the Oligocene, the number of *Cymopolia* species declines progressively, following the general trend for the whole order of Dasycladales (Barattolo, 2002).

SYSTEMATIC PALAEONTOLOGY

General remarks on the genus Cymopolia Lamouroux 1816

The genus *Cymopolia* shows a segmented thallus composed of articles (Berger & Kaeffer, 1992). Each article is separated from the following one by a constriction of the central stem. In the constricted part, whorls of sterile laterals are attached, and fertile whorls occur in the articles (repetitive elements). A fertile whorl consists of primary laterals bearing, at their distal ends, as many terminal globular fertile ampullae (i.e. gametophores). The fact that gametophores directly produce gametes means that they are equivalent to gametangia (actually they are also capable of germinating directly). Each ampulla (= gametangium) is set in the center of a tuft of phloiophorous secondary laterals which form a cortex at their swollen distal ends. A specimen produces gametes not at the end of its life cycle, as happens with the other recent dasycladales, but throughout most of its life. Furthermore, the degree of maturation of gametangia may be the same throughout one article, and different from one article to another (e.g. *Cymopolia barbata*, Berger & Kaeffer, 1992, p. 118). Only two extant species are known, *Cymopolia barbata* (Linné) Lamouroux (type-species) and *C. van-bosseae* Solms Laubach (Berger & Kaeffer, 1992).

Cymopolia miocenica (Karrer) Morellet & Morellet (Pls. 1-4)

- 1868 *Dactylopora miocenica* n. sp. KARRER, pp. 159-161, Pl. III, Figs. 11 a-d, f, i; not Figs. 11 e, g-h.
 1959 *Cymopolia elongata* (Defrance) - BODA, pp. 751-752, Pl. 44, Figs. 4-10.
 1982 *Cymopolia miocenica* (Karrer) - DELOFFRE & GÉNOT, pp. 69-70, Pl. 5, Figs. 8-10 (*cum syn.*).

Material - Karrer's material is stored in ten test-tubes numbered in Roman numerals (I to X). They are placed in small boxes labeled "*Dactylopora miocaenica*". Test-tube I contains several specimens of *Acicularia miocaenica* Reuss, all others mainly contain, or contained, rests of *Cymopolia* (see also Morellet & Morellet, 1927). In detail, test-tubes IV and VII are empty, those labeled as III and IX store numerous heterogeneous algal fragments referable to *Cymopolia* sp., but also *Neomeris* (perhaps *Neomeris ignota* Morellet & Morellet) and other undeterminable

rests. All the other test-tubes hold *Cymopolia miocenica* coming from Kostež, and more often Lapugy. Also written on the labels is the variety epithet formalized by Karrer himself in 1877: *brevis* (test-tubes VI and II), *tenuis* (test-tubes IX and X) and *crassa* (test-tubes VII and VIII). Actually, in Karrer (1877: caption of Pl. XVI b, Figs. 13 a-c) the epithets are *brevis*, *longa* and *ampla*, respectively.

The varieties defined by Karrer (1877), as already affirmed by Morellet & Morellet (1927), have no taxonomical value, but only a morphological one. Most of the sterile and some slender fertile articles fall in the *tenuis*-group, while a great amount of fertile articles have been included in the *crassa*-group and the short and squat fertile articles have been finally included in the *brevis*-group.

The material from Sicily used for the paleontological description is that of Ruggeri. It consists of 186 articles (each one placed on a single-celled slide), both fertile and sterile, usually unbroken and very well preserved. Some of them appear reddish or with their delicate cortical calcification partially or completely eroded. In the latter cases, the calcareous skeleton may be moderately pierced by algae with very thin borings (Pl. 2, fig. 2; Pl. 3, fig. 6). The samples BA.100 and BA.100.a have been used to analyze the lithological characters of the fossil assemblage.

The paleontological description of *C. miocenica* is essentially based on the Ruggeri's material. The type material has been used for comparison and measured for a statistical description.

Statistical analysis - Thirty-two specimens from Karrer's material (Tab. 1) and 62 from the sample A.6321 (Tab. 2) were measured, and the main parameters plotted under a bivariate analysis. The most significant dotted diagrams are reported in Fig. 1. The type-material cannot be considered homogeneous since it was collected from at least two different sites (see "Material" and "Locality" sections). As regards sample A.6321, Professor Giuliano Ruggeri supplied the *Cymopolia* material already prepared, and nothing is known about how it was sorted. Therefore only a mere descriptive analysis together with a qualitative comparison between them is provided here. All parameters of the two samples widely overlap. Only higher inner diameter values of the calcareous skeleton, $d (= d_{int})$, from type material are remarkably greater than that of sample A.6321. Furthermore, fertile and sterile articles are distinctly separated from each other in the chart (Fig. 1a); they occur in both samples and show the same trend. Finally a higher number of laterals per whorl (w) usually is found in fertile specimens.

Lectotype - Because no type has ever been designed, here a lectotype is chosen. As to the specimens illustrated by Morellet & Morellet (1927), they were not recognized in Karrer's collection during my visit in Vienna. Therefore, the specimens of Pl. 1, fig. 15, contained in test-tube IX of Karrer's collection, Naturwissenschaften Museum of Vienna, is chosen as lectotype. The biometrical values of the lectotype are reported in Tab. 1 (specimen no. 27).

