

Metrarabdotos (Bryozoa, Cheilostomatida) from Plio-Pleistocene of southern Italy, with description of new species

Antonietta Rosso

A. Rosso, Dipartimento di Scienze Geologiche, Sezione di Oceanologia e Paleoeologia, Catania University, Corso Italia 55, I-95129 Catania (Italy); rosso@unict.it

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ABSTRACT - The presence of *Metrarabdotos* in Plio-Pleistocene deposits of Sicily and southern Calabria has been evaluated. Five different species, three of which new, have been found: *Metrarabdotos elegantissimus* sp. nov., *M. italicus* sp. nov. and *M. pauciarimatus* sp. nov. Other palaeo-populations have been doubtfully referred to *M. elegans* Buge & Galopim de Carvalho and *M. teixeirai* Buge & Galopim de Carvalho, already known from the European-Mediterranean area. The recorded species lived in different palaeoenvironments from continental shelf (Circalittoral Zone) to the upper slope (Epibathyal), in bottoms constituted by sands or muddy sands. Most species are restricted to Pliocene, when the genus *Metrarabdotos* was particularly speciose in the area. *M. pauciarimatus*, on the contrary, seems to be restricted to the Pleistocene. The presence of *M. moniliferus*, the unique species previously known from Italy, remains to be proven.

RIASSUNTO - [*Metrarabdotos* (Bryozoa, Cheilostomatida) del Plio-Pleistocene dell'Italia meridionale, con descrizione di tre nuove specie] - Viene esaminata la presenza del genere *Metrarabdotos* in depositi plio-pleistocenici della Sicilia e della Calabria meridionale. Questo genere ha due poli di distribuzione, localizzati nel Nuovo Mondo (zona centrale delle Americhe) e nel Vecchio Mondo (Europa e Africa settentrionale) dove è documentato rispettivamente dall'Eocene all'Attuale e dall'Oligocene fino al Pliocene. In Italia meridionale sono state individuate cinque diverse specie, tre delle quali sono nuove: *Metrarabdotos elegantissimus* sp. nov., *M. italicus* sp. nov. e *M. pauciarimatus* sp. nov. In particolare la prima è unica in tutto il genere per l'aspetto dei suoi rami sottili, subcilindrici, e per gli zooidi che individuano un lato frontale e uno dorsale. La seconda, sebbene simile ad altre europee, è ben caratterizzata da dettagli morfologici a livello zooidale e zoarile e dai suoi rapporti morfometrici. *M. pauciarimatus* sp. nov., infine, è facilmente individuabile per l'assenza di aviculi su quasi tutti gli zooidi non marginali dei rami. I restanti paleopopolamenti sono stati riferiti, sebbene con dubbio a causa dell'esiguo numero di esemplari e/o del cattivo stato di conservazione, a due specie già conosciute dall'area europea e africana: *M. elegans* Buge & Galopim de Carvalho e *M. teixeirai* Buge & Galopim de Carvalho. Le specie citate sono ben separate anche per le loro esigenze ecologiche e si distribuiscono in orizzonti batimetrici diversi della piattaforma continentale, limitatamente al piano Circalittorale, e nell'Epibatiale, in fondali da esclusivamente sabbiosi a misti, con una componente pelagica non particolarmente abbondante. Dal punto di vista stratigrafico, la maggior parte delle specie è limitata al Pliocene, durante il quale il genere *Metrarabdotos* era fortemente differenziato nell'area. *M. pauciarimatus*, al contrario, sembra limitato al Pleistocene inferiore ed il suo record consente di ampliare al Quaternario la distribuzione di *Metrarabdotos* nell'area mediterranea. L'effettiva presenza di *M. moniliferus*, l'unica specie finora citata dall'Italia, resta, invece, da provare.

INTRODUCTION

Metrarabdotos is a long living bryozoan genus whose first representatives date back to the Late Eocene. Fossil species are known from the European-North African (Old World) and the American (New World) areas, where both Recent and fossil representatives of the genus are present in both Eastern Pacific and southern North America through the Caribbean (Cheetham et al., 1999). Presently, species number is increasing considerably as several new taxa have been recently identified, although yet not described from American Neogene sediments and living communities (Cheetham et al., 2001, <http://nmia.geology.uiowa.edu>).

In the Old World more than a dozen species are known. The oldest recorded species is likely *M. vigneuxi* Cheetham (Cheetham, 1968), described from French Lower Oligocene sediments. *M. orisensis* Reguant (Reguant, 1990), from the Middle Eocene of Spain, whose inferred ovicells actually correspond to broken zooids, in fact, has been doubtfully placed within the genus. After a period of likely low diversification, *Metrarabdotos* well differentiated during Late Miocene

and Pliocene (see Buge & Galopim de Carvalho, 1963) before becoming extinct in the area, seemingly during (or at the end of?) the Early Pleistocene. This trend somewhat parallels the evolutionary history in the American distribution pole where the genus radiated mainly from 8 to 4 My ago, splitting into some 12 species, most of which were extinguished by the Quaternary (Benton & Pearson, 2001; Cheetham, 2001). Besides *M. moniliferus*, Milne-Edwards, 1836, the type species of the genus, numerous species have been described and/or recorded, mainly from Europe and, subordinately, from a few localities of the Mediterranean Africa (Duvergier, 1924; Pansera, 1932; Roger & Buge, 1946; Lagaij, 1952; Buge, 1957; Reguant, 1961; Buge & Galopim de Carvalho, 1963; Galopim de Carvalho, 1971) partially reviewed by Cheetham (1968).

Notwithstanding the about two hundred years of interest in this genus, well characterised by the remarkable ovicells among other features, new species, such as *M. pouyeti* Marcopoulou-Diacantoni & Wuest, have been recently described (Marcopoulou-Diacantoni & Wuest, 1999) or given in open nomenclature (Moissette, 1988).

Among these known *Metrarabdotos* species, only *M. moniliferus* has been recorded, sometimes doubtfully, from Italy (Seguenza, 1879-80; De Stefani, 1882; Namias, 1891; Neviani, 1891, 1894, 1900a, b; De Angelis d'Ossat & Neviani, 1896; Annoscia, 1963). Cheetham (1968) didn't evaluate such records suggesting that a heterogeneous assemblage of species could have been quoted under the name *M. moniliferus*, the unique recorded also in more recent papers (Poluzzi & Padovani, 1984; Barrier et al., 1987; Di Geronimo et al., 1987).

A careful revision of the already available material and newly collected specimens from several localities, all from Plio-Pleistocene of southern Italy, allowed five different species to be identified. Three of them are new, whereas two have been doubtfully attributed to already known species. The aim of this paper is to describe all of them, outlining their geographical and stratigraphical distribution and discussing their palaeoecological meaning. The actual presence of *M. moniliferus* in the area remains to be proved.

MATERIALS AND METHODS

Studied samples come from sediments cropping out in Sicily and Calabria (southern Italy, central Mediterranean) and deposited during Pliocene and Pleistocene in shelf-to-slope palaeoenvironments (Fig. 1). Detailed information can be found in Barrier et al. (1987) for the Pavigliana section, in Di Geronimo et al. (1987, 1992) for the Ringiglio section and in Rosso (2002a, b) for the Capo Milazzo "yellow marls". Palaeobionomical reconstructions follow the scheme by Pérès (1982). Recognised palaeocommunities are indicated as follows: DC = coastal detritic assemblage; DL = detritic offshore assemblage; SGCF = coarse sands and fine gravels swept by bottom currents; VP = bathyal mud assemblage; CB = white corals

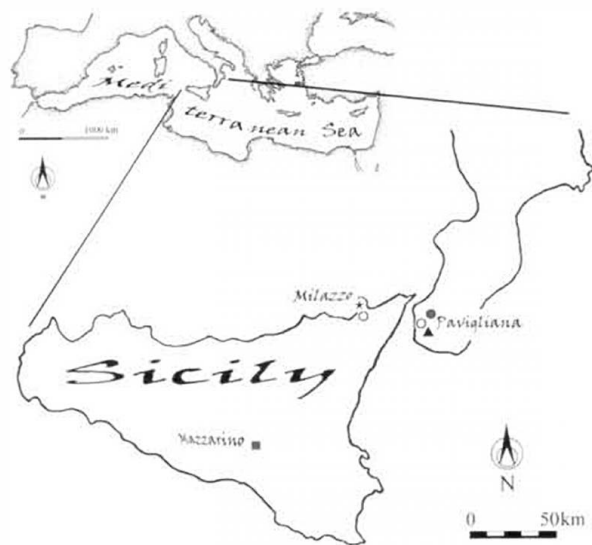


Fig. 1 - Geographical location of the studied samples. Star = *M. elegantissimus*; Open circle = *M. italicus*; Square = *M. pauciarmanus*; Closed circle = *M. cf. teixeirai*; Triangle = *M. cf. elegans*.

assemblage; PE = heterogeneous communities *sensu* Di Geronimo & Robba (1989).

