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A new group of microfossils: Middle Miocene (Badenian) opercular caps (*calottae*) of the tube-dwelling polychaetes *Vermiliopsis* SAINT-JOSEPH, 1894

ABSTRACT: A new group of microfossils, consisting of the calcareous opercular caps, or calottae, of tube-dwelling polychaetes of the genus *Vermiliopsis* SAINT-JOSEPH, 1894, is entertained to describe a Middle Miocene (Badenian) material derived from the Korytnica Basin, southern slopes of the Holy Cross Mountains, Central Poland. The updated reports on any fossil opercula of the tube-dwelling polychaetes are reviewed, to indicate their difference from the studied material. The opercular system in the present-day species of the genus *Vermiliopsis* is shown, to accentuate the structural setting of the studied ancient calottae, among which three morphological groups are distinguished. These groups are described, in the open nomenclature, as the calottae comparable to those of the present-day species, viz. *Vermiliopsis infundibulum* (PHILIPPI, 1844), *V. labiata* (O.G. COSTA, 1861), and *V. monodiscus* ZIBROWIUS, 1968. The noted differences are discussed, and such factors as various stratigraphic age (thus, phylogeny), preservation and/or taphonomic loss (? abrasion), and biotope conditions (environmental stress, various bioprovince connections) are thought to have influenced differences in morphology and/or biomineralization of the studied Middle Miocene calottae and of their present-day counterparts.

INTRODUCTION

The aim of the present paper is to describe a peculiar, and as yet unique material of microfossils derived from the Middle Miocene (Badenian) deposits of the Korytnica Basin, southern slopes of the Holy Cross Mountains, Central Poland. These microfossils have long remained unrecognizable as not having any comparable counterparts in the paleontological literature. Their nature has clarified during a comparative study of present-day polychaetes whose tubes were analyzed in reference to the material from the Korytnica Basin, and recently subjected to its monographic description (RADWAŃSKA 1994). It became apparent that these microfossils represent isolated parts of the opercular system closing the tubes of some present-day polychaetes. A study of present-day materials, kindly supplied by Dr. Helmut ZIBROWIUS, *Station Marine d'Endoume*, Marseilles, indicates an attribution of the fossil specimens to the genus *Vermiliopsis* Saint-Joseph, 1894, whose present-day representatives bear almost the same structural elements. An assemblage of the polychaete tubes from the Korytnica Basin contains, however, both the living (extant) as well as the extinct species of that genus (*see* Radwańska 1994). Thus, to avoid any taxonomic misinterpretation, the collected opercular materials have been excluded from the description of the species based on the tube materials, and thought to be presented in a separate paper.

OPERCULA OF FOSSIL TUBE-DWELLING POLYCHAETES

The investigations of the fossil calcareous opercula, or the lids, closing the polychaete tubes have a long history. Such very lids have first been reported from the Oligocene deposits of Belgium by Nyst (1843; *see also* Nyst & Le Hon 1862, Gerth 1941), who regarded them as corals. The same affinity was indicated almost simultaneously by Michelin (1845, p. 177 and Pl. 46, Fig. 15) who presented similar specimens from the coeval deposits of France. On the other hand, a bryozoan assignment was offered by F.A. Roemer (1863, p. 226 and Pl. 37, Fig. 21*a*-21*b*) when describing comparable Oligocene specimens from Germany.

As shown by Wade (1921), it was L. Agassiz (1842) who supplied the first picture of a fossil polychaete tube, then named "*Serpula crassa* Sowerby" [=*Sclerostyla crassa* (J. Sowerby) in modern taxonomy — *see* Wrigley (1951, p. 184), *and* ten Hove (1973, p. 20)] from the English Eocene, provided with an operculum in position, that is, closing the tube (*see* Agassiz 1842, p. 52 and Pl. 30; *redrawn by* Wade 1921, Pl. 10, Fig. 11). As L. Agassiz' picture was taken as an outer view, none of the contemporaneous authors took into account a similarity (or, identity) of that operculum with isolated specimens they were dealing with.

To the present Author's knowledge, it was certainly Rovereto (1904, p. 25 and Pl. 3, Fig. 10*f*) who first recognized the true nature of various isolated opercula and reported also on their single occurrence *in situ* at the aperture of a polychaete tube, precisely of the species *Sclerostyla mellevillei* Nyst & Le Hon, 1862 [for the validity of this species *see* Wrigley (1951, pp. 185-187), Howell (1962, p. *W*160), *and* Jäger (1983, pp. 78-80)].

A further advance in the study of fossil polychaete opercula was performed by many authors since the early twenties of this century (Gardner 1916; Wade 1921, 1926; Schmitt 1927), and especially by those who during the Second World War contributed in some not easily available journals of various countries (Avnimelech 1941, Gerth 1941, Howell 1943, Albrecht & Valk 1943). This period of investigation continued with a series of thorough contributions by Wrigley (1950, 1951, 1952), supplemented by several newer accounts (Regenhardt 1961, pp. 15-16; Wiesner 1962; Nestler 1963, 1965, 1975; Müller 1964; Lommerzheim 1979), and completed by a critical analysis presented by Cupedo (1980a, b) who, unfortunately, published his papers in a very remote journal.

A REVIEW OF FORMER REPORTS ON THE FOSSIL OPERCULA OF TUBE-DWELLING POLYCHAETES

The actual state of knowledge on the fossil opercula of tube-dwelling polychaetes may be summarized in a sentence that such structures have been recognized in five polychaete genera of the family **Serpulidae** Rafinesque, 1815, and two or three genera of the family **Spirorbidae** Pillai, 1970. This concerns the following genera.

The family **Serpulidae** Rafinesque, 1815:

(1) *Turbinia* Michelin, 1845, from the Eocene and Oligocene of western Europe (Michelin 1845; F.A. Roemer 1863; Rovereto 1904, Pl. 4, Fig. 12*c*-12*d*; Wrigley 1950, 1951);

(2) *Sclerostyla* Mørch, 1863, from the Eocene and Oligocene of western Europe (Nyst 1843; Nyst & Le Hon 1862; Rovereto 1904, Pl. 3, Figs 10*f* and 10*k*; Schmitt 1927; Gerth 1941; Albrecht & Valk 1943; Wrigley 1950, 1951; Regenhardt 1961; ten Hove 1973; Lommerzheim 1979; Cupedo 1980b);

(3) *Hamulus* Morton, 1834, from the Upper Cretaceous of the United States (Wade 1921, 1926; Howell 1943, 1962), Israel (Avnimelech 1941), Germany (Lommerzheim 1979), and the Netherlands (Cupedo 1980a);

(4) *Ornataporta* Gardner, 1916, from the Upper Cretaceous of the United States (Gardner 1916; Howell 1962, Fig. 97/*9a-9b*, as *Ornatopora* [sic!]);

(5) "*Serpula*" of Wrigley (1950) from the Upper Cretaceous (Wrigley 1952; Regenhardt 1961, pp. 15-16 and Fig. 5) and Eocene of western Europe (Wrigley 1950, 1951, 1952; *see also* Cupedo 1980b).

The family **Spirorbidae** Pillai, 1970:

(1) *Neomicrorbis* Rovereto, 1904, the higher taxonomic position of which is however uncertain (*see* Jäger 1993, pp. 101-103); opercula reported primarily in the species *N. crenatostriatus* (Münster *in* Goldfuss, 1831) from the Upper Cretaceous of Germany (Nestler 1963, 1965, 1975; Müller 1964; Lommerzheim 1979; Jäger 1983, pp. 122-125 and Pl. 15, Fig. 6*a*-6*c*); for another operculum-bearing taxon of this genus, *N. parietalis jagti* Jäger, from the lowermost Tertiary (Danian) of the Netherlands *see* Jäger (1993, pp. 103-105 and Pl. 9, Fig. 7*a*-7*d*);

(2) ?other spirorbids from the Upper Cretaceous of Germany ("*Spirorbis*? sp. ind. C, D, E" of Müller 1964), not included into the synonymy of the former genus by Jäger (1983, p. 123);

(3) *Spirorbis* Daudin, 1800, precisely in the species *S. spirorbis* (Linnaeus, 1758) from the Lower Miocene (? Upper Oligocene) of Germany (Wiesner 1962).

Of the aforegoing reports, only few illustrate the opercula preserved *in situ* (Rovereto 1904, Pl. 3, Fig. 10*f*; Wade 1922, Pl. 9, Fig. 6, *and* 1926, Pl. 2, Fig. 12; Schmitt 1927, Pl. 10, Fig. 5; Wrigley 1951, Figs 33, 43 and 52; Nestler 1963, Figs 3-4, *and* 1965, Pl. 4, Fig. 16, *and* 1975, Fig. 93; Cupedo 1980a, Fig. 7, *and* 1980b, Figs 9*b*, 14*d* and 15).