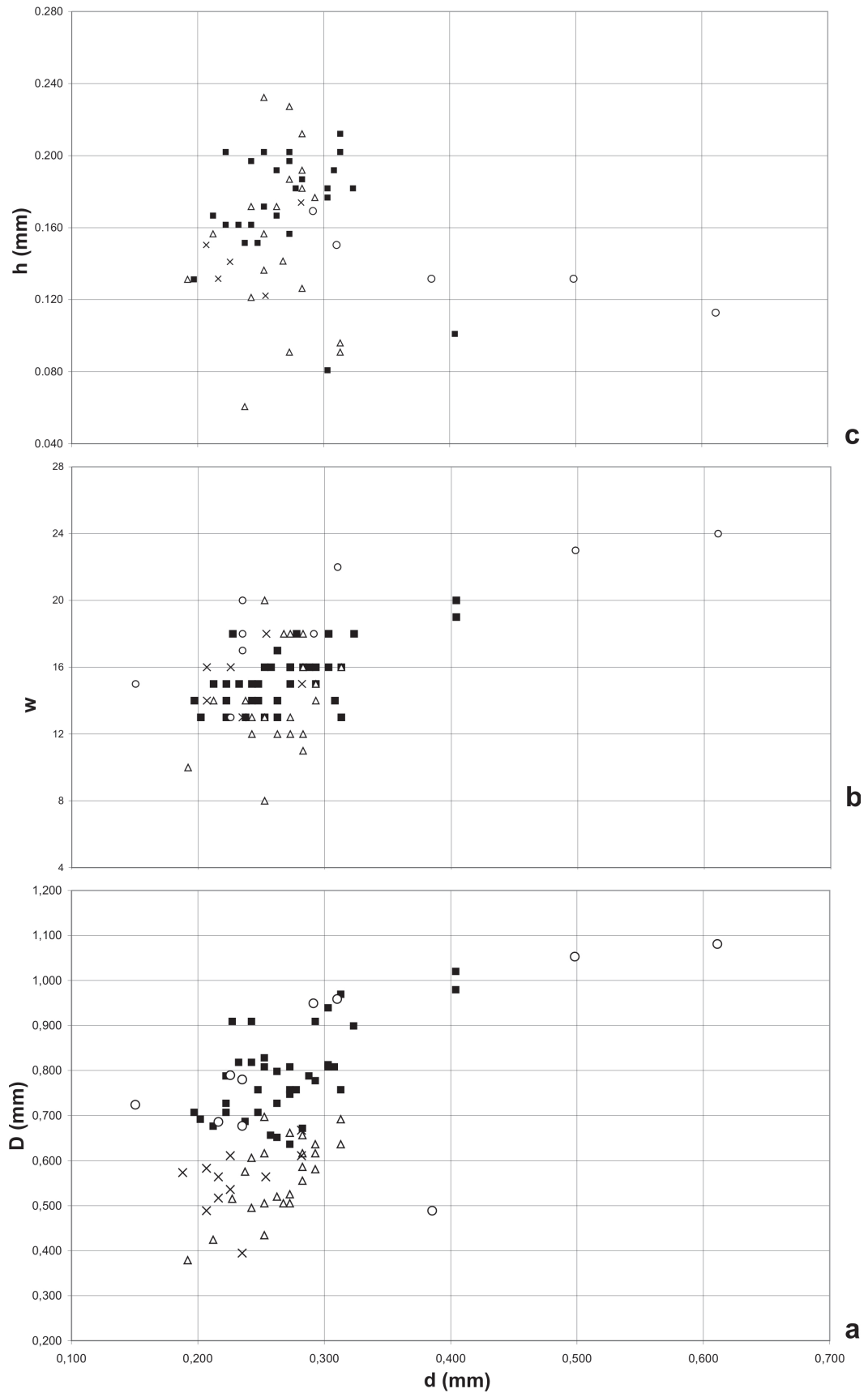


Fig. 1 - *Cymopolia miocenica* (Karrer). Diagram comparing the type material (Karrer collection) and the sample from Sicily; a - outer diameter of the calcareous skeleton (D); b - number of primary laterals per whorl (w); c - height between whorls (h), versus inner diameter of the calcareous skeleton (d); $\blacksquare$ = fertile specimen, sample A.6321; $\triangle$ = sterile specimen, sample A.6321; $\circ$ = fertile specimen, type-material; $\times$ = sterile specimen, type-material.

Cymopolia miocenica (Karrer), Karrer material																				
N.	Tube	F/S	Var.	Locality	Dext	Hart	dint	pi	pd	ll	li	ld	w	h	p'	l'	p'd	dsw	dsv	la
1	VI	f	brevis	Lapugy	0.79		0.23	0.033		0.132			13					0.12		0.14
2	VI	f	brevis	Lapugy	0.69		0.22													
3	VI	f	brevis	Lapugy	0.68		0.24			0.094			20					0.08		0.11
5	II	s	C. m.?	Kosteĵ	0.58		0.21			0.075			14	0.15		0.12				
6	VIII	s	crassa	Lapugy	0.61		0.23						16	0.14						
7	VIII	f	crassa	Lapugy	0.88	1.34														
8	VIII	s	crassa	Lapugy	0.49		0.21						16							
9	VIII	s	crassa	Lapugy	0.61		0.28						15	0.17						
10	VIII	s	crassa	Lapugy	0.39		0.24						13							
11	X	s	tenuis	Kosteĵ	0.49	1.46								0.14						
12	X	s	tenuis	Kosteĵ	0.43	1.24														
13	X	s	tenuis	Kosteĵ	0.52	0.80	0.22							0.13						
14	X	s	tenuis	Kosteĵ	0.63	1.60											0.066			
15	X	s	tenuis	Kosteĵ	0.57	1.36	0.19													
16	X	s	tenuis	Kosteĵ	0.40	1.41											0.066			
17	X	s	tenuis	Kosteĵ	0.46	1.69								0.17						
18	X	s	tenuis	Kosteĵ	0.56	1.32	0.25			0.056			18	0.12		0.09				
19	X	s	tenuis	Kosteĵ	0.53	0.82														
20	X	f	tenuis	Kosteĵ	0.49	1.27	0.39							0.13						
21	X	s	tenuis	Kosteĵ	0.47	1.13														
22	X	s	tenuis	Kosteĵ	0.55	1.05														
23	X	s	tenuis	Kosteĵ	0.67	1.05	0.28													
24	X	s	tenuis	Kosteĵ	0.54		0.23													
25	IX	f	tenuis	Kosteĵ	1.05		0.50		0.056	0.113			23	0.13					0.08	0.12
26	IX	f	tenuis	Kosteĵ	0.95		0.29	0.014	0.047	0.122	0.075	0.047	18	0.17					0.13	0.17
27	IX	f	tenuis	Kosteĵ	0.96	1.97	0.31	0.014	0.056	0.113	0.066	0.047	22	0.15					0.14	0.17
28	IX	f	tenuis	Kosteĵ	1.08		0.61						24	0.11					0.08	0.14
29	IX	f	tenuis	Kosteĵ	0.78		0.24						17						0.08	0.13
30	IX	f	tenuis	Kosteĵ	0.72		0.15	0.014		0.075	0.038	0.038	15					0.10		0.12
31	IX	s	tenuis	Kosteĵ	0.56		0.22			0.085						0.10				
32	IX	f	tenuis	Kosteĵ	0.78		0.24	0.022	0.066	0.103	0.056	0.047	18		0.014	0.16		0.12		0.13
Nr.					31	15	22	5	4	10	4	4	15	12	1	4	2	4	5	9
Average					0.643	1.301	0.270	0.019	0.056	0.097	0.059	0.045	17.467	0.144	0.014	0.120	0.066	0.106	0.100	0.138
min					0.395	0.799	0.150	0.014	0.047	0.056	0.038	0.038	13	0.113	0.014	0.094	0.066	0.075	0.075	0.113
Max					1.081	1.974	0.611	0.033	0.066	0.132	0.075	0.047	24	0.174	0.014	0.160	0.066	0.122	0.141	0.169
Standard deviation					0.18724	0.31390	0.10529	0.00824	0.00768	0.02388	0.01605	0.00470	3.48193	0.01948		0.02910		0.02221	0.03363	0.01994

Tab. 1 - *Cymopolia miocenica* (Karrer). Most significant biometrical values from the type material (Karrer collection). All values are given in millimeters. *Dext* = outer diameter of the calcareous skeleton, *Hart* = length of the article, *dint* = inner diameter of the calcareous skeleton, *pi* = width of the primary lateral (only inner part for fertile article), *pd* = width of the primary lateral distal part (for fertile article), *ll* = length of the primary lateral, *li* = length of the primary lateral inner part (fertile article), *ld* = length of the primary lateral outer part (fertile article), *w* = number of primary laterals per whorl, *h* = height between whorls, *p'* = width of the secondary lateral, *l'* = length of the secondary lateral, *p'd* = width of the secondary lateral distal part, *w'* = number of secondary laterals per primary lateral, *dsw* = verticillar width of the ampulla, *dsv* = vertical width of the ampulla, *la* = length of the ampulla, *f/s* = type of article (fertile or sterile).