Samples were routinely treated: sediments were washed and sieved and specimens sorted from residues coarser than 500 μm . Measures and some photos were performed by means of a stereomicroscope equipped with a JVC TK1381 Video Camera and a Zeiss KS100 3.00 program. Selected specimens were washed using H_2O_2 and diluted acetic acid to remove pelitic particles prior coating for scanning electron microscope. Measures have been taken following the scheme by Cheetham (1968).

Described material and types of the new species are deposited at the Palaeontological Museum of the Catania University (PMC).

SYSTEMATICS

Family METRARABDOTOSIDAE Vigneaux, 1949
Genus *Metrarabdotos* Canù, 1914

Type species: *Eschara monilifera* Milne-Edwards, 1836

Metrarabdotos elegantissimus sp. nov.
(Figs. 2a-d, Figs. 3a-f)

Etymology - Superlative; from the Latin adjective *elegans*, alluding to the distinct beauty of the slender branches.

Material - Cala S. Antonino West: sample 1 (1998). Holotype: a fertile branch (PMC B. 13 a 21.4.2003). Paratypes: about one hundred fertile and sterile fragments (PMC B. 13 b 21.4.2003).

Additional material: Cala S. Antonino Centre 1 (1999): 32 fragments; 2 (1999): 14 fragments; 4 (1998): 60 worn fragments. Cala S. Antonino East: sample 14 (2000): 2 worn fragments. Punta Mazza: sample 7 (2000): 55 not well preserved fragments; sample 8 (2000): a single fragment.

All samples Late Pliocene in age; VP assemblages with a variable amount of contaminants from CB assemblages and the local addition of shelf species.

Description - Colony erect, dichotomously branching at long intervals, originating from an extremely small encrusting base sealed by the frontal thickening of zooids.

Branches roughly cylindrical in cross section from about 600 to 1000 μm reaching 1400 μm near the base. Zooids in four alternating longitudinal rows, those of the central ones opening on a single side and the lateral ones along the margins, thus forming a frontal and a dorsal surface. Bifurcating rows absent.

Zooids elongated hexagonal, those of the lateral rows enlarged at mid length, their limits forming a slightly zigzagging line on the dorsal surface. Zooidal boundaries well marked by raised rims and a median groove early in ontogeny, obscured by increasing calcification.

Frontal wall thin and slightly convex in new zooids progressively thickened and flat in the older ones.

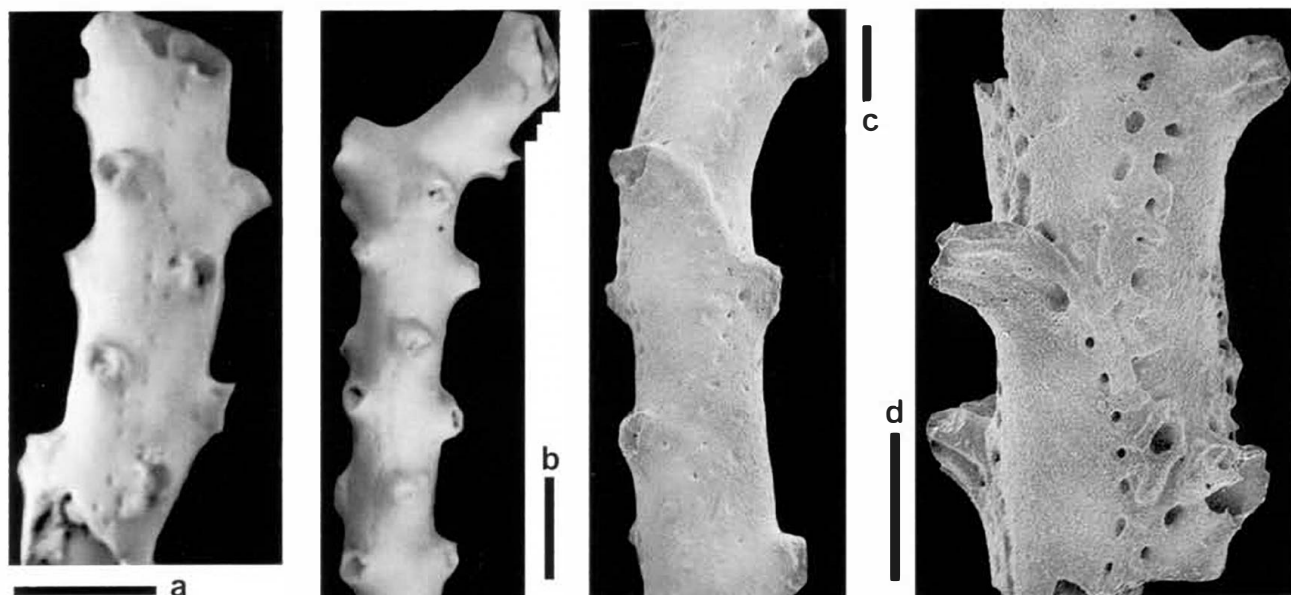


Fig. 2 - *Metrarabdotos elegantissimus* sp. nov. All specimens from Cala S. Antonino (Milazzo), Late Pliocene. Scale bars: 500 µm for a, b, d; 100 µm for c.

- a) Frontal view of a young branch with protruding peristomes. Sample 1 (1998).
 b) A bifurcating adult branch. Sample 1 (1999).
 c) Dorsal view of an adult sterile branch. Sample 2 (1999).
 d) Dorsal view of a young branch with incipient secondary calcification. Sample 1 (1998).

Surface finely granular and limited by about 20 well spaced, evenly distributed, round to longitudinally elongated, small marginal pores. Interareolar costulae not developed. Primary orifice deeply hidden within the peristome, with a small arched and concave, pouch-shaped distal shelf. Peristome tubular, about 300 µm in diameter, sharply protruding (up to 300 µm), forming a high angle to the branch; proximal interior with a pair of pointed lateral denticles continuing into invaginations of the peristome to form a tubular proximal part limited externally by two longitudinal grooves, well evident only on young zooids. The resulting secondary orifice roughly rounded and deeply sinuate proximally.

Ordinary avicularia paired, persisting on ovicellate zooecia; rising from the distalmost lateral pair of areolae, placed on distolateral margins of the secondary orifice, the tubular avicularian chamber lining the peristome, the rostrum partly resting on the secondary orifice, proximally and upward directed, nearly perpendicular to the branch surface. Rostrum pointed; cross bar complete. On ovicelled zooids, avicularia tend to be smaller and inserted along the edge of the peristome, lateral to the ovicell, at about 1/4 of its high.

Special avicularia absent.

Fertile zooids larger, although not sensibly longer, than normal zooids, progressively enlarging towards the orifice, invariably and exclusively found in the two central rows of zooids. Orifice crescent-like, with a slightly arched distal lip showing a narrow reflected flange and an inflated protruding, but not really hooked proximal lip projecting over the ovicell and reaching its mid-line when fully developed. Proximal lip edge sculptured near the midline by 3-6 short, alternatively more and less marked, diverging ribs. Ooecial cover

rounded, the margin regularly arched distally. Sculpture nearly absent on the proximal region, evenly perforate and tuberculate in the middle and with basically aligned pores and granules to form a costulate pattern on the periphery.

Ancestrula sealed by calcification.

Measures (µm) -

	number	mean	range	standard deviation
Zooidal length	26	1652	1340-1910	171.29
Zooidal width	13	513	450-600	53.60
Fertile zooidal length	4	1775	1680-1880	85.44
Fertile zooidal width	5	802	720-900	79.50
Avicularian length	10	195	150-260	16.73
Avicularian width	10	97	90-110	6.75

Variability - Variability involves branch and zooidal dimensions as well as their shape, the latter mainly related to ontogeny. Zooidal boundaries are marked by raised sutures on springing branches, becoming more and more undefined, the marginal pores evolving into small pits. With increasing secondary calcification frontal walls thicken up to 350 µm; wide and discontinuous layers of calcification appear on the branch surface; avicularia and peristomes become occluded and coated and finally progressively smothered to simulate tubercles whereas surface becomes irregularly wrinkled.