Moreover, it is to note that there exist two taxa, established by Lommerzheim (1979) solely on the isolated opercula from the Upper Cretaceous deposits of Germany. This is the species *elegans* Lommerzheim, 1979, assigned by Lommerzheim (1979) to the serpulid genus *Paliurus* Gabb, 1876, and *Ornatovinea communis* Lommerzheim, 1979, postulated as a new genus and species of spirorbids. In regard to the taxonomy of the polychaetes, these two taxa are evidently the parataxa.

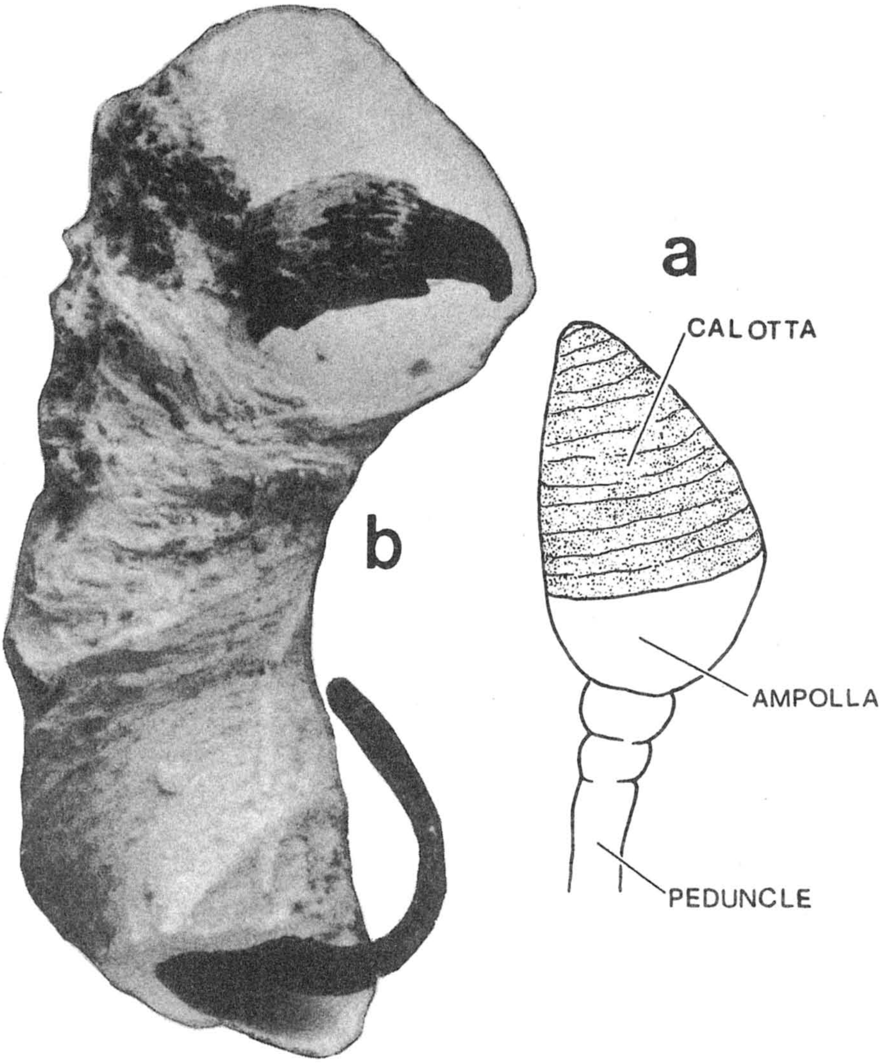


Fig. 1. Operculum in the polychaete genus *Vermiliopsis* SAINT-JOSEPH, 1894

a — Overall structure of the operculum, as exemplified by the present-day species *V. infundibulum* (PHILIPPI, 1844) from the Mediterranean; stippled is the calcified part of the operculum, that is the **calotta**; for its setting within the animal body and its tube, *see* Text-fig. 3

Redrawn *from*: BIANCHI (1981, Fig. 3)

b — Tube fragment of the present-day species *V. striaticeps* (GRUBE, 1862) from the Mediterranean (coll. H. ZIBROWIUS), to show position of the calotta stretching from the aperture; distal part of the tube is broken off, with the polychaete body exposed (*cf.* BIANCHI 1981, Fig. 26); alcohol preparation; photo × 10, taken by S. KOLANOWSKI

As apparent from the above review, all fossil polychaete opercula are known from the Upper Cretaceous deposits of various parts of the world, and from the Paleogene (primarily Eocene — Oligocene) deposits of western Europe. Except of the stratigraphically unclear report by WIESNER (1962), no evidently Neogene (Miocene — Pliocene) polychaete opercula have as yet been recognized.

THE PROVENANCE OF THE STUDIED MATERIAL

The whole studied material comes from the Middle Miocene (Badenian stage of the Central Paratethys basins in Central Europe, or the Upper Langhian — Lower Serravalian interval of the Mediterranean stage division, about 15 million years ago; *see* RADWAŃSKA 1992, p. 144). Its provenance is from the Korytnica Basin on the southern slopes of the Holy Cross Mountains, Central Poland, precisely from the oyster shellbed that forms a littoral facies of the world-famous Korytnica Clays filling entirely this small, shallow-water basin, being a terminal part of the bay developed along a dismembered shoreline (*see* BAŁUK & RADWAŃSKI 1977; RADWAŃSKA 1992, 1994).

The collected material, totally detached from the polychaete tubes, and numbering up to about 110 specimens, is morphologically much distant from any hitherto known from the fossil record. It is herein ascribed to the extant polychaete genus *Vermiliopsis* SAINT-JOSEPH, 1894, ranging since the Neogene (*see* SCHMIDT 1955, 1969; HOWELL 1962; BIANCHI 1981), and whose opercula in the present-day species form a complex structure, as reviewed hereafter.

THE OPERCULA OF PRESENT-DAY *VERMILIOPSIS*

In the present-day species of the polychaete genus *Vermiliopsis* SAINT-JOSEPH, 1894, living in the Mediterranean (*see* ZIBROWIUS 1968a, b; BIANCHI 1981), all are well characterized by their opercula (*see* ZIBROWIUS 1968b, pp. 1206-1207; BIANCHI 1981, pp. 70-79, Figs 25-28) which, however, are only partly calcified. The same concerns tropical species of *Vermiliopsis* living along the shores of Ceylon (*see* PILLAI 1960, 1971).

In general, within the genus *Vermiliopsis* the bilaterally symmetrical operculum is composed (*see* Text-fig. 1) of the three parts: (1) the **peduncle**, which passes more or less gradually upward into (2) the **ampolla**, and the latter is covered by (3) the **calotta**. Of these parts, only the calotta (the name herein adopted as if neo-Latinized, thus the plural being **calottae**) which basically is horny, may be calcified to a variable extent, even fully (*see* BIANCHI 1981).

For a calotta, which makes up a kind of the cap in the operculum (or, rather in the opercular system), a vernacular English name of an **opercular cap** is herein coined up, as already used (in its plural) in the title of this paper. The term of *an opercular cap* is herein preferred as better suited than *an end-plate*, or *an endplate*, being in use for the polychaete genus *Ditrupa* by TEN HOVE & SMITH (1990, p. 111 and Figs 38-40).

In other genera of the *Vermilia* group, to which *Vermiliopsis* belongs, namely in such genera as *Metavermilia* BUSH, 1904, *Neovermilia* DAY, 1961, and *Semivermilia* TEN HOVE, 1975, the opercular caps (calottae) are not calcified (*see* ZIBROWIUS 1971, p. 1374; BIANCHI 1981, pp. 80 and 83; ZIBROWIUS & TEN HOVE 1987, p. 260).

In particular present-day species of the genus *Vermiliopsis*, the morphology of the calotta is either relatively stable, or it is much variable but with some features constant (*see* BIANCHI 1981). The pictures of the opercula of three present-day species are herein re-illustrated (Text-figs 2-4), to make a comparison with the studied material which is totally composed of the isolated calottae.