Locality - As regards Karrer's material, part of the samples was collected near Kosteĵ (today Coșteiu de sus, West Romania). Karrer (1868) indicated three localities: Poren Ungurluj (probably corresponding to Valea Ungurului, Dușa 1969), Funtina botrina (probably corresponding to Fântâna bătrână, Dușa 1969, p. 51) and Valja Gemini (probably corresponding to Valea Gemenii, Dușa 1969, p. 51). The first two lie between Coșteiu de sus and Nemesey (today Nemessești), a village about 4 km WSW of Coșteiu

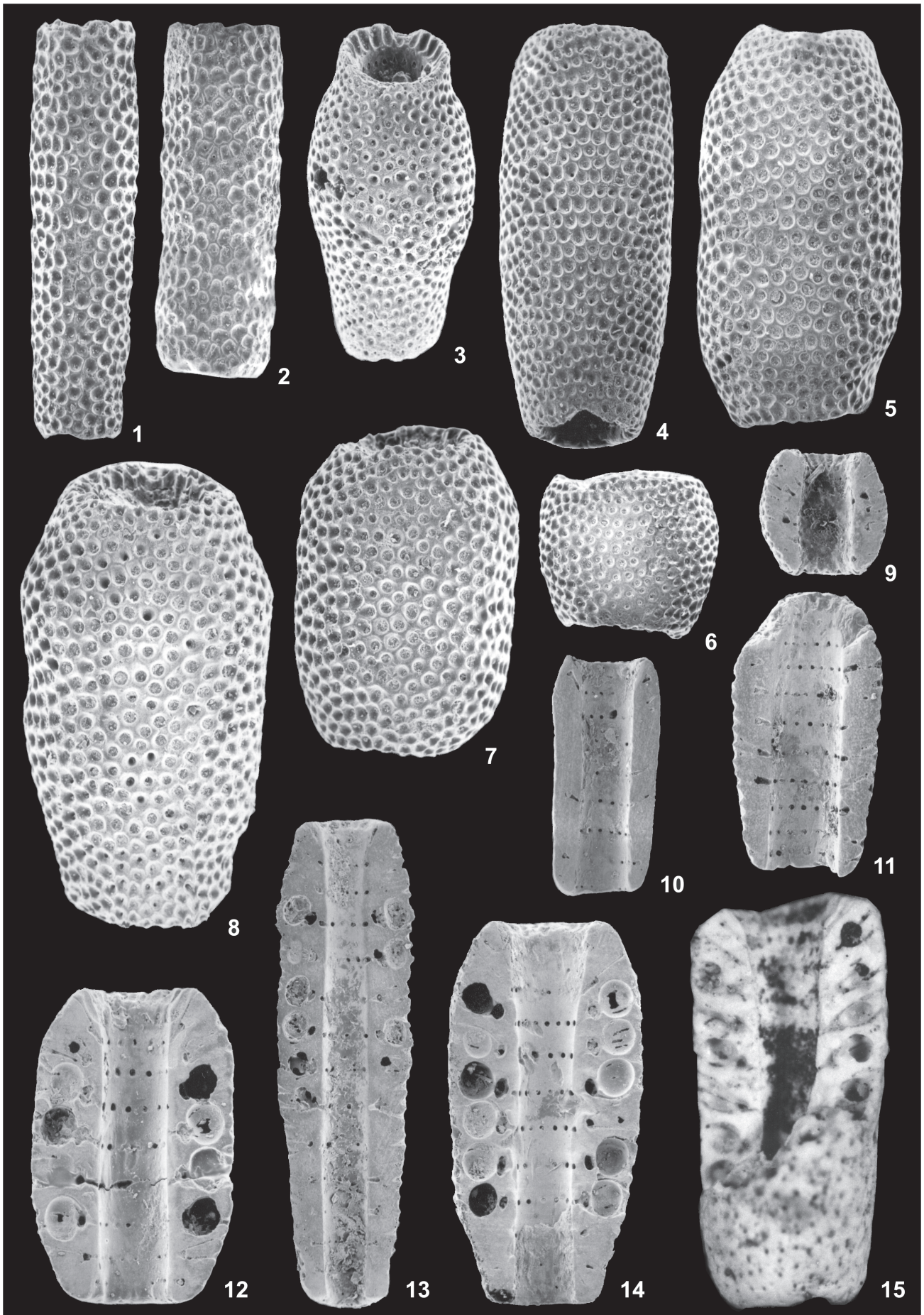
de sus. "Valja Gemini" is situated in the wood of Nemessești (Karrer, 1868, p. 2). The other samples studied by Karrer were collected near Lapugy (today Lăpugiu, probably Lăpugiu de sus), a village about 10 km SE of Coșteiu de sus.

The sampling locality of the Sicilian specimens (Ruggieri's material) is Contrada Abbadia, about 5 km South of Petralia Sottana (Palermo). Samples BA.100 and BA.100.a were collected by the present author about 1.5 km farther South of the previous toponym at

EXPLANATION OF PLATE 1

Cymopolia miocenica (Karrer). Note the various shapes of articles.