Remarks - *Metrarabdotos elegantissimus* sp. nov. is easily recognisable within all known *Metrarabdotos* species, also at first sight, for its unique growth form consisting of slender, subcylindrical two-sided branches and for the frontal sculpture. The species is

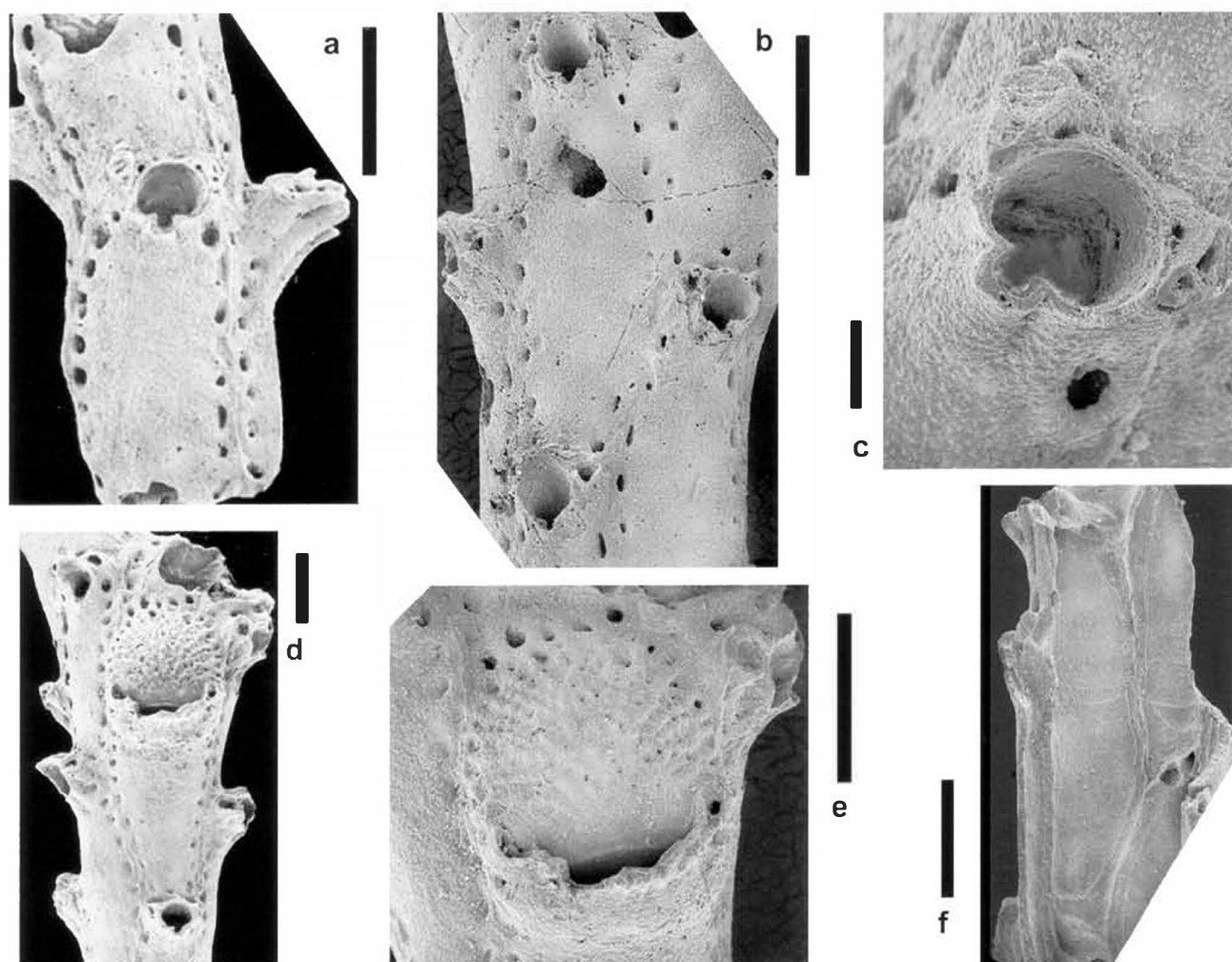


Fig. 3 - *Metrarabdotos elegantissimus* sp. nov. All specimens from Cala S. Antonino (Milazzo), Late Pliocene. Scale bars: 500 µm.
 a) Frontal view of a young tip. Well protruded peristomes lined by symmetrical avicularia are evident. Sample 1 (1998).
 b) A bifurcating branch with adult zooids, the boundaries only marked by peripheral areolae. A predator boring is obvious on the frontal surface of one zooid. Sample 1 (1999).
 c) Close-up of (a) showing the secondary orifice with its large squared sinus and the paired distally located avicularia. Sample 1 (1998).
 d) A fertile branch. Sample 1 (1998).
 e) A nearly complete ovicell, the cover smooth proximally and sculptured by radiating ribs separated by perforate furrows at the periphery. Sample 1 (1998).
 f) Longitudinal section of a branch with zooidal internal view and ring scars. Sample 1 (1999).

furthermore characterised by the peculiar shape and position of the avicularia, the morphology of both peristomes and ovicells.

Distribution - *Metrarabdotos elegantissimus* sp. nov. has been found exclusively in deep-water sediments cropping out at Capo Milazzo peninsula (north-eastern Sicily). These sediments, actually consisting of silts and sands with an extremely high content in CaCO_3 , are part of a Plio-Pleistocene succession, known as "yellow calcareous marls", which deposited after the post Messinian transgression, filling previous depressions (Fois, 1989, 1990). Sediments are mainly constituted by planktonic foraminiferan oozes locally comprising fossiliferous beds with abundant skeletons of benthic organisms, such as isidids, echinoderms,

bryozoans, benthic foraminiferans and brachiopods. *Metrarabdotos elegantissimus* sp. nov. comes from layers recording the MP15 and MP16 zones (Violanti, 1988 and pers. comm.), largely overlapping with the Gelasian Stage of Rio et al. (1994).

Paleoecology - Specimens of *Metrarabdotos elegantissimus* sp. nov., completely absent from pure foraminiferan muds, were found in almost all organogenic sandy layers, their abundance usually positively related to the gravelly fraction amount. The new species, in fact, forms erect colonies, which, although possessing a small encrusting base not exceeding 2 mm in diameter, needed suitably large hard substrata. A relatively small number of basal fragments, representing less than 0.5% of the total number, have

been found. Also ovicells are rare and fertile branches account for less than 1%. Finally, regeneration after fragmentation, a reproductive strategy common within some species belonging to the same genus (Cheetham et al., 2001; Cheetham, 2002), appears irrelevant as only two fragments show some evidence of regeneration. All this data could indicate that the species was present in the Capo Milazzo Upper Pliocene deep-water sediments, although always represented by a few colonies. The depositional palaeoenvironment was located in the epibathyal zone, as pointed out by studied assemblages allowing a palaeodepth of 500-600 m to be inferred (see Gaetani & Saccà, 1984; Gaetani, 1986; Violanti, 1988; Sciuto, 2003).

Metrarabdotos italicus sp. nov.
(Figs. 4a-l)

1987 *Metrarabdotos moniliferum* (Milne-Edwards) - BARRIER ET AL., tab.1 (*pars*), pl. 3, fig.4.

Etymology - Relating to the geographical area, which the species comes from.

Material - Pavigliana section sample 9, DL-VP 150-180 m, Late Pliocene. Holotype: a fertile branch (PMC B. 14a, 26.4.2003). Paratypes: the remaining fertile and sterile 119 branches (PMC B. 14b, 26.4.2003).

Pavigliana section: sample 4: 60 specimens, DC, 40 m; Early Pliocene; sample 8: 40 specimens, DC and SGCF, 100-120 m, Late Pliocene.

Cala S. Antonino centre: sample 2 (1999): 10 specimens VP and CB, 500-600 m, Late Pliocene (MPI5 Zone).

Description - Colony erect, originating from an encrusting base which gives rise to a subcylindrical stem, which in turns forms dichotomous branches. Branches roughly cylindrical or narrow, ribbon-like 1-2 mm in width, rarely more, compressed, before bifurcating.

Zooids in 6-10 alternating longitudinal rows, rarely up to 12-14. Insertion of new rows by bifurcation, observed only on a few of the available small fragments and apparently not related with other features. The first zooid of a new row proximally pointed, except for those distal to an ovicell.

Zooids rectangular elongated; strongly curved when placed laterally to an ovicell. Zooidal boundaries well marked by raised rims and a median groove early in ontogeny, suddenly obscured by calcification.

Frontal shield umbonuloid with finely granular and slightly convex surface, limited by about 20 evenly distributed marginal pores becoming less obvious after the thickening of the frontal surface late in ontogeny. Interareolar costulae not evident. Primary orifice hidden within peristome with an arched, not well developed, pouch-shaped distal shelf. Peristome tubular, about 300 μ m in diameter, and not very raised except on zooids of the lateral rows where sharply protrudes, up to 350 μ m; proximal interior with a longitudinal groove marked by two lateral ridges tending to converge at mid length

thus simulating two pair of pointed lateral denticles subsequently placed inside the peristome. Secondary orifice semielliptical, with a marked narrow and deep proximal sinus.