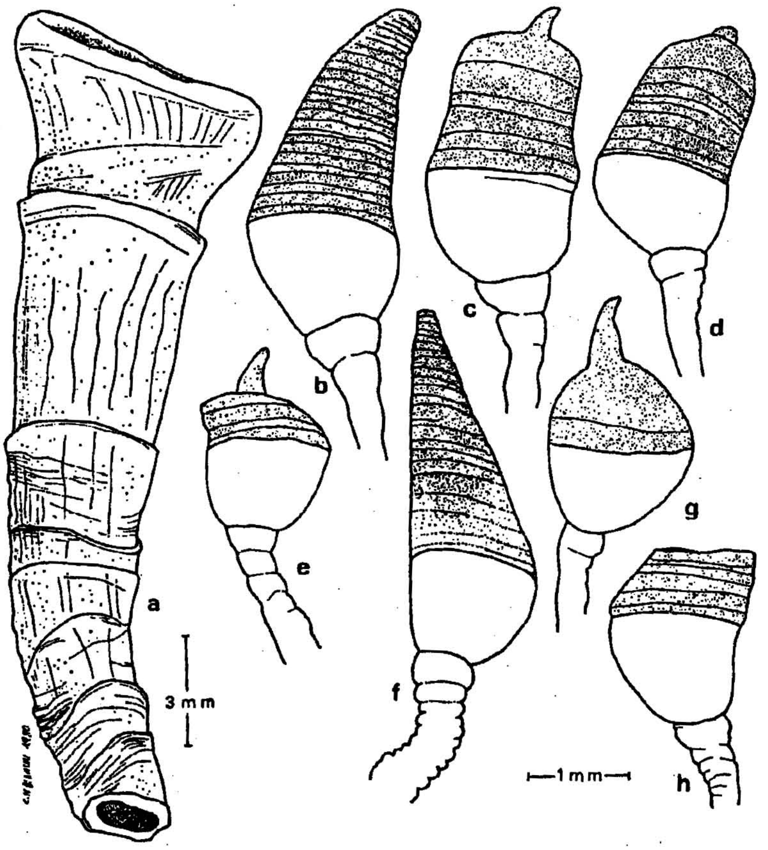


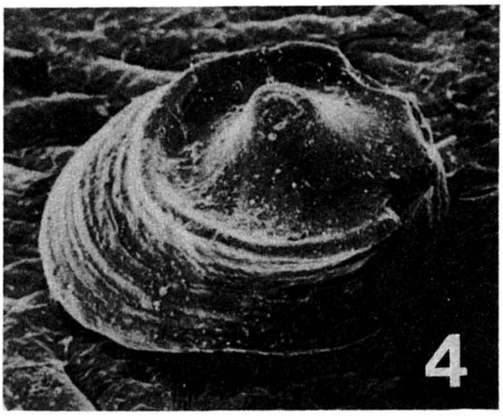
Fig. 2. Present-day specimens of *Vermiliopsis infundibulum* (PHILIPPI, 1844) from the Mediterranean: **a** — tube, **b-h** — opercula capped with calottae (*stippled*)

Redrawn *from*: BIANCHI (1981, Fig. 25)

PLATE 1

Middle Miocene (Badenian) calottae comparable to those of the present-day species *Vermiliopsis infundibulum* (PHILIPPI, 1844)

1-6 — Low-conical specimens; all in outer view, SEM × 50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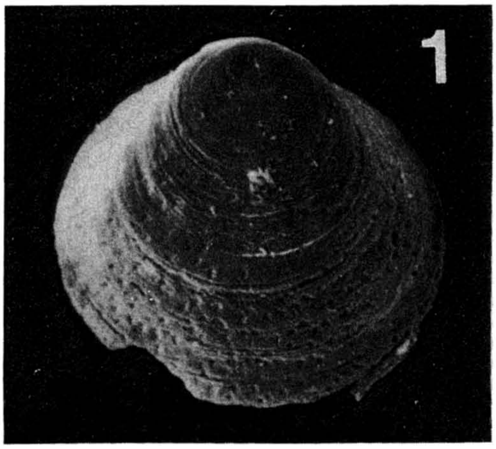
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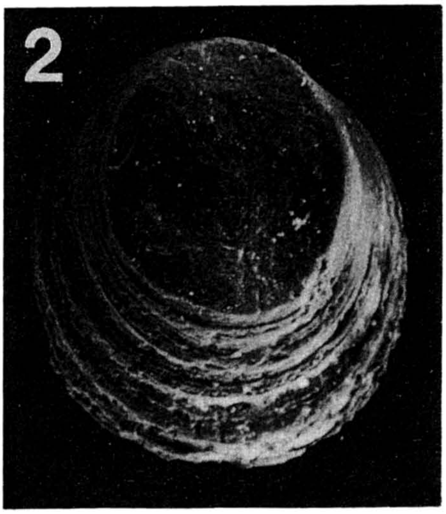
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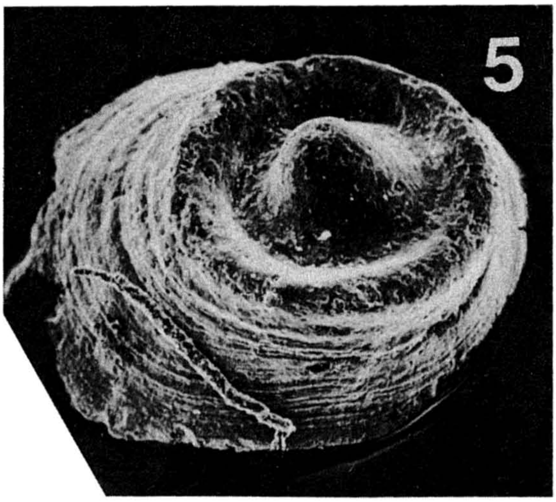
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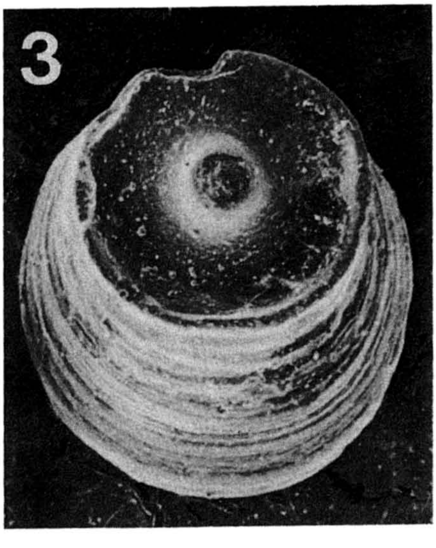
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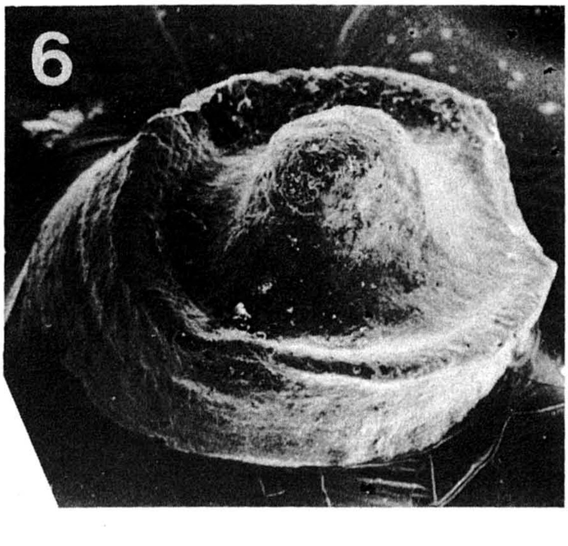
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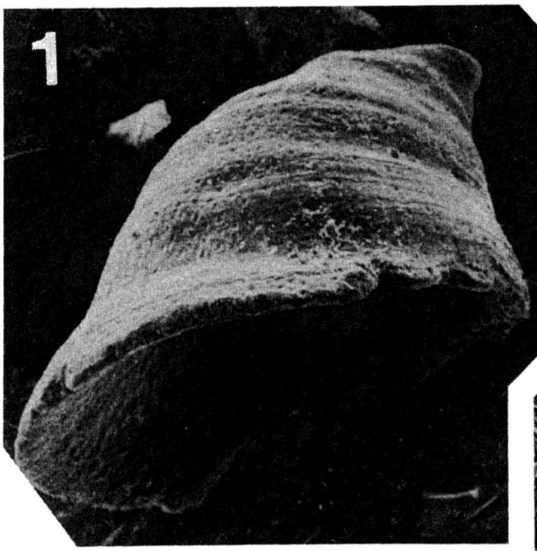

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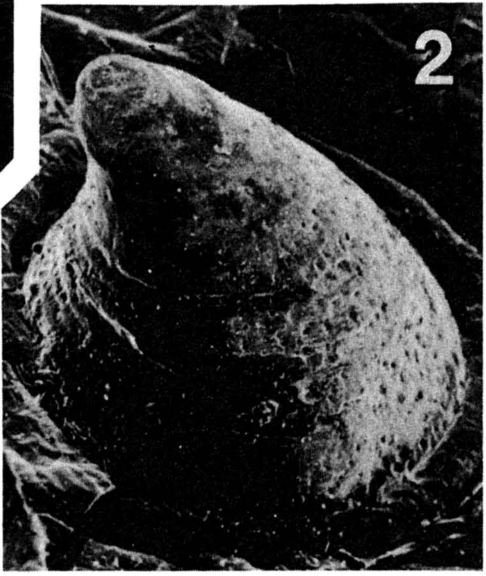