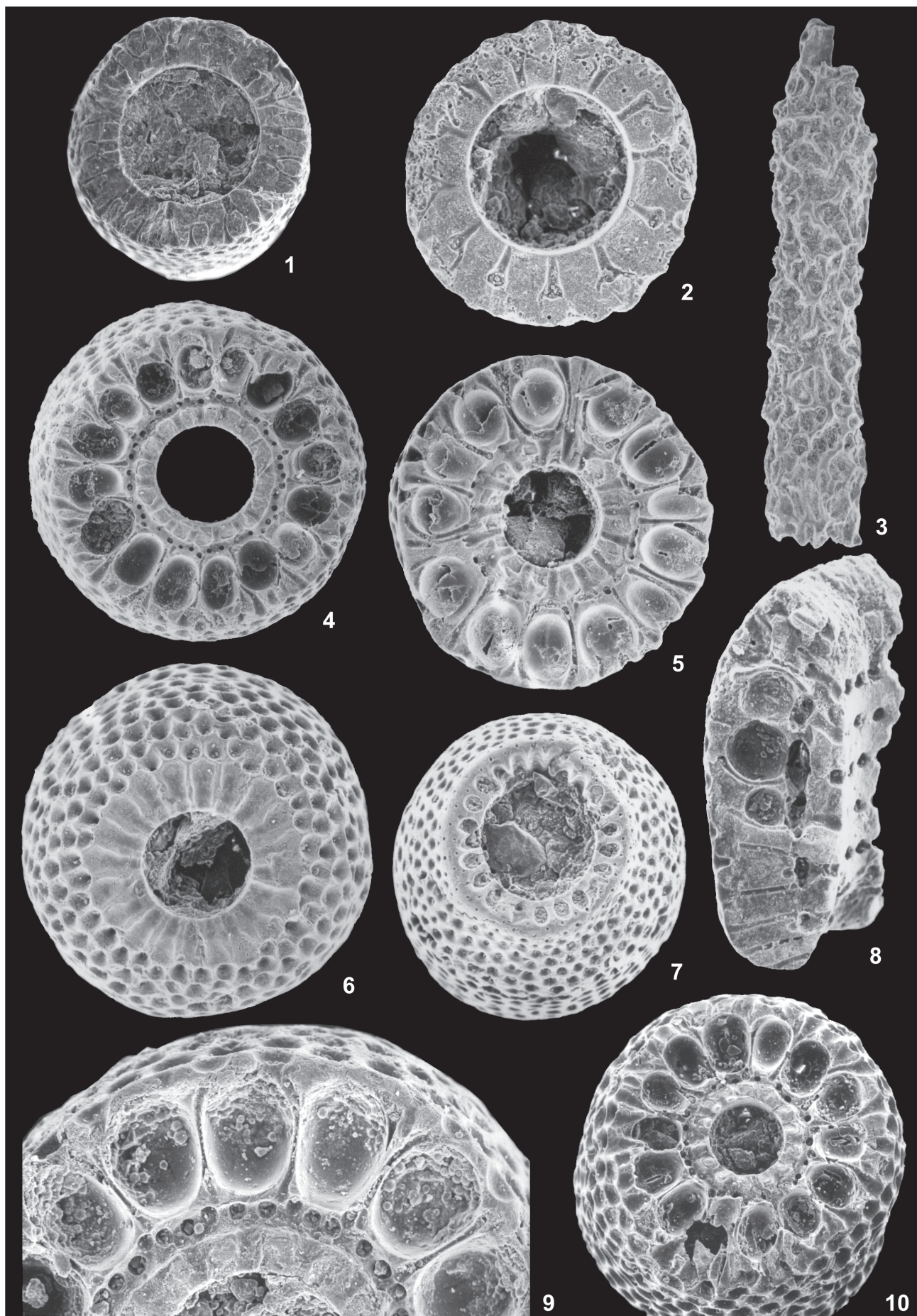
- figs. 1-8 - Calcified articles in outer view (x 40). Petralia Sottana (Palermo, Italy). Lower Messinian.
 1 - Sterile article; A.6321.167. 2 - Sterile article; A.6321.115. 3 - Fertile article; A.6321.25. 4 - Fertile article; A.6321.20.
 5 - Fertile article; A.6321.21. 6 - Fertile article; A.6321.141. 7 - Fertile article; A.6321.11. 8 - Fertile article; A.6321.4.
 figs. 9-14 - Sectioned articles (all x 40, except fig. 13, x 30). Petralia Sottana (Palermo, Italy). Lower Messinian.
 9 - Sterile article; A.6321.45. 10 - Sterile article; A.6321.158. 11 - Sterile article; A.6321.153. 12 - Fertile article; A.6321.28. 13 - Fertile article; A.6321.2. 14 - Fertile article; A.6321.74.
 fig. 15 - Lectotype, lower Badenian (Langhian), Coșteiu (Banat, Romania), Karrer collection (x 40).



Tab. 2 - *Cymopolia miocenica* (Karrer). Most significant biometrical values from the sample A.6321 (lower Messinian, Sicily). For abbreviation of parameters, see Tab. 1; *nw/art* = number of whorls per article, *swS* = number of sterile whorls at the top of the article, *swI* = number of sterile whorls at the bottom of the article, *shape* = shape of the article (CY, cylindrical; TC, truncated cone; EB, elongated barrel; SB, short barrel; BP, bi-pedunculate).

Cymopolia miocenica (Karrer), Petralia Sottana (Palermo, Italy). Lower Messinian.

- figs. 1-3 - Sterile articles in transversal view (broken specimens, figs. 1-2) and outer view (fig. 3).
1 - A.6321.89, x 66; 2 - A.6321.136, x 133; 3 - A.6321.179, x 75.
- figs. 4-5, 10 - Fertile articles broken at whorl level.
4 - A.6321.40, x 75; 5 - A.6321.28, x 75; 10 - A.6321.3, x 75.
- figs. 6-7 - Fertile articles in lower (fig. 6) and upper (fig. 7) view showing traces of uncalcified primary laterals placed between articles.
6 - A.6321.5, x 75; 7 - A.6321.15, x 75.
- fig. 8 - Fertile article broken longitudinally. Note the development of the ampulla upwards and the fusion of primary pores at their swollen outer part (middle part of figure). A.6321.108, x 100.
- fig. 9 - Detail of a fertile article broken at whorl level. A.6321.106, x 150.



the point of kilometric coordinates 7945/2010, 870 m a.s.l. They were used to check the paleontological assemblage and to deduce sedimentological data.

Stratigraphical level - All Karrer's material was sampled from limestones and marls of "Tegel" facies containing a rich fauna with mollusks, corals, bryozoans and echinoderms (Karrer, 1968, pp. 2-3). This facies is generally referred to Lower Badenian which corresponds to the Langhian (see stratigraphic scheme in Popov et al., 2004). Also in the recent literature, the terrains cropping out near Coşteiu and Lăpuş are ascribed to this time interval (Chira & Măruţeanu, 1999; Mihailescu et al., 1987; Marinescu & Popescu, 1993).

The *Cymopolia* horizon from Sicily can be ascribed to the lower Messinian grey-blue clay succession, slightly marly, more than 100 m thick (Torre, 1971).

Macrofossils are represented mainly by mollusks (gastropods and bivalves). Algal microfossils are represented mainly by *C. miocenica* (Karrer) and, to a lesser extent, by *Halimeda* sp.; foraminifers (*Dendritina* sp., *Borelis* sp) and ostracods, such as *Heliocythere vejhonensis* (Pochaczka) (Bonaduce et al., 1988), also occur.

Description - Articulated thallus with a cylindrical central stem. Sterile articles are in shape of elongated cylindrical calcareous bodies; the fertile ones are elongated to squat barrel-like.

The primary laterals are often arranged in rather spaced verticils, rarely in a closely packed way (euspondyl type). They are usually set in continuity in subsequent whorls.

The primary lateral of sterile articles is subcylindrical, slightly swollen at its distal end, set nearly orthogonal to the main axis (80-90°). The primary lateral of fertile articles (fertile whorls) is less inclined (60°) and consists of an akrophorous, stem-like proximal portion followed outwards by a very swollen, lenticular distal part. Primary laterals of sterile whorls occurring at the lower and upper end of fertile articles look like those of sterile articles.

Each primary lateral supports a tuft of five long, very thin secondary laterals. They flare quickly at their distal ends to form a polygonal meshed cortex. A single, globular ampulla, sometimes laterally compressed, is

placed at the distal end of each primary lateral, and is tightly enclosed within the tuft of secondary laterals.

The calcareous skeleton is perannulated: each series of verticils is defined by the different shape, size and inclination of primary laterals and the presence of reproductive organs. Calcification envelops the central stem, primary laterals, secondary laterals and ampullae.

The values of the most significant parameters are shown in Tab. 2.

General features of the calcareous skeleton - The calcification is arranged in a clear articulated calcareous skeleton (perannulation). The calcification envelops the central stem, the primary laterals, the fertile ampullae and the secondary laterals up to their widened distal ends. The inner surface of the calcareous skeleton is smooth and cylindrical in both sterile and fertile articles. Only a single sterile article has been observed showing an inner surface provided with longitudinal furrows and an irregular cortical outer surface (Pl. 2, fig. 3); it probably represents a sterile article at the lowermost part of the thallus.