Ordinary avicularia paired, persisting on ovicellate zoecia; originating from the distalmost lateral pair of areolae, distolaterally placed to the secondary orifice, the avicularian chamber lining the peristome, the rostrum perpendicular to the branch surface, proximally and inward directed. Rostrum pointed, elongated; cross bar complete. On ovicelled zooids, avicularia are smaller and curved along the edge of the peristome, lateral to the ovicell, at about 1/3 of its high.

Special avicularia *sensu stricto* are absent although some avicularia placed along branch margins and, more rarely, on zooids distal to ovicells could be slightly curved and a bit larger than normal ones.

Fertile zooids longer than normal ones, sensibly and suddenly enlarging, their maximum width at level of the modified peristomes. Orifice crescent-like, with a straight distal lip edged by a smooth reversed flange and deeply hidden by the smooth-to-lightly tuberculate, extremely inflated, protruding proximal lip, which largely projects over the ovicell, when fully developed. Ovicell roughly rounded, arched-to-truncated distally; the ooecial cover moderately convex, sculptured by numerous radial ribs separated by porous grooves and margined by a row of areolae, similar to the frontal ones.

Ancestrula sealed by calcification; in a single instance an ancestrular triad, each part accounting for a sector of about 120°, is visible in basal view.

Measures (μ m) -

	number	mean	range	standard deviation
Zooidal length	33	1104	990-1220	63.54
Zooidal width	26	393	330-520	42.87
Fertile zooidal length	8	1498	1320-1630	101.38
Fertile zooidal width	8	776	700-820	37.39
Avicularian length	12	228	200-320	37.90
Avicularian width	12	122	110-150	12.67

Variability - Variability involves branch flattening and width, zooidal shape and dimensions. Secondary calcification increasing in ontogeny seals zooidal boundaries and marginal pores and occludes orifices transforming basal branches in strongly calcified stems with a somewhat uniform surface only marked by light, irregular longitudinal furrows.

Remarks - *Metrarabdotos italicus* sp. nov. roughly resembles *M. nysti* Lagaaij, 1952, for the salient peristomes, the somewhat costulate ovicell shield and the well protruded proximal lip of ovicelled zooids. Nevertheless, this latter species, seemingly with larger branches, has proximally located, slightly distally directed peristomial avicularia and a heavily costulate proximal lip in ovicellate zooids. *M. italicus* sp. nov. recalls also *M. elegantissimus* sp. nov. for zooidal characters, from which it is although easily recognisable, at first sight, for the branch shape and the peculiar arrangement of zooids along them. Besides, *M. italicus* sp. nov. has sensibly smaller zooids (more

obviously shorter than slender), more differentiated from fertile zooids, which are sensibly longer and above all wider, than the sterile ones. The oral distal shelf is wider and the secondary orifice in *M. italicus* sp. nov. appears larger and marked by a comparatively narrower proximal sinus. Peristomial avicularia are altogether

more developed and somewhat differentiated, placed in a slightly proximal position. Ovicells show a more developed, apparently not sculptured proximal lip, more projecting on the ooecial cover. Furthermore, the narrow, ribbon-like branches together with the shape and position of the peristomial avicularia, the

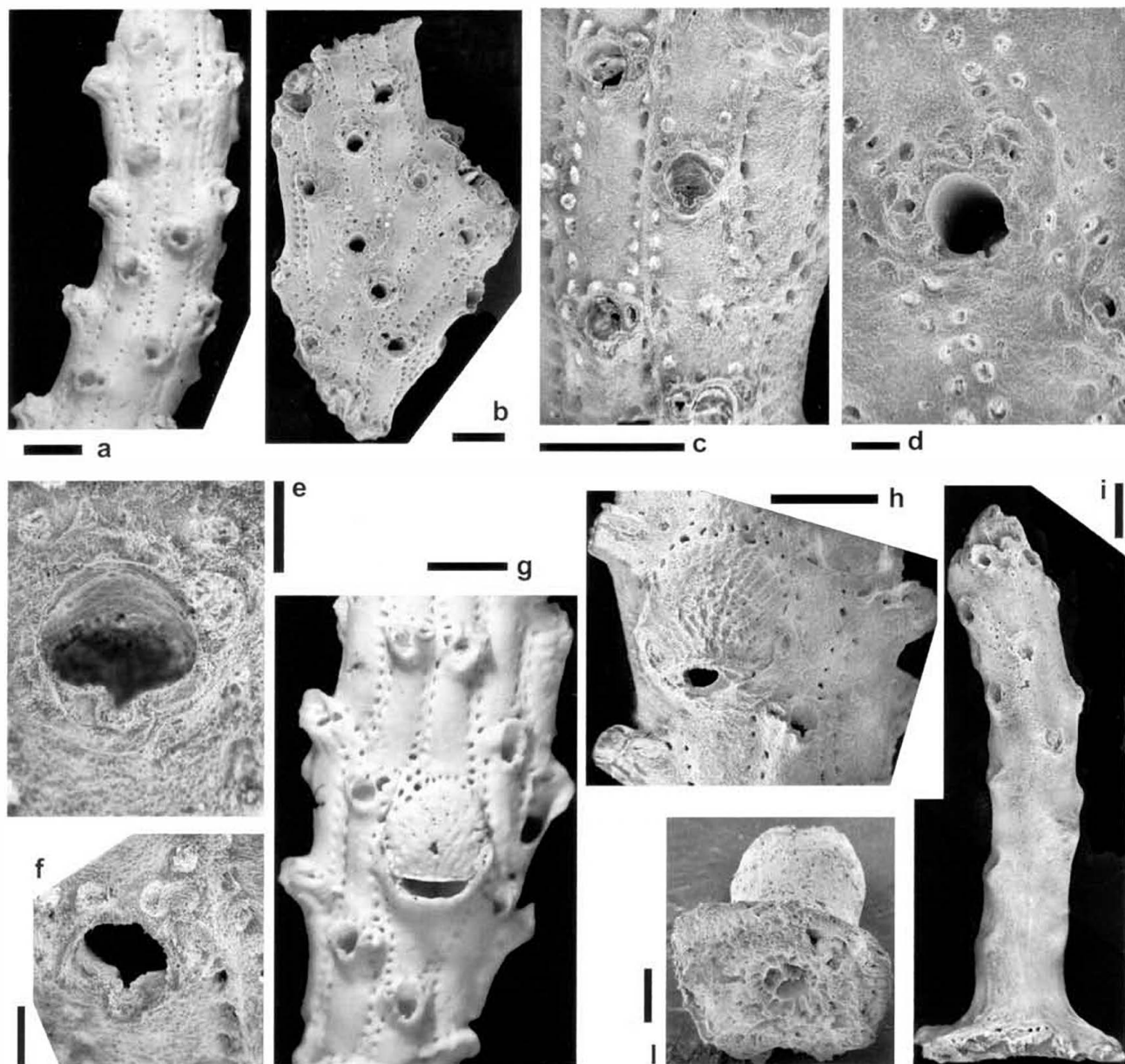


Fig. 4 - *Metrarabdotos italicus* sp. nov. All specimens from the Pavigliana section (Reggio Calabria). Scale bars: 500 μ m for a-c, and g-l; 100 μ m for d-f.

- a) A young sterile branch with protruding peristomes. Sample 9. Late Pliocene.
- b) An adult sterile branch. Sample 4. Early Pliocene.
- c) Cluster of zooids with a bifurcating row from a proximally cuneiform zooid. Sample 9. Late Pliocene.
- d) Secondary orifice with narrow sinus and peristomial, paired avicularia. Sample 9. Late Pliocene.
- e) Close-up of a secondary orifice. Sample 9. Late Pliocene.
- f) Orifice inclined to show the longitudinal internal groove and the lateral ridges slightly converging at mid length. Sample 9. Late Pliocene.
- g) Fertile branch with a complete ovicell. Sample 9. Late Pliocene.
- h) Close-up of an ovicell sculptured by radiating ribs; the orifice partly occluded. Sample 9. Late Pliocene.
- i) A colony stem and its small encrusting base, covered by extrazoooidal calcification. Old, not functional zooids show occluded orifices. Sample 9. Late Pliocene.
- l) Bottom view of the encrusting base with the centrally located circular ancestrular complex formed by three 120° sectors. Sample 9. Late Pliocene.

development of marginal pores as well as the morphology of ovicells characterise this species among other European cogenetic ones. Similarities could be stressed with an undescribed species from Rhodes figured by Cheetham (2002) although specimen examination is needed to state conspecificity.