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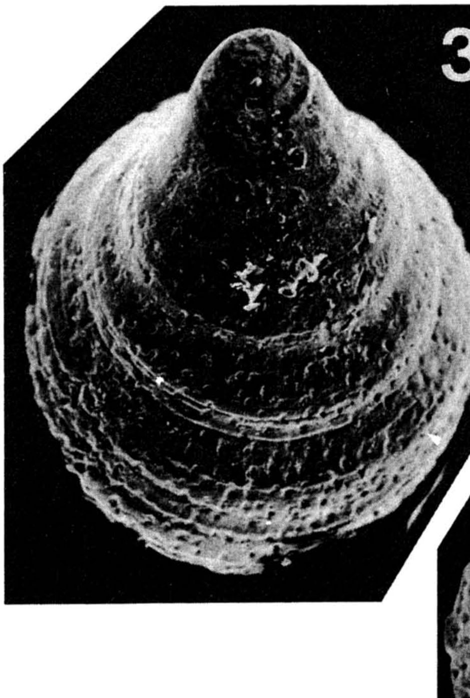

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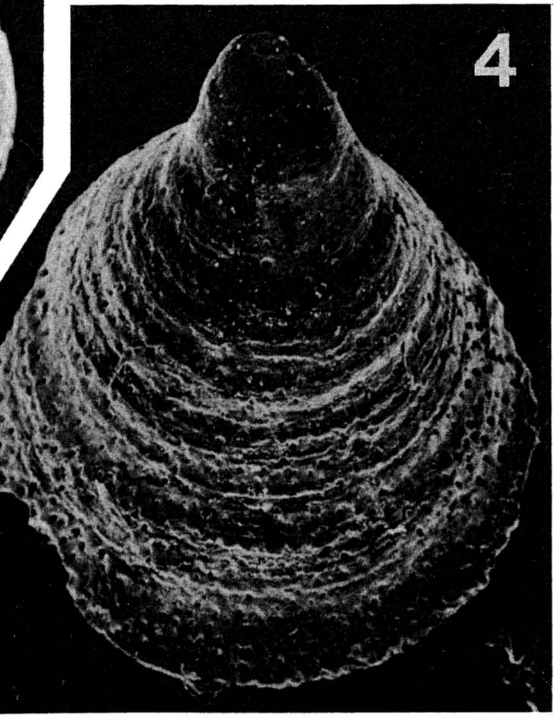


4

THE STUDIED CALOTTAE OF *VERMILIOPSIS*

Within the collected Middle Miocene (Badenian) material from the Korytnica Basin, three morphological groups of the **calottae** are distinguishable, as given in the following account. The distinguished groups are labelled in the open nomenclature, as these comprising calottae comparable to those of the present-day *Vermiliopsis* species.

The electron microprobe energy-dispersive spectra indicate the calottae of all three distinguished groups to be composed of calcium carbonate with a quite subordinate, nearly trace amounts of silicon, aluminium, potassium, magnesium, sodium, iron, and sulfur, all of them interpreted as of layer silicates, iron hydroxides, and probably a sulfate (of calcium?) from the clay minerals adhered to specimens coming from the Korytnica Clays sequence. To note, no phosphates are recorded.

The nature of calcium carbonate, as given by the infrared absorption spectrum analysis, is precisely indicated as calcite, and this very mineral is regarded to have been originally deposited during biomineralization of the studied calottae. No IR-absorption bands were found that could be considered as caused by the presence of organic matter.

Group (i): Comparable to calottae of *V. infundibulum* (PHILIPPI, 1844)

Material: 39 specimens (*see* Pls 1 — 2).

Calottae variably elongated, ranging from quite short and low- to high-conical, slightly arcuate, with the apex either rounded or truncated flat, and with its top either smooth or furnished with a more or less inflated node which may develop from a central depression.

In all specimens, the outer surface shows distinct growth lamellae, and more or less discernible, densely spaced pores.

These calottae, so morphologically variable, are very close to those of the present-day Mediterranean species *Vermiliopsis infundibulum* (PHILIPPI, 1844) which also displays a remarkable variability of shapes (*see* Text-fig. 2; redrawn *from* BIANCHI 1981, Fig. 25).

The high-conical, apically rounded calottae of the latter species are indistinguishable from those of the tropical species from Ceylon, *Vermiliopsis pygidalis* (WILLEY, 1905), whose other morphologic features are evidently distinct (*compare* PILLAI 1960, *and* ZIBROWIUS 1968a).

In the Middle Miocene (Badenian) material from the Korytnica Basin this group of calottae may be ascribed to the forms whose tubes are described (RADWAŃSKA 1994) as *Vermiliopsis* sp. (*see* RADWAŃSKA 1994, Pl. 6, Figs 5-8).

PLATE 2

Middle Miocene (Badenian) calottae comparable to those of the present-day species *Vermiliopsis infundibulum* (PHILIPPI, 1844)

1-4 — High-conical specimens; all in outer view, SEM × 50

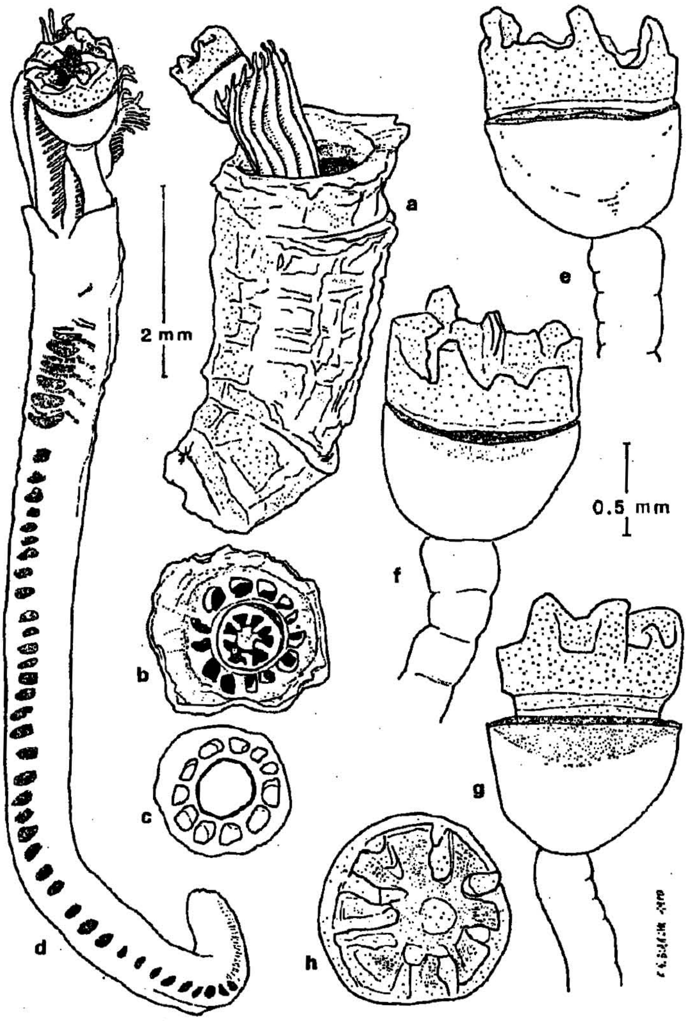


Fig. 3. Present-day specimens of *Vermiliopsis labiata* (O.G. COSTA, 1861) from the Mediterranean

a — Tube; **b** — tube aperture, seen from above, closed by the operculum; **c** — section of the tube, below the aperture; **d** — animal taken from the tube; **e-g** — opercula capped with calottae (*stippled*); **h** — calcified calotta, seen from above

Redrawn *from*: BIANCHI (1981, Fig. 27)

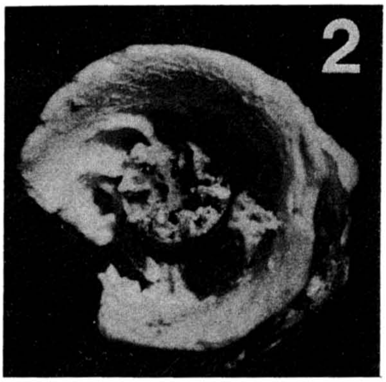
PLATE 3

1-3 — Present-day specimens of *Vermiliopsis labiata* (O.G. COSTA, 1861)

1a — Tube, bottom view (× 5); 1b — Tube, apertural view (× 10), to show calotta in position; 2 — Another tube, apertural view (× 10), to show calotta in position; 3 — Isolated operculum (alcohol preparation), to show the calotta (SEM × 50)

4-5 — Middle Miocene (Badenian) calottae comparable to those of the present-day species *Vermiliopsis labiata* (O.G. COSTA, 1861); both specimens in outer and inner views, × 15