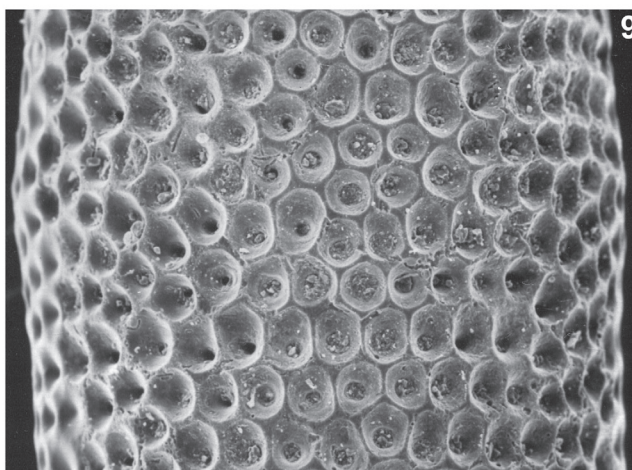
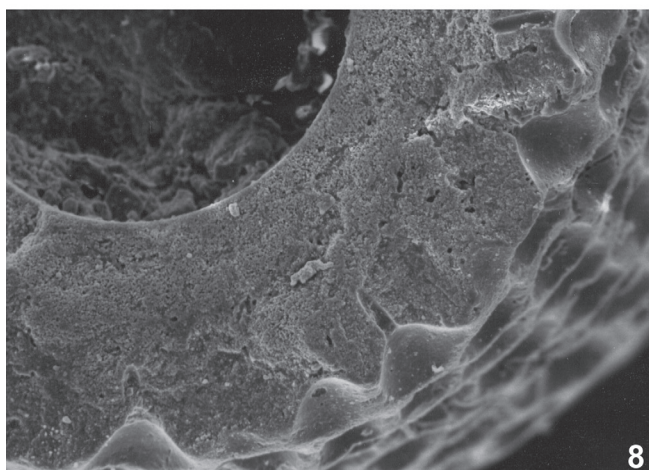
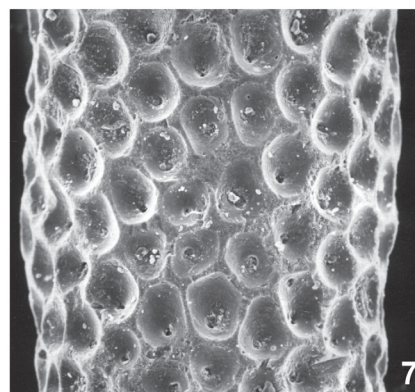
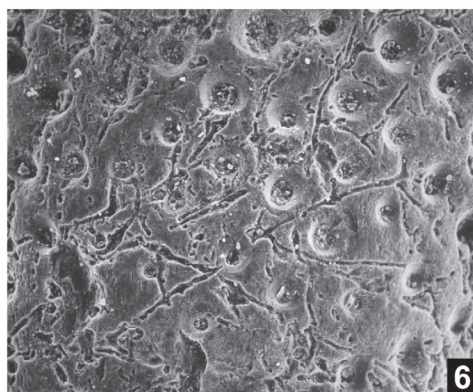
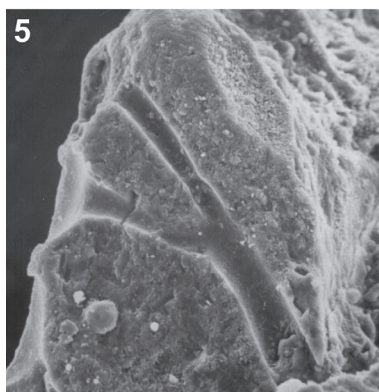
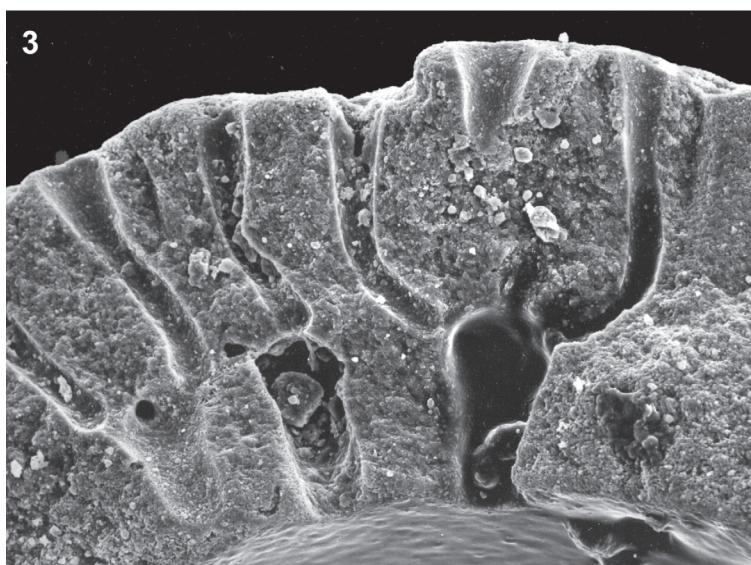
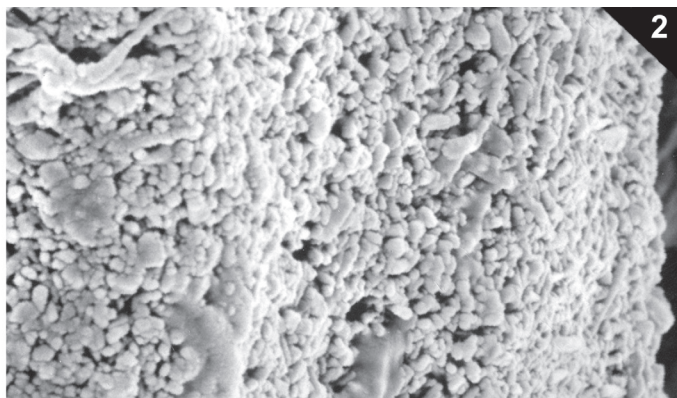
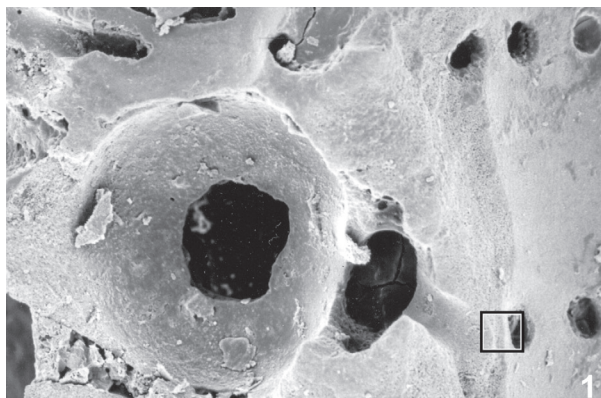
Sterile articles are in the form of slender cylinders (Pl. 1, figs. 1-2, 10). A small amount of them is very slightly widened at the middle-upper part (Pl. 1, fig. 11) or in the shape of a short barrel (Pl. 1, fig. 9) or truncated cone. Calcification of sterile articles spreads uniformly from the central stem up to the distal cortical ends of the secondary laterals. From the microstructural point of view it is made up of short, massive crystals (aragonite?) arranged irregularly.