Distribution - *Metrarabdotos italicus* sp. nov. has been found in two nearby localities from southern Italy: Pavigliana in southern Calabria and Capo Milazzo in the north-eastern corner of Sicily. Stratigraphically, the species seems to be widely distributed in the Pliocene, from the *Globorotalia puncticulata* to the *G. inflata* Zone in the Pavigliana section (Barrier et al., 1987). Within this time interval, probably in the MPI5 Zone, deposited also the Cala S. Antonino layers containing *M. italicus* sp. nov.

Paleoecology - Most specimens of *Metrarabdotos italicus* sp. nov. come from sandy (mainly medium-to-coarse sands) sediments containing abundant skeletal remains of benthic organisms (essentially molluscs, bryozoans and subordinate brachiopods) pointing to middle-to-outer shelf environments (Barrier et al., 1987). Fossil associations allow to infer that sands were colonised by coastal detritic assemblages (DC) near the Infralittoral-Circalittoral boundary, and detritic offshore assemblages (DL) at the shelf edge, testifying depths up to 150-180 m. Palaeoenvironments were characterised by strong bottom currents (Barrier et al., 1987). In a single case, sample 2 (1999) from Cala S. Antonino, a few specimens were found in deep-water sediments, though probably containing inputs from nearby, shallower edge shelf environments. Like the preceding species, also *M. italicus* sp. nov. seemingly developed small sized colonies, arising from encrusting bases not exceeding 2 millimetres in the present material, thus exploiting coarse sandy or the rare fine gravelly elements, as substrates. Sexual propagation was probably the unique reproductive strategy for this species as only a single doubtfully regenerated branch has been observed; ovicelled fragments are common with an incidence of about 18% whereas bases are rare, not exceeding 2% of total fragments.

Metrarabdotos pauciararmatus sp. nov.
(Figs. 5a-m)

1987 *Metrarabdotos* cf. *moniliferum* (Milne-Edwards) - DI GERONIMO ET AL., tab. 1.

1992 *Metrarabdotos* sp. DI GERONIMO ET AL., tab. 3 (pars).

Etymology - Relating to the scantiness of avicularia and to their complete absence on most zooids.

Material - Ringiglio section: sample 2, PE1, about 30 m. Holotype: a sterile branch with avicularia on lateral zooids (PMC B. 15a, 26.4.2003). Paratypes: the remaining 237 sterile fragments (PMC B. 15b, 26.4.2003); Early Pleistocene.

Ringiglio section: sample 1: 80 specimens, PE1, about 20 m; sample 3: 1 specimen, PE1, 20-30 m; Early Pleistocene.

Description - Colony erect formed by ribbon-like branches 1-4 mm in width, compressed, enlarged before bifurcating. Trifurcation and irregular branching giving rise to slightly twisted branches common.

Zooids in 10-20, sometimes up to 30, alternating longitudinal rows. Common insertion of new rows by bifurcation in zones of rapid widening; first zooids of new rows proximally cuneiform.

Zooids relatively small, rectangular elongated or club-shaped, sometimes constricted in the middle. Zooidal boundaries markedly raised to form swollen thick ribs, more and more obvious with increasing calcification, up to as wide as the proximal half of a zooid, late in ontogeny. Zooids placed along the margins wider than the central ones. Frontal shield convex and coarsely granular tending to develop a few large tubercles aligned on the midline; limited by 18-20 evenly distributed large rounded marginal pores, except at the proximal end where they become larger and quadrangular or often develop as a unique arched cleft, becoming more and more obvious late in ontogeny. Interareolar costulae usually weak and peripheral, sometimes marked by granule arched alignments. Primary orifice marked by a small proximally projecting pouch-shaped distal shelf. Peristome low except on zooids of the lateral rows where it extends slightly on the distal margin of the zooid and protrudes giving a serrated appearance to the branch margin; denticles, a proximal lateral pointed pair, shallowly set. Secondary orifice distally developing in a thin, proximally sinuate, round tubule.

Ordinary avicularia absent on most zooids, single and small, laterally placed to the peristome and proximally directed, not easily distinguishable from marginal areolae. They are present in a very few instances on zooids of the central part of the branches, more common on lateral zooids and, above all, on the marginal broader ones, often paired with larger sized special avicularia, characterised by a chamber extending distally beyond the orifice; rostrum pointed and slightly curved around the margin of the orifice, directed proximally.

Fertile zooids not present on the studied material. Ancestrulae and bases not observed.

Measures (μm) -

	number	mean	range	standard deviation
Zooidal length	26	843	760-940	44.98
Zooidal width	18	329	290-400	32.08
Lateral zooidal length	23	909	810-1020	55.10
Lateral zooidal width	17	484	420-580	46.38
Avicularian length	11	167	140-220	26.11
Avicularian width	12	94	70-130	16.76

Variability - Branch width and number of longitudinal zooidal rows varying to some extent as well as zooidal size and shape. Nevertheless, variability appears mainly related to ontogenetic stage, involving increasing secondary and extrazooidal calcification. Zooidal margins, raised but comparably thin in young stages, become thick and swollen; surfaces granular at the beginning, can develop coarser granules up to true tubercles along the mid line; zooidal interareolar

costulae sometimes evolve into vertical walls above frontal surfaces. The abnormal development of the latter two features, enlarging, strongly rising and coalescing to some extent, form patches of irregular "spongy" surfaces. Some fragments, seemingly corresponding to stems or near-base branches, are draped by a thin layer of extrazoooidal calcification, the surface marked by irregularly anastomosing longitudinal ridges and furrows, locally by coarse tubercles.

Remarks - *Metrarabdotos pauciararmatus* sp. nov. is easily recognisable amongst all the species known from the European-African area for the absence of avicularia in nearly all zooids except the marginal ones. When present, ordinary avicularia are single. The presence of a single avicularium is a feature shared only with *M. pouyeti* Marcopoulou-Diacantoni & Wuest from the Late Pliocene of Greece, but no marginal special avicularia have been reported for this species. Finally, *M. terraconensis* Reguant, 1960, from the Burdigalian of Spain, showing somewhat similar zooidal characters (low peristomes and large peripheral areolae) completely lacks avicularia. Thus, it is likely that these three species could be closely allied. Taking into account the trend absence/presence of avicularia through single normal avicularia versus normal plus special avicularia, an increasing complexity can be envisaged, seemingly pointing to a phyletic relationship *M. terraconensis*-*M. pouyeti*-*M. pauciararmatus*. Nevertheless, further knowledge is needed about distribution in time and space of *Metrarabdotos* species in the area, to put forward more valuable hypotheses.

Distribution - *Metrarabdotos pauciararmatus* sp. nov. has been found only in sediments cropping out along the Ringiglio section, near Mazzarino (central Sicily) which have been referred to the Early Pleistocene (Di Geronimo et al., 1987), namely to the uppermost part of the Emilian stage.

Paleoecology - *Metrarabdotos pauciararmatus* sp. nov. comes from fine sands comprising an about 30% mud fraction; specimens reducing dramatically when mud rises to about 50%. Bryozoan assemblages are oligospecific and mainly represented by the lunulitiforms *Reussirella reussiana* (Manzoni) and *Cupuladria gr. canariensis* (Busk) to which *Biflustra savartii* (Audouin) and *Chaperiopsis annulus* (Manzoni) add. Macrofaunas are largely constituted (ca. 90%) by the free living serpulid *Ditrupea arietina* (Mueller) and the bivalve *Corbula gibba* (Olivi), two filter-feeding, opportunistic species, whose dominance is indicative of the so called heterogeneous communities living in biotopes largely influenced by water turbidity linked to high muddy inputs, mainly in basin instability conditions (Di Geronimo et al., 1987, 1992; Di Geronimo & Robba, 1989).

M. pauciararmatus sp. nov. is exclusively represented by fragments, the largest of which, three times branched, is about 2 cm high and 4 mm wide. It is likely that colonies were larger and comparable in size

to those of other Neogene-to-Recent Mediterranean adeonelliform species, which grow up to 10-20 cm in high, or more. It is worth noting that neither bases nor ovicells were found in the studied material. In addition, some of the largest fragments show some evidence of twisting and irregular branching, often linked to regeneration, usually by distal budding. In a single instance a short branch arises from two adjacent zooids by frontal budding. Finally, some fragments show evidence of secondary, extrazoooidal calcification enveloping previously broken branch surfaces. All this points to hypothesise as fossil populations of *M. pauciararmatus* sp. nov. seemingly exploited an asexually reproductive strategy, at least in the inferred, particularly stressed palaeohabitat, where colonisation likely happened through the input of broken branches from neighbouring hard and/or coarse-grained bottoms, which survived and continued to grow by regeneration in the palaeobiotope. Similar adaptations have been sometimes observed for adeonelliform species, such as *Smittina cervicornis* (Pallas) and *Adeonella calveti* (Canu & Bassler).