1a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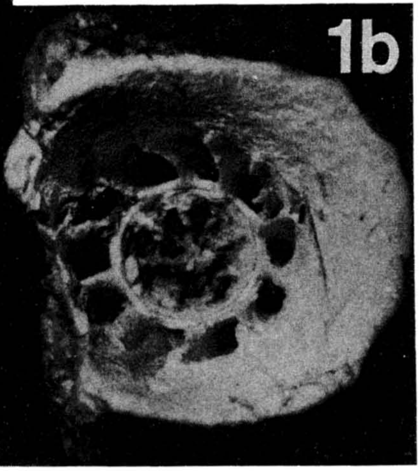
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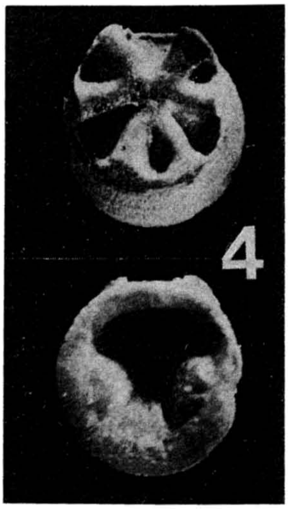
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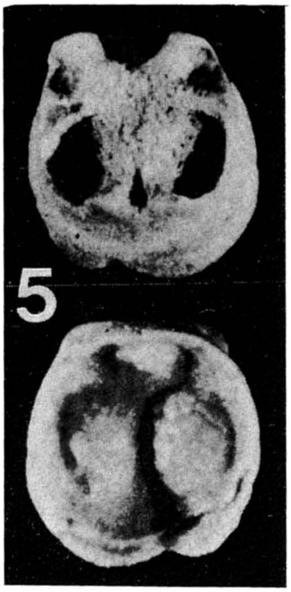
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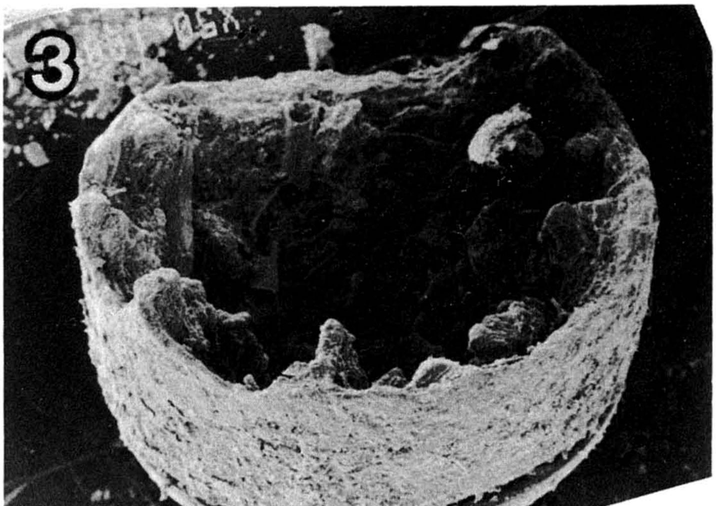
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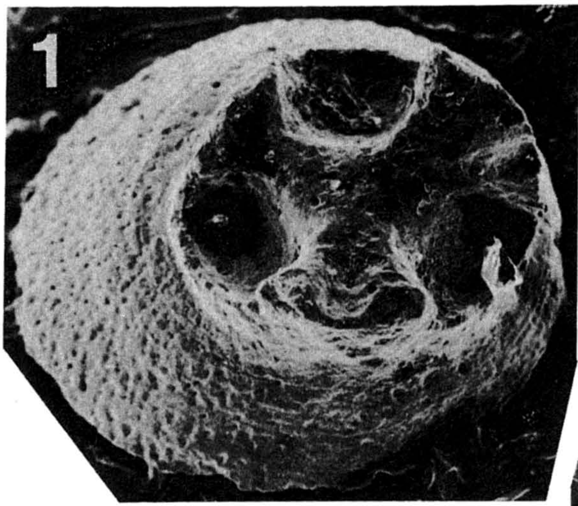
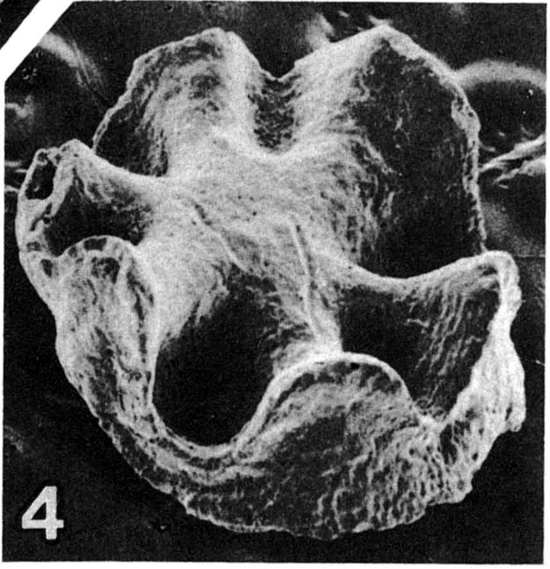
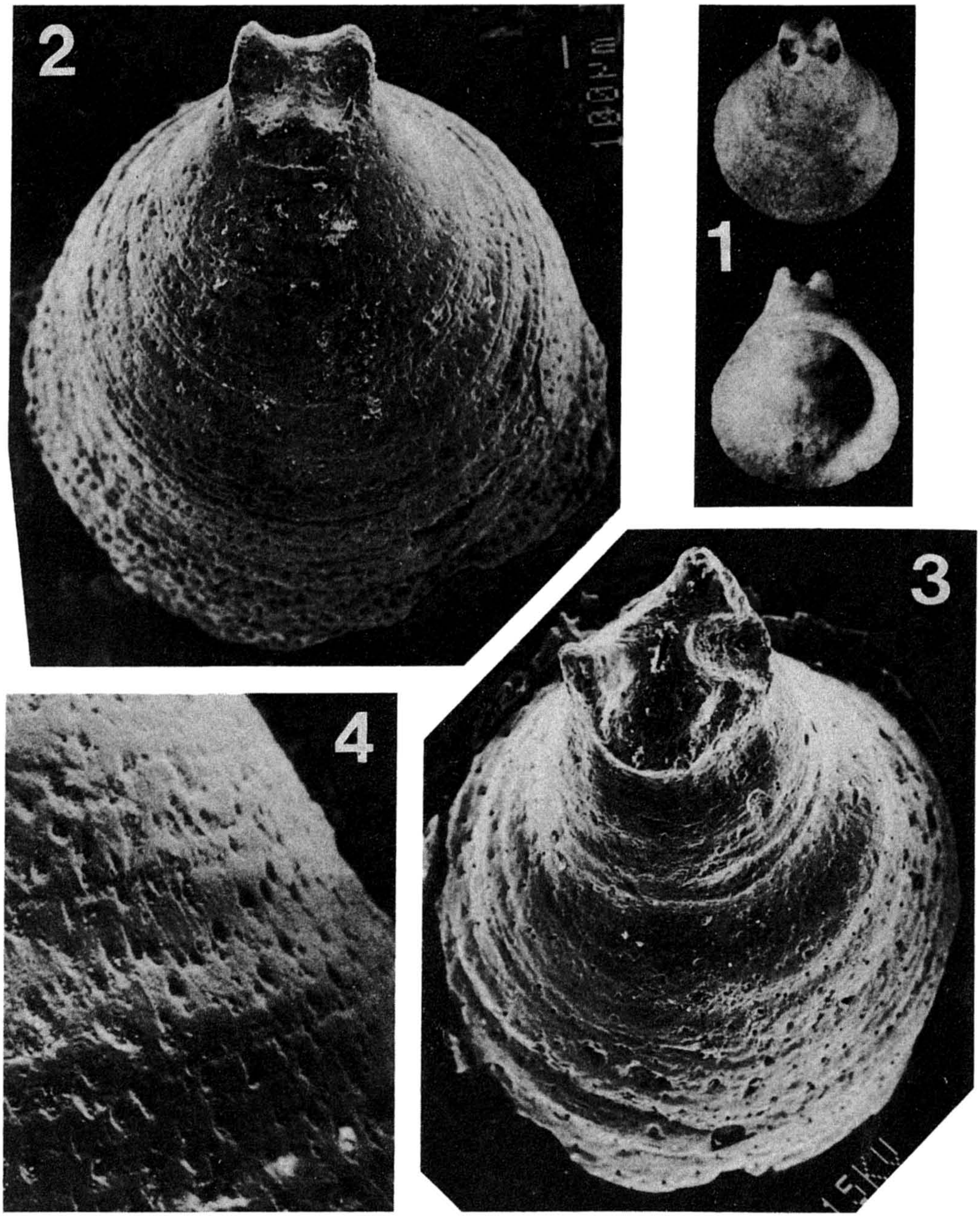