Fertile articles are in the form of elongated to rather squat, barrel-like bodies (Pl. 1, figs. 4-8). Some elongated fertile article is tapered at both ends to form a sort of short pedunculate portions (Pl. 1, fig. 3). The calcification of fertile articles exhibits the same distribution as in sterile articles, but is less massive. Calcification is looser mainly around the swollen outer part of primary laterals between primary laterals of the same verticil. In this way, a sort of annular channel can occur at whorl-level, thus dividing the calcareous skeleton in an inner (inner portion of primary laterals) and an outer part (secondary laterals and the fertile ampulla) as in Pl. 2, fig. 8 and Pl. 4, fig. 3. Calcification can also be lacking in the space between subsequent whorls at the level of the swollen part of primary laterals (Pl. 2, fig. 6) as well as at the secondary lateral/ampulla

EXPLANATION OF PLATE 3

Cymopolia miocenica (Karrer), Petralia Sottana (Palermo, Italy). Lower Messinian.

- fig. 1 - Detail of a specimen broken longitudinally showing a primary pore and a gametangial cavity; A.6321.38, x 190.
- fig. 2 - Detail of fig. 1 (black square) showing the arrangement of crystals close to the central stem; A.6321.38, x 4650.
- figs. 3, 5, 8 - Sterile primary and secondary laterals in different views.
3 - A.6321.41, x 390; 5 - A.6321.135, x 380; 8 - A.6321.89, x 210.
- fig. 4 - Detail of Pl. 1, fig. 14. Note the uncalcified contact between secondary laterals and ampulla; A.6321.74, x 130.
- figs. 6-7, 9 - Detail of articles in outer view. Note the cortical facets (figs. 7, 9) and borings (fig. 6).
6 - A.6321.8, x 106; 7 - Detail of Pl. 1, fig. 1; A.6321.167, x 106; 9 - Detail of Pl. 1, fig. 4; A.6321.20, x 106.



contact (Pl. 3, fig. 2) and sometimes at the ampulla/ampulla contact (Pl. 3, fig. 2; Pl. 4, fig. 3). A thin calcification occurs around the fertile ampullae, but it becomes thicker and thicker toward the distal end of secondary laterals.

From a microstructural point of view, calcification of fertile articles looks more complex than that of sterile articles. In fact, a moderately compact layer of crossed needle-like crystals (aragonite?) occurs around the outer part of primary laterals (Pl. 4, figs. 1-2) and in the upper end of the article (Pl. 4, figs. 5-6), while a massive, very compact layer of short, densely packed crystals, like in sterile articles, can be observed around fertile ampullae and secondary laterals (Pl. 4, figs. 3-4).

The outer diameter (Dext) and the inner diameter (dint) of the calcareous skeleton are 0.37-1.02 mm and 0.19-0.40 mm, respectively. The article is 0.56-2.96 mm high (Hart); the number of whorls per article varies from 7 to 15.

Inclination and arrangement of primary laterals

The primary laterals of sterile articles are set at 80-90° with the main axis. The inclination does not change significantly from the bottom to the top of each sterile article. In fertile articles, primary laterals are inclined 60-80° to the main axis. In particular, at the bottom they are to the right of the main axis, and decrease more and more in inclination upwards so that they exhibit their minimum inclination at the top (30-45°).

The primary laterals are usually arranged in spaced simple verticils, 0.06-0.23 mm high (h), and are in continuity in subsequent whorls. Moderate close whorls (lower values of h), have been found in fertile articles only. The arrangement in continuity is sometimes broken by the number of primary laterals per whorl which increases from the bottom to the top of the article. Thus the whorls can be arranged in continuity toward the bottom, and they appear alternating upwards.

The number of pores in a whorl (w) is about 8-20. Lower values occur in sterile articles and in small fertile ones, as well as in the bottom part of the article with respect to the top.

Shape and size of primary laterals - Primary laterals exhibit different shape and size according to whether

they occur in sterile or fertile article and to their position within the fertile article.

The primary laterals from sterile articles are moderately long, sub-cylindrical in shape, and circular in cross section; they are about 0.05-0.12 mm long (ll) and 0.02-0.03 mm wide (p). Their distal end is slightly swollen and rounded.

The primary laterals from fertile articles, in particular those of sterile whorls, i.e. not supporting ampullae, look like the ones from the sterile articles and are placed at both article ends. The primary lateral supporting a fertile ampulla consists of a thin stem-like proximal portion and a very swollen lenticular distal one (with the radial axis compressed). The former is 0.03-0.08 mm long (li) and as wide as primary laterals of sterile articles (pi), the latter is 0.02-0.08 mm long (ld) and 0.06-0.10 mm wide (pd).

Secondary laterals - Each primary lateral supports a tuft of five long, thin, distally swollen (phloiophorous), secondary laterals. They are joined at the periphery of the distal end of primary laterals. When present, the fertile ampulla is closely embraced by the secondary laterals which bend according to its surface. The secondary lateral is subcylindrical for most of its length and is 0.005-0.018 mm wide (p'); then, just beyond the ampulla, it sharply flares out at the distal cortical end.

Cortical meshes of sterile articles are in the form of upright elongated polygons (usually hexagons), whereas those of fertile articles are not elongated, but more or less regular hexagonal polygons. They decrease in size toward the bottom and top of the article. They are 0.03-0.07 mm wide (p'w) in both sterile and fertile articles.