Metrarabdotos cf. *elegans* Buge & Galopim de Carvalho, 1963
(Fig. 6f)

- 1963 *Metrarabdotos elegans* BUGE & GALOPIM DE CARVALHO, p.162, pl. 1, figs. 3-4, text-figs. 13-14.
- 1966 *Metrarabdotos elegans* Buge & Galopim de Carvalho - BUGE, p. 42, pl. C, fig. 5.
- 1971 *Metrarabdotos elegans* Buge & Galopim de Carvalho - GALOPIM DE CARVALHO, p. 141, text-fig. 20.
- 1976 *Metrarabdotos elegans* Buge & Galopim de Carvalho - POUYET, p. 74, pl. 12, figs. 1-2, 7.
- 1987 *Metrarabdotos moniliferum* (Milne-Edwards) - BARRIER ET AL., tab.1 (pars), non pl. 3, fig.4.
- 1992 *Metrarabdotos elegans* Buge & Galopim de Carvalho - EL HAJJAJI, p. 230, pl.14, fig. 6.
- 1997 *Metrarabdotos elegans* Buge & Galopim de Carvalho - HAMDANE & MOISSETTE, fig. 15 (2).

Material - Pavigliana section: sample 16b, VP, 500 m, Early Pleistocene (Emilian).

Description - Colony seemingly formed by branches, at least up to 3 mm in width.

Zooids in 18, irregularly alternating longitudinal rows, in the unique observed fragment comprising only a margin. Common insertion of new rows by bifurcation, the first zooid proximally cuneiform.

Zooids relatively small, subrectangular or variously constricted. Zooidal boundaries marked by a thin raised rim. Frontal shield convex and granular limited by about 20 marginal pores, separated by moderate interareolar costulae. Peristome thin and raised, more developed and longitudinally channelled proximally. Secondary orifice orbicular, with a proximal narrow and deep sinus.

Ordinary avicularia paired, proximo-laterally placed to the orifice, the avicularian chamber lining the peristome; cross bar complete; rostrum pointed, upward and inward directed.

Fertile zooids, ancestrulae and bases not observed.

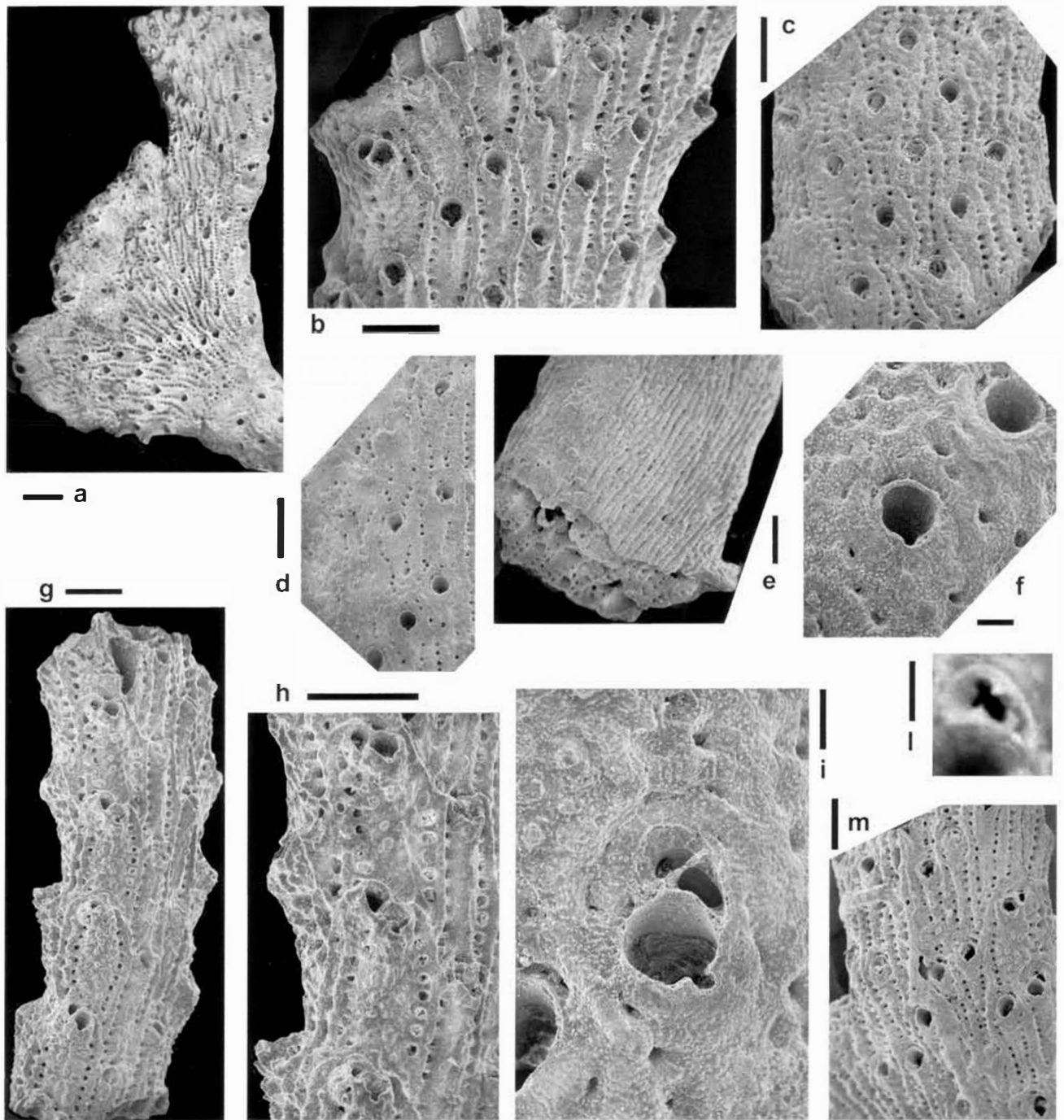


Fig. 5 - *Metrarabdotos pauciarimatus* sp. nov. All specimens from the Ringiglio section (Mazzarino), Early Pleistocene. Scale bars: 500 µm for a-e, g-h and m; 100 µm for f, i-l.

- a) Large, irregularly lobate and partly regenerated branch. Sample 2.
- b) Young branch with serrated margins. Note the inarmate centrally located zooids. Sample 2.
- c) Adult branch with heavily calcified zooids. Secondary calcification better seen at basal left. Sample 2.
- d) Near base portion showing increasing calcification leading to orifice occlusion. Sample 2.
- e) Near-base portion of a branch showing extrazoooidal calcification forming longitudinal ridges and furrows. Sample 3.
- f) Secondary orifices with low peristomes partly hidden by secondary calcification. Sample 2.
- g) Branch side showing larger peripheral zooids with special avicularia. Sample 2.
- h) Close-up of (g) with the branch margin. Sample 2.
- i) Detail of the orifice of a marginal zooid showing the proximally sinuate thin peristome and the single peristomial avicularium. Sample 2.
- j) Peristomial avicularium. Sample 2.
- k) A fragment overgrown during life. Sample 2.

Measures (µm) -

	number	mean	range	standard deviation
Zooidal length	9	906	830-1060	84.87
Zooidal width	9	374	310-450	50.03
Avicularian length	8	195	170-220	19.27
Avicularian width	8	96	80-110	11.88

Variability - Variability relates to zooidal and avicularian shape and size on the unique available fragment.

Remarks - The observed fragment has been tentatively assigned to *M. elegans* as it is the unique species in the area with paired lateral avicularia proximally located in respect to the orifice. Nevertheless, the present fragment actually differs from figures and descriptions in literature for the zooidal shape, not constantly sandglass-shaped, and for avicularian shape and position, more elongated and not so proximal as in *M. elegans*. Available data is inadequate to state if it surely falls or not within *M. elegans* variability.

Distribution - Until now *Metrarabdotos elegans* was known from the westernmost Mediterranean area coming back from the Messinian (Morocco: El Hajjaji, 1992) and the Pliocene (Morocco and Portugal: Buge & Galopim de Carvalho, 1963; Galopim de Carvalho, 1971; Spain: Pouyet, 1976; Algeria: Hamdane & Moissette, 1997).

Palaeoecology - The species has been recorded from shelf environments and the not well-preserved fragment found in Pleistocene bathyal sediments could have been displaced or likely reworked from older (Pliocene) shallower sediments.