Middle Miocene (Badenian) calottae comparable to those of the present-day species *Vermiliopsis labiata* (O.G. COSTA, 1861)

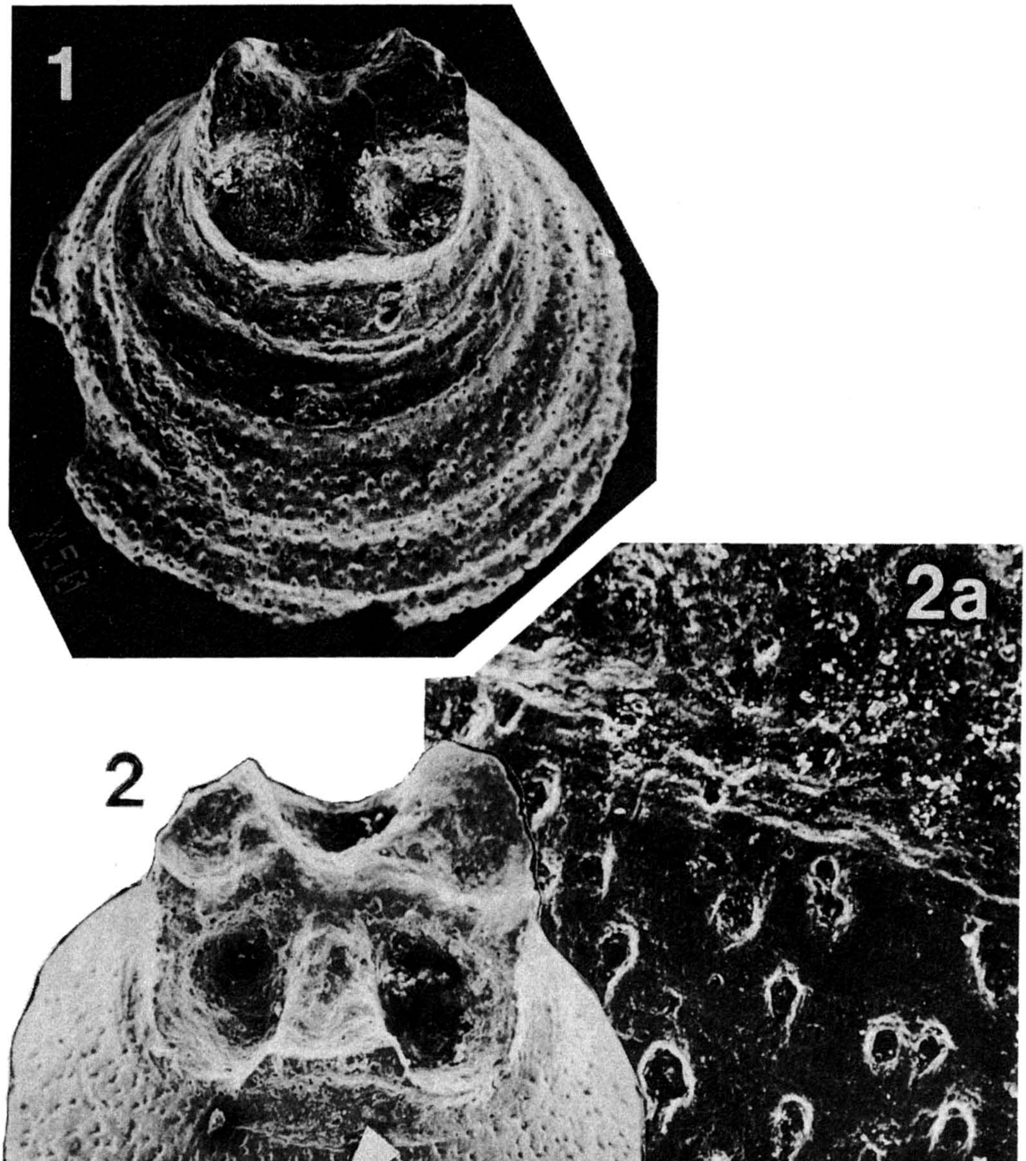


Middle Miocene (Badenian) calottae comparable to those of the present-day species *Vermiliopsis labiata* (O.G. Costa, 1861)

1 — Conical specimen with a small cross; outer and inner view, × 15; **2-3** — Other conical specimens with a small cross; **4** — Close-up, to show the microstructure; all in outer view, SEM × 50 (except of Fig. 4, taken × 100)

PLATE 4: **1** — Low-conical specimen with a slightly developed cross; **2-4** — Very low-conical specimens with a cross developing to the whole diameter of the calotta

All specimens in outer views; SEM × 50 (Figs 1-2), × 30 (Figs 3-4)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X50
2a
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Group (ii): Comparable to calottae of *V. labiata* (O.G. COSTA, 1861)

Material: 47 specimens (*see* Pl. 3, Figs 4-5 and Pls 4 — 6).

Calottae variable in shape, ranging from conical, slightly arcuate, to more or less flattened, all furnished with a characteristic tip of various extent and developed as a three- or six-armed cross which may even enlarge to the whole diameter of a calotta.

The outer surface bears distinct growth lamellae and densely spaced pores, similarly as in the preceding group.

These calottae are comparable in part to those of the present-day Mediterranean species *Vermiliopsis labiata* (O.G. COSTA, 1861), formerly referred (ZIBROWIUS 1968a, b) to as *V. richardi* FAUVEL, 1909. In this species, the reported calottae (ZIBROWIUS 1968a, BIANCHI 1981) are of a stable shape and almost equal diameter through their height, provided with marginal denticles or septa-like ridges rather than arms of a regular cross (*see* Text-fig. 3; redrawn *from* BIANCHI 1981, Fig. 27; *cf. also* Pl. 3, Figs 1-3).

In the Middle Miocene (Badenian) material from the Korytnica Basin this group of calottae may be ascribed to the species *Vermiliopsis quinquesignata* (REUSS, 1860), whose tubes (*see* RADWAŃSKA 1994, Pl. 5, Figs 1-9) display features well comparable with those of the present-day *V. labiata* (O.G. COSTA, 1861).

Group (iii): Comparable to *V. monodiscus* ZIBROWIUS, 1968

Material: 17 specimens (*see* Pl. 7).

Calottae flat, slightly depressed, smooth or furnished with a large, often eccentrically placed, mound-like node.

The outer surface shows very indinstinct growth lamellae, and irregularly dispersed pores which pierce centrally through more or less swollen warts.

These calottae are very close to those of the present-day Mediterranean species *Vermiliopsis monodiscus* ZIBROWIUS, 1968, in which (*see* ZIBROWIUS 1968b, BIANCHI 1981) they display a similar variability (*see* Text-fig. 4; redrawn *from* BIANCHI 1981, Fig. 28), although their warty outer surface has not yet been reported.

In the Middle Miocene (Badenian) material from the Korytnica Basin this group of calottae may be ascribed just to the discussed species *Vermiliopsis monodiscus* ZIBROWIUS, 1968, as based on the tubes indistinguishable from those of the present-day representatives of the species (*see* RADWAŃSKA 1994,

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PLATE 6

Middle Miocene (Badenian) calottae comparable to those of the present-day species *Vermiliopsis labiata* (O.G. COSTA, 1861)

1 — Average specimen with the pores well discernible; 2 — Another specimen, and a close-up (2a, taken in place arrowed in 2), to show the pattern of pores; both in outer view, SEM × 50 (Fig. 2a × 300)

Pl. 4, Figs 8-10). It is to note, however, that the present-day specimens of this species have never been stated to bear their calottae calcified (*see* Zibrowius 1968b, pp. 1206-1207; Bianchi 1981, p. 78).