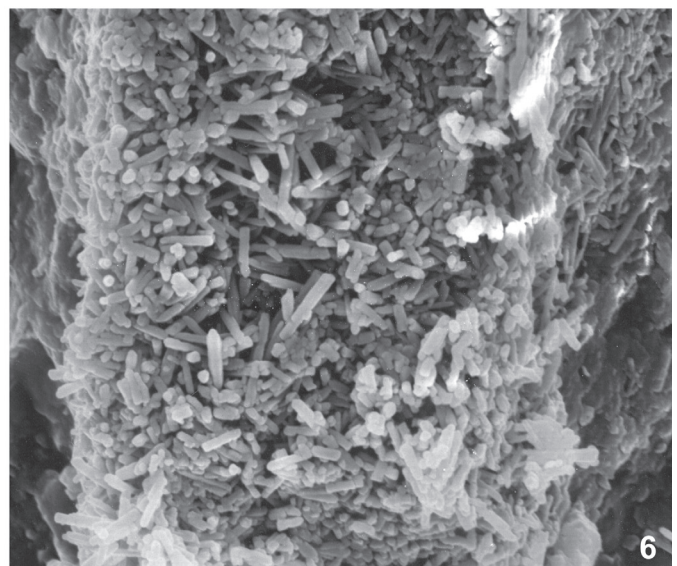
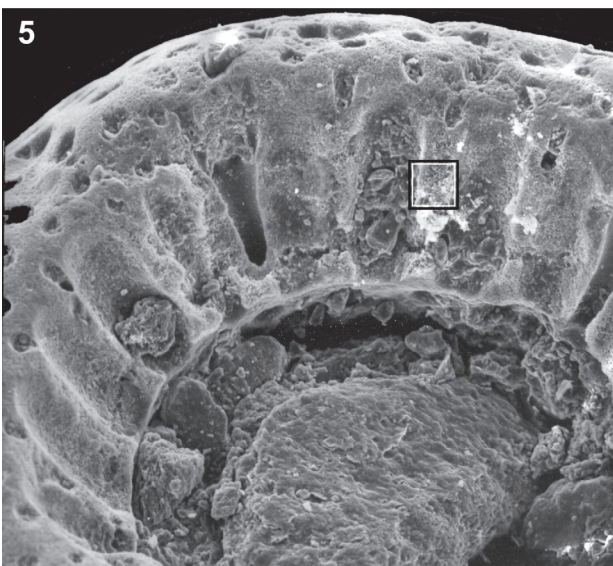
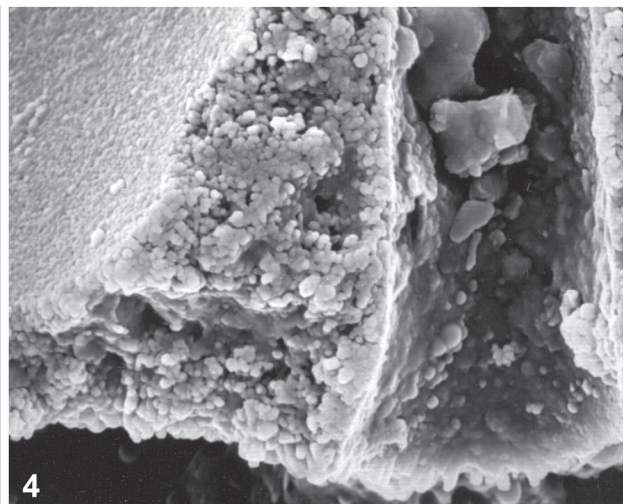
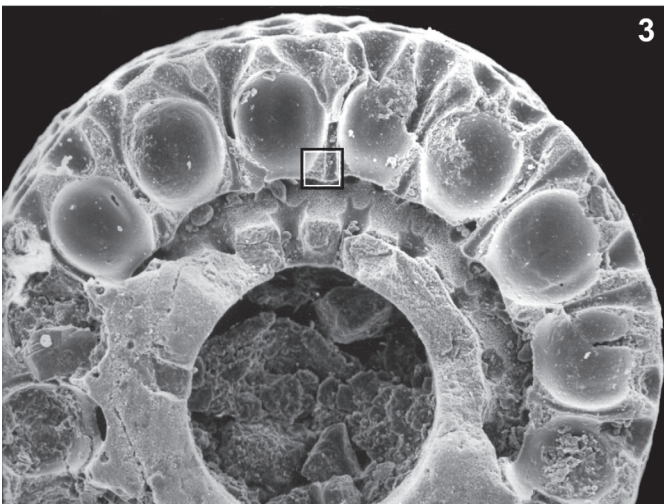
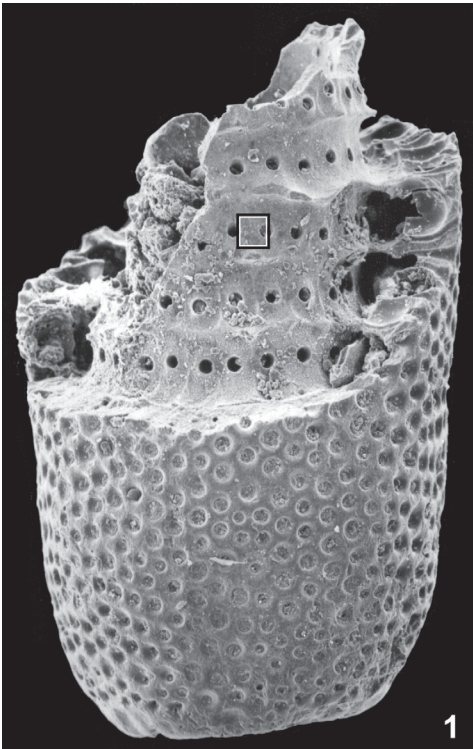
The secondary laterals are on the whole 0.04-0.26 mm long (l'); lower values (0.04-0.14 mm) occur in sterile articles and greater values (0.12-0.26 mm) occur in fertile ones.

Reproductive organs - The primary lateral often supports at its distal end a simple fertile ampulla which is set in the same extension and is surrounded by secondary laterals. Each fertile article exhibits 2-5 fertile whorls placed in the middle to middle-upper part of it. The ampullae of subsequent whorls are of different

EXPLANATION OF PLATE 4

Cymopolia miocenica (Karrer), Petralia Sottana (Palermo, Italy). Lower Messinian.

- fig. 1 - Specimens partly broken longitudinally showing whorls of primary pores; (black square) showing the arrangement of crystals close to the swollen distal part of primary laterals; A.6321.44, x 70.
- fig. 2 - Detail of fig. 1 (black square) showing the arrangement of crystals close to the swollen distal part of primary laterals; A.6321.44, x 2130.
- fig. 3 - Detail of a whorl in transversal view; A.6321.107, x 150.
- fig. 4 - Detail of fig. 3 (black square) showing the arrangement of crystals between the ampulla (left cavity) and the secondary lateral (right cavity); A.6321.107, x 2300.
- fig. 5 - Detail of an article in its apical part. Note the traces of sterile laterals in the constricted part of the stalk (front and left of the photo); A.6321.85, x 200.
- fig. 6 - Detail of fig. 5 (black square) showing the arrangement of long aragonite (?) crystals; A.6321.85, x 2550.



size (Pl. 2, fig. 8); this allows us to argue that the gametangia were in different developmental stages. Fertile ampullae appear as globular, laterally compressed, large cavities. They are circular in vertical section, elliptic to sub-trapezoidal in the verticillar section and elliptic to sub-rectangular (set upright) in cross section.

The vertical width (dsv) is 0.13-0.21 mm, the verticillar width (dsw) is 0.10-0.15 mm, and the length (la) is 0.10-0.17 mm.

Reconstruction of the thallus - Most morphological characters have been deduced by observation of calcified parts. The top and the bottom of the thallus, as well as the general shape of the alga, can be inferred on the basis of extant species.

The top of the thallus of extant species is constantly formed by laterals decreasing in size and inclination upwards and closed like a bud at the top, and bearing tufts of hair-like tertiary laterals. The same framework has been supposed also for *C. miocenica*. The fact that one article (specimen A.6321.33) shows an upper opening far narrower than usual (also if compared to the lower opening of the same article) could be a proof of this.

The lower part of the thallus, as is the case in extant species, is formed by a very short, branchless stalk-like segment of the siphon.

As regards the general shape of the thallus, recent *Cymopolia*-species exhibit both a simple (*C. van bosseae*) and a branching thallus (*C. barbata*) (Berger & Kaefer, 1992). For the present species no clear evidence has been found to strengthen the second hypothesis; the first simpler hypothesis has been adopted. On the whole, *C. miocenica* most likely consisted of a long, articulated, simple thallus showing cylindrical sterile articles in the lower part and upwards fertile, elongated to barrel-like ones (Fig. 2).