Metrarabdotos cf. *teixeirai* Buge & Galopim de Carvalho, 1963
(Figs. 6a-e)

- 1963 *Metrarabdotos teixeirai* BUGE & GALOPIM DE CARVALHO, p. 157, pl. 1, figs. 1-2, text-figs. 10-11;
1966 *Metrarabdotos teixeirai* Buge & Galopim de Carvalho - BUGE, p. 41, pl. C, fig. 1;
1971 *Metrarabdotos teixeirai* Buge & Galopim de Carvalho - GALOPIM DE CARVALHO, p. 143, pl. 22, figs. 2, 4, text-fig. 21.
1987 *Metrarabdotos moniliferum* (Milne-Edwards) - BARRIER ET AL., tab.1 (pars), non pl. 3, fig.4.

Material - Pavigliana section: sample 4, 78 specimens, DC, 40 m; sample 5: 28 specimens, DC and SGCF, 50 m, Early Pliocene; sample 8: 9 specimens, DC and SGCF, 100-120 m, Late Pliocene.

Description - Colony erect. Branches ribbon-like slightly enlarged before bifurcating, the largest about 3 mm wide and 8 mm high.

Zooids in 14-16, often up to 24, regularly alternating longitudinal rows; the disposition of orifices simulating a pinnate pattern along branches. First zooids in bifurcating rows proximally cuneiform.

Zooids small, rectangular to club-shaped, sometimes undulate; laterally arched and proximally tapered, when lateral to ovicells; somewhat raised distally. Zooidal boundaries raised and swollen, with a median furrow. Marginal zooids wider and slightly longer than the central ones. Frontal shield with nearly 20 small marginal pores evenly distributed, separated by interareolar costulae on the periphery; central area convex, granular. Peristome low. Secondary orifice rounded and proximally sinuated.

Ordinary avicularia, paired or single, constant and persisting on ovicellate zooids; placed laterally and level to the peristome, rarely slightly distally; proximally directed; their chambers tubular, commonly broken. Rostrum pointed, cross bar complete.

Special avicularia larger, located on marginal and/or peri-ovicellate zooids, sometimes sporadically on zooids of the central rows, usually paired with a normal one. Their chamber extends distally beyond the orifice; the rostrum sharply pointed, directed proximally.

Fertile zooids common, placed in central rows, often clustered (up to 5-6) on some branches, sensibly larger and longer than normal zooids, suddenly and sharply enlarging at peristome level. Orifice invariably broken; distal lip straight with a narrow reflected flange; proximal lip protruding and projecting, for at least 1/4, over the ovicell. Ooecial cover rounded-to-mitre-shaped, sometimes truncated distally. Sculpture given by tuberculate ribs alternating with perforate furrows forming a costulate pattern.

An ancestrular tetrad is hardly visible on the unique base surrounded by extrazoooidal calcification occluding orifices of basal zooids and making the surface winding sulcate.

Measures (µm) -

	number	mean	range	standard deviation
Zooidal length	22	760	620-860	66.26
Zooidal width	18	313	280-360	24.01
Fertile zooidal length	12	1183	960-1300	82.28
Fertile zooidal width	12	719	640-850	58.07
Lateral zooidal length	9	816	720-970	80.48
Lateral zooidal width	9	477	430-500	26.93
Avicularian length	6	125	110-140	13.78
Avicularian width	6	80	70-90	6.32
Special avicularian length	10	254	200-340	52.54
Special avicularian width	10	130	110-140	13.36

Variability - Zooidal and avicularian measures show a certain degree of variability, as well as zooidal shape. Ontogenesis, with increasing frontal and extrazoooidal calcification, accounts for branch thickening.

Remarks - Present material has a bad preservation state owing to heavy recrystallization processes, preventing some characters to be observed. Specimens have been referred to *Metrarabdotos teixeirai*, owing to zooidal shape, position of paired normal avicularia and ovicell sculpture, although doubtfully, as sizes of both sterile and fertile zooids are smaller than those reported by Buge (1966) and Galopim de Carvalho (1971). The presence of special avicularia and marginal wider zooids observed in the studied specimens, but

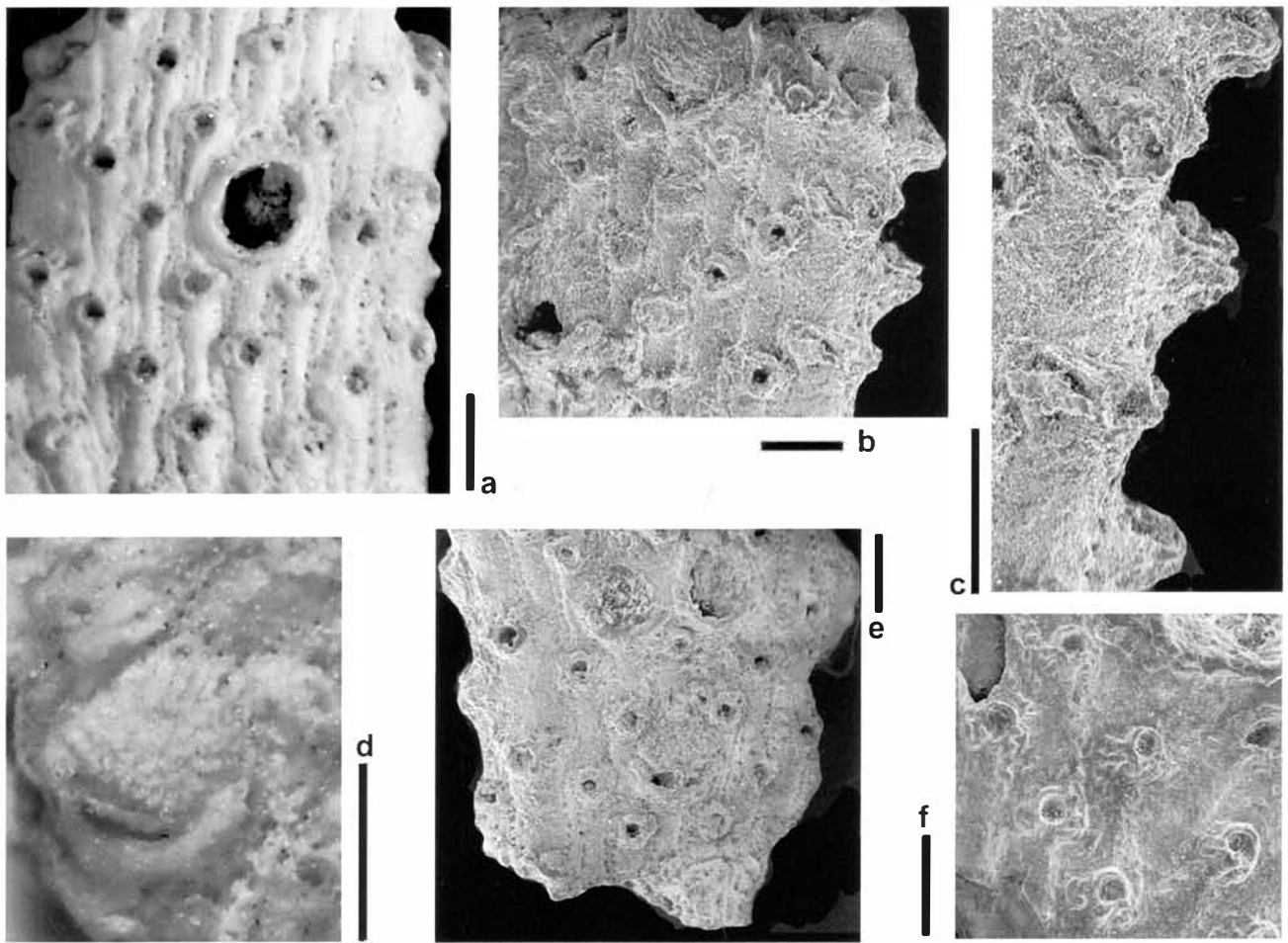


Fig. 6 - a-e: *Metrarabdotos* cf. *teixeirai* Buge & Galopim de Carvalho, 1963. All samples from the Pavigliana section, Early Pliocene, f: *Metrarabdotos* cf. *elegans* Buge & Galopim de Carvalho, 1963. Scale bars: 500 μ m for a-b, d-f; 200 μ m for c.

a) Adult branch. Sample 4.

b) Fertile recrystallised branch with two ovicells. Note the normal, relatively small avicularia and the large special marginal ones. Sample 5.

c) Close-up of (b) to show marginal special avicularia. Sample 5.

d) Detail of an ovicell. The radial discontinuous ribs separated by perforated furrows are evident despite the heavy recrystallisation. Sample 5.

e) Characteristically clustered ovicells. A well preserved orifice is visible at the left top. Sample 5.

f) Partly abraded specimen showing secondary orifices and peristomial avicularia. Pavigliana section (Reggio Calabria), Early Pleistocene. Sample 16b.

not recorded in literature, would make desirable the examination of type material for a better confidence in the suggested attribution. It is worth noting that although some of the species erected by Buge & Galopim de Carvalho (1963) were redescribed, after the paper by Cheetham (1968) had been published, by Galopim de Carvalho (1971), this latter author didn't supply any information about special avicularia and other diagnostic characters. Nevertheless, special avicularia have been recently described for the closely related species *M. lecointrei* Buge & Galopim de Carvalho, by El Hajaji (1992).