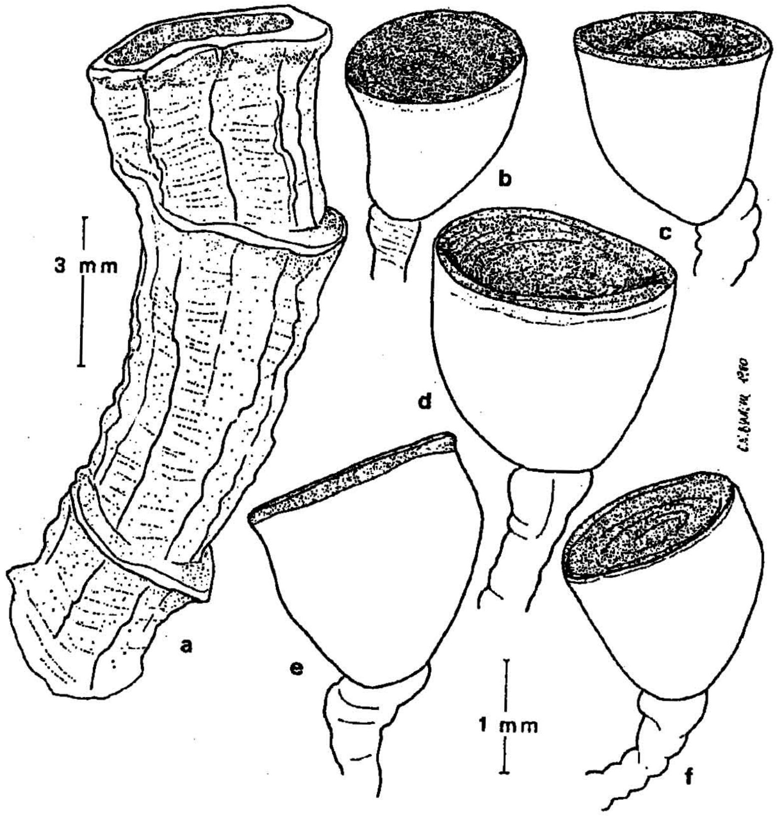


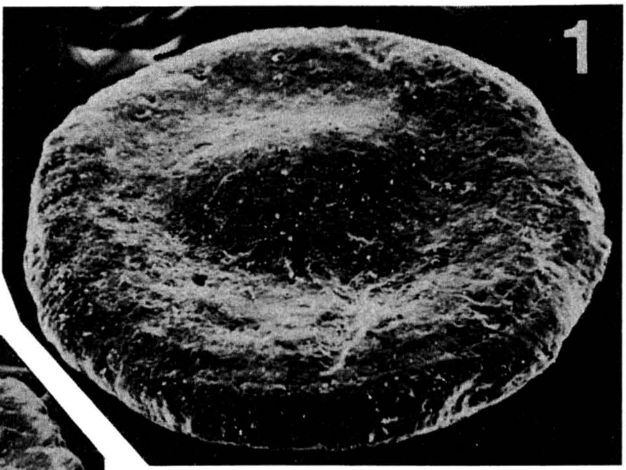
Fig. 4. Present-day specimens of *Vermiliopsis monodiscus* Zibrowius, 1968, from the Mediterranean: **a** — tube, **b-f** — opercula capped with calottae (*stippled*)

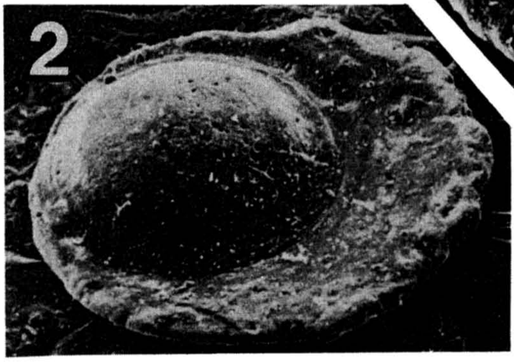
Redrawn *from*: Bianchi (1981, Fig. 28)

PLATE 7

Middle Miocene (Badenian) calottae comparable to those of the present-day species *Vermiliopsis monodiscus* Zibrowius, 1968

1 — Specimen with a node placed centrally; **2** — Specimen with a strongly eccentric node; **3** — Specimen much depressed, with a smaller node, and furnished with distinct warts; arrowed is a close-up given in **3a**, to show the structure of warts; Figs 1-3 in outer view, SEM × 50, Fig. 3a taken × 100


1


2


3a


3

PROBLEMS OF TAXONOMIC ATTRIBUTION

It is noteworthy that, within the studied Middle Miocene (Badenian) material from the Korytnica Basin, the distinguished groups of the calottae are numbering three, thus the same as the taxa recognized earlier by the present Author (RADWAŃSKA 1994) within the tube material attributed to the genus *Vermiliopsis* SAINT-JOSEPH, 1894. This certainly makes an assessment of groups of the studied calottae to the particular species of *Vermiliopsis* reasonable. Some discrepancies remain, however, unsolved.

In the first group, the morphological identity of the studied calottae to those of the present-day specimens of *V. infundibulum* (PHILIPPI, 1844) is evident, but the tube material from the Korytnica Basin (*see* RADWAŃSKA 1994) cannot be classified as identical with the present-day tubes of that species.

In the second group, an attribution of the studied calottae to the extinct species, *V. quinquesignata* (REUSS, 1860), is only a scientific guess. A similarity of some of these calottae to those of the present-day species *V. labiata* (O.G. COSTA, 1861) is very impressive indeed (*compare* Pl. 3, Figs 1*b*, 2-3 with Figs 4-5 of that plate), but it may indicate a phyletic relation rather than a conspecifity. In the specimens of the latter species the cross-like arrangement of ridges is not suited, the number of ridges varies from six to ten (*see* BIANCHI 1981, p. 71), and the specific variability of the overall shape is drastically lesser.

In the third group, the studied calottae are almost identical with those of the present-day specimens of *V. monodiscus* ZIBROWIUS, 1968, which however are unknown to be calcified, and never reported to be warty. On the other way, as stated above, the tube material from the Korytnica Basin is indistinguishable from that of the present-day specimens of that species.

DISCUSSION

The above-listed discrepancies in the morphology of ancient and modern calottae certainly result from various factors, the nature of which is thought open to discussion. As the materials used for a comparison — Recent and Middle Miocene (Badenian, that is Langhian to Serravalian) — differ about 15 million years in their age, one of these factors may be the evolution. Moreover, as the knowledge of the Miocene polychaetes is still very scanty and primarily based on the tube materials that bear a poor diagnostic potential at the species level (*see* RADWAŃSKA 1994, and discussion therein), it escapes a recognition whether the modern polychaete taxa are progressive or regressive links in the evolution of their Miocene (or older) ancestors. These two traits should be taken into account as responsible, for instance, for the vanishing calcification of calottae in the *Vermiliopss monodiscus* lineage, or a decreasing variability of shapes in the calottae of the *V. quinquesignata* — *V. labiata* stock.

Another factor invoked is the preservational and/or taphonomic loss. The present-day *Vermiliopsis* calottae, especially their outer parts and projecting tips, are very delicate, faintly plumose and friable, what is well visible in the comparative material from the Mediterranean (*see* Pl. 3, Figs 1*b*, 2 and 3). This is certainly a more general rule in the growth of the polychaete opercula, as such a structure is also displayed by the opercula of the genus *Sclerostyla*, as seen in the photos of *S. ctenactis* (MØRCH, 1863) and *S. semiannulata* TEN HOVE, 1973, presented from the Caribbean by TEN HOVE (1973, Pl. 3, Figs A-D and Pl. 4, Fig. D).

On the contrary, all the studied Middle Miocene (Badenian) calottae are massive and solid. Their preservation is conspicuous, as indicated by the details of their primary microstructure (growth lamellae, warts, pores) diagenetically intact. Nevertheless, as all they come from an oyster shellbed deposited under high-energy shore environment, they certainly underwent some abrasion and/or transport, and could become worn to various extent, at the surface at least. It could thus happen that their solid appearance has been acquired due to a mechanical removal of the outermost parts, so delicate in their structure as in the comparable, above referenced present-day opercula. Possibly, however, that the biomineralization not only in the discussed fossil representatives of the species *Vermiliopsis monodiscus* ZIBROWIUS, 1968, but also in all of the studied Middle Miocene (Badenian) calottae was much more advanced than in the comparable present-day specimens.

Still another factor is an environmental stress, controlled by bathymetric, thermic, and haline conditions. The oyster shellbed that yields the studied material from the Korytnica Basin was deposited in extreme shallow-marine, littoral waters at rocky shores, of normal salinity, and tropical to subtropical climatic conditions (*see* BAŁUK & RADWAŃSKI 1977, RADWAŃSKA 1992).

The present-day Mediterranean polychaete faunas and their biomineralization may be, thus, not fully comparable with that of the Korytnica Basin. This problem has already been announced by the present Author when studying the polychaete tube materials from the Korytnica Basin (RADWAŃSKA 1994). Consequently, it cannot be excluded that the species similarities of the polychaete calottae suggested in this paper may need a revision when the better comparable present-day polychaete faunas are recognized outside the Mediterranean, particularly within the Indo-Pacific bioprovince.

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REFERENCES

Albrecht, J.C.H. & Valk, W. 1943. Oligocäne Invertebraten von Süd-Limburg. *Meded. Geol. Stichting, Ser. C-IV-1,* 3, 1-163. Maastricht.

Avnimelech, M. 1941. Upper Cretaceous serpulids and scaphopods from Palestine. *Bull. Geol. Dept., Hebrew Univ.*, 3 (2), 1-16. Jerusalem.

Bałuk, W. & Radwański, A. 1977. Organic communities and facies development of the Korytnica Basin (Middle Miocene; Holy Cross Mountains, Central Poland). *Acta Geol. Polon.*, **27** (2), 85-123. Warszawa.