Paleoecology - The ecology of *C. barbata* (Valet, 1979; Berger & Kaefer, 1992) can throw light on the environment of the fossil *Cymopolia*, and specifically of *C. miocenica*. This extant species lives in a very warm and calm shallow water marine environment, but it can be found under quite different conditions of water energy, light intensity, temperature and salinity. Geographically it ranges from Mexico Gulf to Cadiz (Spain). This species can also survive a moderate desiccation during low tide by means of its cortical layer that prevents a more severe drying-out process. The alga is usually attached on rocks or clasts of sandy

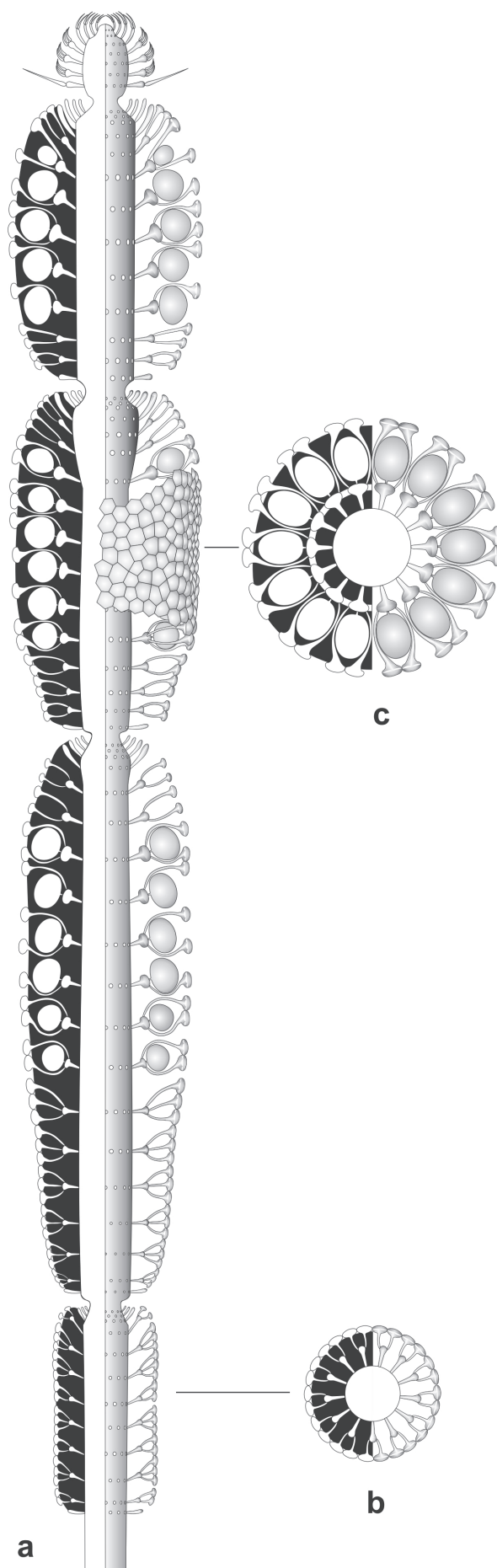


Fig. 2 - *Cymopolia miocenica* (Karrer). Reconstruction of the thallus in longitudinal view (a), x 30. The central stem shows the junctions of primary laterals, the third article shows the faceted cortex. Reconstruction of a sterile article (b) and a fertile article (c) in transversal view, x 40. *Left-hand side*: stem, primary laterals, secondary laterals, gametangia (only in the fertile articles), and calcification (black). *Right-hand side*: articles without calcification.

bottoms. The shape of articles and calcification may change according to ecological factors. In fact, articles of specimens living in intertidal environments are longer and narrower than subtidal ones. Moreover, the calcification appears stronger if the alga lives under more agitated conditions.

The *C. miocenica*-rich clay sediment from Sicily contains frequent millimetric to centimetric, more or less rounded extraclasts. This fact, together with data from extant species, allows us to suppose that *C. miocenica* lived attached on small pebbles in a very protected, shallow muddy marine environment, in warm to temperate-warm water.

Chronostratigraphy and paleogeography - *C. miocenica* is known from the Lower Badenian-Sarmatian (Langhian-Serravallian) of western Paratethys (Romania and Hungary, i.e. the Pannonian Basin) and in the early Messinian of the present western Mediterranean (northwestern Sicily), which at that time belonged to the eastern Mediterranean. The species is therefore recorded from two different areas, almost separated in time and space, when quite a complex paleogeography was accompanied by rapidly changing scenarios (Popov et al., 2004).

During the Langhian (see Goncharova et al., 2004) the Pannonian Basin was connected to the Mediterranean Sea, but separated by eastern Paratethys, which communicated with the eastern Mediterranean and Mesopotamian Basin. Already in the Serravallian, the direct communication between the Pannonian Basin and the Mediterranean closed; thus only a passageway through the eastern Paratethys existed. In the late Tortonian-early Messinian (Ilyina et al., 2004) the Pannonian Basin partly dried up, while the rest turned into a lacustrine facies.

Given the Miocene paleogeographical evolution, two main hypothesis can be prospected:

a) During the Langhian, *C. miocenica* populated both the Pannonian Basin and the Mediterranean, but in the first it survived until the Lake Pannon episode occurred, and in the second it lived just before the "salinity crisis" (late Messinian).

b) During the Langhian, *C. miocenica* populated only the Pannonian Basin, then it migrated to the Mediterranean through eastern Paratethys during the Serravallian-early Messinian interval.

Comparison - *C. miocenica* shares with *C. morelletorum* Beckmann & Beckmann (Campanian-Maastrichtian of Cuba, Deloffre & Génot, 1982), *C. tibetica* Morellet & Morellet (Maastrichtian of Central Tibet, Deloffre & Génot, 1982), *C. zitteli* Morellet & Morellet (Lutetian-lower Bartonian of Paris Basin, Génot, 1987) the occurrence, in fertile articles, of primary laterals swollen at their distal ends bearing a single ampulla. Among them *C. zitteli* looks very similar to *C. miocenica*, but differs for the ampulla being more elongated and the distal part of the primary lateral less inflated (Génot, 1987, Pl. 11, fig. 10).

CONCLUSIONS

In spite of their distance in terms of time and perhaps ecological conditions, it is remarkable how surprisingly close the two populations of *C. miocenica* are to each other. Further researches on Middle-Upper Miocene shallow water sediments will be able to fill in the time and space gap between the two records.

Furthermore, the comparison between the Karrer species and the extant counterparts allows us to open up some point of discussion. *C. miocenica* shows some peculiar features which are not recorded in the present-day species, such as the importance of sterile whorls occurring at both ends of each fertile article. Furthermore, the fact that gametangia at different developmental stage occurred within the same article (i.e. repetitive element), is something not experienced by extant species (e.g. *C. barbata*, Berger & Kaever, 1992). Finally, the occurrence in fertile whorls of primary laterals with a swollen distal part (a character common to other species formerly placed in the genus *Karrereria*) could be explained as a strategy to favor the gametes escaping from the calcified fertile whorl. In fact, the mutual contact of parts produces wide areas deprived of calcification with easier passageways.

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