M. cf. teixeirai recalls *M. italicus* but differences are obvious, such as the distalmost position of larger peristomial avicularia and the absence of truly differentiated special avicularia on marginal zooids. Last

but not least, sizes of both sterile and fertile zooids are sensibly larger in *M. italicus*, which shows a lower incidence (see above) of never clustered fertile zooids.

The species is also similar to *M. lecointrei* Buge & Galopim de Carvalho, the latter characterised by larger zooids showing marginal pores, locally in double rows and by larger sized peristomial avicularia in a distalmost position.

Distribution - In southern Italy *Metrarabdotos* cf. *teixeirai* has been found only in sediments cropping out along the Pavigliana section (southern Calabria), from Early-to-Late Pliocene in age (Barrier et al., 1987). Previous records refer to Pliocene from Portugal and Morocco (Buge, 1966; Buge & Galopim de Carvalho, 1963; Galopim de Carvalho, 1971).

Paleoecology - *Metrarabdotos* cf. *teixeirai* has been found in sandy sediments containing faunas belonging to the coarse sands and fine gravels under the influence of bottom currents (SGCF) and the detritic bottom (DC) assemblages, thus testifying deposition in soft, mid shelf, current swept bottoms. Bryozoans are mainly constituted by *Turbicellepora tubigera* (Busk), *Smittina cervicornis* (Pallas), *Melicerita charlesworthi* Milne-Edwards, *Entalophoroecia deflexa* (Couch) and *Tervia irregularis* (Meneghini) and by minor percentages of *Onychocella marioni* Jullien, *Tremopora radificera* (Hincks) and *Hippopleurifera sedgwicki* (Milne-Edwards).

A single base has been found in the present material but, unlike most of the previously cogenetic described species, *M.* cf. *teixeirai* shows a high incidence of ovicellate fragments, with a mean value of 32%, ranging from 14% (sample 5) to 77% (sample 8). This, joined with the absence of regenerated fragments, points to a sexual reproductive strategy.

CONCLUSIONS

The present study allowed the identification of five different species belonging to the genus *Metrarabdotos* Canù, 1914 from southern Italy, namely central-eastern Sicily and southern Calabria.

Three of them (*Metrarabdotos elegantissimus* sp. nov., *M. italicus* sp. nov. and *M. pauciarmatus* sp. nov.) are new, whereas the remaining two have been referred, although doubtfully, to *M. elegans* Buge & Galopim de Carvalho and *M. teixeirai* Buge & Galopim de Carvalho. The latter two species were previously known from the Iberian Peninsula and Morocco, with *M. elegans* recorded from the Algeria too. All but not *M. pauciarmatus* lived during Pliocene; with *M. elegantissimus* seemingly restricted to Late Pliocene and *M. elegans*, recorded since the Messinian, in Morocco, probably the long living species. The younger species seems to be *M. pauciarmatus*, which has been found only in Emilian (Lower Pleistocene) sediments. To the present knowledge, this taxon could be one of the younger or even the youngest one in the Old World area.

A further species, *M. moniliferus*, the unique one previously recorded from Italy is perhaps quite absent from the area. This taxon was quoted, mainly by 1800 researchers, from Pliocene and Quaternary sediments (Seguenza, 1879-80; De Stefani, 1882; Namias, 1891; Neviani, 1891, 1894, 1900a, b; De Angelis d'Ossat & Neviani, 1896) and most recently from Lower Pleistocene clays in southern Italy (Calabrian, Venosa: Annoscia, 1963) and Crotonian sands from western Sicily (Poluzzi & Padovani, 1984). Nevertheless, all or, at least, part of the old material (only partly and

		<i>M. vigneauxi</i> Cheetham, 1968	<i>M. maleku</i> Cheetham, 1968	<i>M. terraconensis</i> Reguani, 1960	<i>M. canui</i> Buge & Galopim de Carvalho, 1963	<i>M. vinassai</i> Pantera, 1932	<i>M. helveticus</i> Roger & Buge, 1943	<i>M. girondicus</i> Duvergier, 1924	<i>M. nysti</i> Lagaail, 1952	<i>M. h. canariense</i> Cheetham, 1968	<i>Metrarabdotos</i> sp. Moissette, 1968	<i>M. moniliferus</i> Milne-Edwards, 1836	<i>M. lecointrei</i> Buge & Galopim de Carvalho, 1963	<i>M. elegans</i> Buge & Galopim de Carvalho, 1963	<i>M. teixeirai</i> Buge & Galopim de Carvalho, 1963	<i>M. pouyeti</i> Marcopoulou-Diacantoni & West, 1999	<i>M. italicus</i> sp. nov.	<i>M. elegantissimus</i> sp. nov.	<i>M. pauciarmatus</i> sp. nov.
Pleistocene																			I (e)
Pliocene	Gelasian								R*	B F UK *	M*	P S M *	P M I *	C	I	I			
	Piacenzian								R*	B F UK *	M*	P S M *	P M I *	C (I?)	I	I (I)			
	Zanclean								R*	B F UK *	M*	P S M *	P M I *		I (I)				
Miocene	Messinian								B	Ca?*	A								
	Tortonian				S	L	L F	F	B	Ca?*									
	Serravallian				?					?									
	Langhian				?					?									
	Burdigalian		Au Cz Po Ru Y	S	S					?									
	Aquitainian									?									
Oligocene	Chattian																		
	Rupelian	F																	

Tab. 1 - Stratigraphic distribution of the "Old Word" species of *Metrarabdotos*. A = Algeria; Au = Austria; B = Belgium; C = Crete; Ca = Canarian; Cz = Czech Republic; F = France; I = Italy; L = Libya; M = Morocco; P = Portugal; Po = Poland; R = Rhodes; Ru = Rumania; S = Spain; UK = United Kingdom; Y = Yugoslavia. Asterisks indicate that in literature only the Epoch is given without reference to Ages; (e) = Early; (I) = Late.

hardly available) clearly doesn't belong to *M. moniliferus*, as often a costulate ovicell was been described (see Seguenza, 1880: p. 208, for example). Moreover, both the most recent (1990s) records appear doubtful, either for the bad preservation of specimens (abraded and showing broken ovicells as obvious also from figures) either for the sedimentary context allowing reworking processes to be hypothesised. Otherwise, most records of *M. moniliferus* need to be re-evaluated (see Cheetham, 1968) and the distribution of this species seems presently restricted to Pliocene sediments of some European localities (U.K., the Netherlands, France, Iberian Peninsula: Lagaaij, 1952; Buge, 1957; Buge & Galopim de Carvalho, 1963; Galopim de Carvalho, 1971) and maybe North Africa (Morocco, Tunisia: Galopim de Carvalho, 1971). Pleistocene specimens from the U.K. and the Netherlands, on the contrary, have been considered probably reworked (Cheetham, 1968).

Species of *Metrarabdotos*, which are easily distinguishable for their morphological characters, appear also well separated ecologically. Apart from *M. elegans*, for which a few data is available, the three Pliocene species placed themselves in different bathymetric horizons also exploiting slightly to sharply diverse substrata. *M. teixeirai* seemingly lived on soft sands, in mid-to-outer shelf environments. This distribution was partly overlapped by *M. italicus*, yet extending towards major depths, to the shelf break. *M. elegantissimus* thrived in epibathyal bottoms with palaeodepths of about 500-600 meters. It could be worth noting as these three species line up subsequently in a two axes diagram considering zooidal width *versus* zooidal length, both for sterile and fertile zooids. The line up, from species with small-sized towards large-sized zooids, fits well with the inferred distribution from shallow shelf waters to deep slope waters. Within species and within genotype zooidal size variability, both in time and space, has been observed in several cheilostome bryozoans and related to water temperature (see O'Dea & Okamura, 2000 for a review). If we assume that similar changes extend also to interspecific, within genus variability, the progressively increasing zooidal size registered in the above-recorded species, could be linked to physiological changes related to decreasing water temperature, at great depths, in an area seemingly subject to upwellings.

Finally, *M. pauciararmatus*, seemingly the shallowest species, was capable of exploiting a particularly stressed palaeoenvironment characterised by abnormal sedimentary inputs. Broken fragments seemingly survived and continued to grow adopting twisting and combining sexual and asexual reproduction, by fragmentation, as a winning adaptation strategy.

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