Bianchi, C.N. 1981. Policheti Serpuloidei. *Consiglio Nazionale delle Ricerche; Guide per il riconoscimento delle specie animali delle acque lagunari e costiere italiane*, **5**, 1-187. Genova.

Cupedo, F. 1980a. De opercula van *Hamulus sexcarinatus* Goldfuss (Polychaeta Sedentaria, Serpulidae) uit het Boven-Krijt van Zuid-Limburg. *Publ. Natuurhist. Gen. Limburg*, **29** (2), 1-4. Maastricht.

— 1980b. De opercula van *Sclerostyla mellevillei* (Nyst & Le Hon), "*Serpula*" *instabilis* (Wrigley) en "*Ditrupa mosae*" (Bronn), en hun betekenis voor de systematiek van deze soorten. *Publ. Natuurhist. Gen. Limburg*, **29** (3), 1-19. Maastricht.

Gardner, J.A. 1916. Systematic paleontology, Upper Cretaceous: Vermes. *Maryland Geol. Survey, Upper Cretaceous Volume*, pp. 745-749. *John Hopkins Press*; Baltimore.

Gerth, H. 1941. Over het voorkomen van deksels van een *Serpula*-Soort in het Oligoceen van Zuid-Limburg. *Geol. en Mijnbouw*, **3** (5), 160-163. Den Haag.

Howell, B.F. 1943. *Hamalus*, "*Falcula*", and other Cretaceous Tubicola of New Jersey. *Proc. Acad. Nat. Sci. Philadelphia*, **95**, 139-166. Philadelphia.

— 1962. Worms. *In*: R.C. Moore (*Ed.*), Treatise on Invertebrate Paleontology, Part W (*Miscellanea*), pp. *W*144-*W*177. Lawrence, Kansas.

Jäger, M. 1983. Serpulidae (Polychaeta sedentaria) aus der norddeutschen höheren Oberkreide — Systematik, Stratigraphie, Ökologie. *Geol. Jb., Reihe A*, **68**, 1-219. Hannover.

— 1993. Danian Serpulidae and Spirorbidae from NE Belgium and SE Netherlands: K/T boundary extinction, survival, and origination patterns. *Contr. Tert. Quatern. Geol.*, **29** (3/4), 73-137. Leiden.

Lommerzheim, A. 1979. Monographische Bearbeitung der Serpulidae (Polychaeta sedentaria) aus dem Cenoman (Oberkreide) am Südwestrand des Münsterländer Beckens. *Decheniana*, 132, 110-195. Bonn.

Michelin, H. 1845. Iconographie zoophytologique; description par localités et terrains des polypiers fossiles de France et pays environnants. Paris.

Müller, A.H. 1964. Deckel von Serpuliden (Annelida, Polychaeta) aus der Schreibkreide (Unteres Maastricht) von Jasmund (Rügen). *Geologie*, **13** (1), 90-97. Berlin.

Nestler, H. 1963. Das Operculum von *Neomicrorbis* (*Granorbis*) *verrucosus* Regenhardt (Polychaeta sedentaria) aus dem Unter-Maastricht von Rügen. *Geologie*, **12** (3), 355-358. Berlin.

— 1965. Die Rekonstruktion des Lebensraumes der Rügener Schreibkreide-Fauna (Unter-Maastricht) mit Hilfe der Paläoökologie und Paläobiologie. *Beiheft zur Zeitschrift Geologie*, **49**, 1-147. Berlin.

— 1975. Die Fossilien der Rügener Schreibkreide. *Die Neue Brehm-Bücherei*, **486**, 1-120. Wittenberg Lutherstadt.

NYST, P-H. 1843. Description des coquilles et des polypiers fossiles des terrains tertiaires de la Belgique. *Mém. Acad. Roy. Belg.*, **17**. Bruxelles.

— & LE HON, H. 1862. Déscriptions succinctes de quelques nouvelles espèces animales et végétales fossiles, des terrains tertiaires éocènes des environs de Bruxelles, pp. 1-10. *Ch. Lelong*; Bruxelles.

PILLAI, T.G. 1960. Some marine and brackish-water Serpulid Polychaeta from Ceylon, including new genera and species. *Ceylon J. Sci. (Bio. Sci.)*, **3** (1), 1-40. Peradeniya.

— 1971. Studies on a collection of marine and brackish-water polychaete annelids of the family Serpulidae from Ceylon. *Ceylon J. Sci. (Bio. Sci.)*, **9** (2), 88-130. Peradeniya.

RADWAŃSKA, U. 1992. Fish otoliths in the Middle Miocene (Badenian) deposits of southern Poland. *Acta Geol. Polon.*, **42** (3/4), 141-328. Warszawa.

— 1994. Tube-dwelling polychaetes from the Korytnica Basin (Middle Miocene; Holy Cross Mountains, Central Poland). *Acta Geol. Polon.*, **44** (1/2), 35-81 [*this issue*]. Warszawa.

REGENHARDT, H. 1961. Serpulidae (Polychaeta sedentaria) aus der Kreide Mitteleuropas, ihre ökologische, taxionomische und stratigraphische Bewertung. *Mitt. Geol. Staatsinst. Hamburg*, **30**, 5-115. Hamburg.

ROEMER, F.A. 1863. Beschreibung der norddeutchen tertiären Polyparien. *Palaentographica*, **9** (6), 199-246. Cassel.

ROVERETO, G. 1904. Studi monografici sugli Anellidi fossili; *1.* Terziario. *Palaeontograph. Ital.*, **10**, 1-73. Pisa.

SCHMIDT, W.J. 1955. Die tertiären Würmer Österreichs. *Denkschr. Österr. Akad. Wiss., Math.-Naturwiss. Kl.*, **109** (7), 1-121. Wien.

— 1969. Vermes. *In*: Catalogus Fossilium Austriae, Heft Va, 1-56. Wien.

SCHMITT, W. 1927. Über Opercula von *Serpula* aus der Unteroligozänscholle von Calbe a.d. Saale und dem französichen Eozän. *Zt. f. Geschiebeforschung*, **3**, 138-142. Berlin.

TEN HOVE, H.A. 1973. Serpulinae (Polychaeta) from the Caribbean: II — The genus *Sclerostyla*. *Studies on the Fauna of Curaçao and other Caribbean Islands*, **43**, No. 139, 1-21. Den Haag.

— & SMITH, R.S. 1990. A re-description of *Ditrupa gracillima* GRUBE, 1878 (Polychaeta, Serpulidae) from the Indo-Pacific, with a discussion of the genus. *Records of the Australian Museum*, **42** (1), 101-118. Sydney.

WADE, B. 1921. The fossil annelid genus *Hamulus* MORTON, an operculate *Serpula*. *Proc. U.S. Nation. Museum*, **59**, No. 2359, 41-46. Washington.

— 1926. The fauna of the Ripley Formation on Coon Creek, Tennessee. *U.S. Geol. Survey Prof. Paper*, **137**, 1-272. Washington.

WIESNER, E. 1962. *Spirorbis*-Deckel aus dem Frankfurter Aquitan. *Senck. Lethaea*, **43** (5), 367-374. Frankfurt am Main.

WRIGLEY, A. 1950. Les opercules de Serpulidés de l'Éocène du Bassin de Paris. *Bull. Soc. Géol. France, Sér. 5*, **19**, 499-505. Paris.

— 1951. Some Eocene serpulids. *Proc. Geol. Assoc. London*, **62** (3), 177-202. London.

— 1952. Serpulid opercula from the Kunrade-limestone (Upper Cretaceous, Maestrichtian). *Mitt. Geol. Staatsinst. Hamburg*, **21**, 162-164. Hamburg.

ZIBROWIUS, H. 1968a. Étude morphologique, systématique et écologique, des Serpulidae (Annelida Polychaeta) de la région de Marseille. *Bull. Rec. Trav. Station Mar. Endoume*, **43** (Fasc. 59), 81-253. Marseille.

— 1968b. Description de *Vermiliopsis monodiscus* n.sp. espèce Méditerranéenne nouvelle de Serpulidae (Polychaeta Sedentaria). *Bull. Muséum Nation. d'Hist. Natur., Sér. 2*, **39** (6), 1202-1210. Paris.

— 1971. Revision of *Metavermilia* BUSH (Polychaeta, Serpulidae), with descriptions of three new species from off Portugal, Gulf of Guinea, and western Indian Ocean. *J. Fisheries Res. Board Canada*, **28** (10), 1373-1383. Ottawa.

— & TEN HOVE, H.A. 1987. *Neovermilia falcigera* (ROULE, 1898) a deep- and cold-water serpulid polychaete common in the Mediterranean Plio-Pleistocene. *Bull. Bio. Soc. Wash.*, **7**, 259-271. Washington.