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NOTA BREVE

TUBE MORPHOLOGY AND STRUCTURE OF THE BATHYAL MEDITERRANEAN SERPULID *HYALOPOMATUS VARIORUGOSUS* BEN-ELIAHU & FIEGE, 1996 (ANNELIDA, POLYCHAETA)

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Riassunto. Il polichete serpulide *Hyalopomatus variorugosus*, recentemente descritto da Ben-Eliahu & Fiege (1996), mostra una peculiare rugosità sulla superficie esterna del tubo, a differenza delle altre specie cogeneriche. Tale carattere presenta una notevole variabilità, anche lungo uno stesso tubo. Osservazioni al SEM rivelano che la rugosità è data dalla presenza da "scaglie", irregolari per forma e dimensione, disposte lungo le strie di accrescimento. Viene discusso il valore sistematico di questo ed altri caratteri morfologici. Da osservazioni su fratture, la parete del tubo presenta cristalli di carbonato di calcio equidimensionali, ad habitus prismatico. Questi hanno una struttura omogenea microcristallina granulare e sono disposti in strati che si sovrappongono durante l'accrescimento intorno al lume del tubo secondo superfici coniche. Una pellicola discontinua di cristalli a struttura amorfa criptocristallina può ricoprire la superficie esterna del tubo. Tubi fossili di tale specie non sembrano presentare modificazioni diagenetiche dal punto di vista strutturale.

La specie, di minuscole dimensioni, colonizza piccoli substrati duri sparsi su fondali fangosi del Piano Batiale. Può anche essere gregaria; in questo caso i tubi incrostano microcavità come l'interno dei calici di coralli.

Sono, infine, riportate nuove segnalazioni di *H. variorugosus* in tanatocenosi profonde del Mediterraneo occidentale, oltre che in depositi batiali pleistocenici dell'Italia meridionale.

Abstract. The species studied differs from the other *Hyalopomatus* species by having a peculiar rugose sculptured outer tube surface. This character is markedly variable; it can be more or less developed and may also vary along the same tube. Observed by SEM, this rugosity proves to consist of irregular flaps, roughly following the growth lines.

SEM observations on transverse fractures show a homogeneous composition of the tube wall, consisting of calcium carbonate crystals. These crystals show a prismatic habitus and are arranged in a homogeneous granular microcrystalline structure.

New records of *H. variorugosus* are from deep water stations in the Western Mediterranean and from Pleistocene bathyal deposits of Southern Italy.

The discussion covers aspects of tube characters of use for taxonomy.

Introduction.

Expeditions URANIA 92, EOCUMM 94 and EOCUMM 95 in the Southern Tyrrhenian Sea provided material of the recently described serpulid *Hyalopomatus variorugosus* Ben-Eliahu & Fiege, 1996. The species has also been found in Pleistocene pelitic sediments from Southern Italy (Di Geronimo et al., in press).

Previously tubes of this species had been mentioned as "Serpulidae sp." in Barrier et al. (1989) and as *Protis* sp.1 in Di Geronimo et al. (1995). These records were from Mediterranean bathyal thanatocoenoses and Pleistocene deposits in Southern Italy.

Ben-Eliahu & Fiege (1996) described *H. variorugosus* from the Levant Basin.

In the present paper, the tube morphology and structure of *H. variorugosus* are investigated in more detail. The tube is characterised by a rugose microsculpture, which allows an easy identification even of empty tubes (dead or fossil specimens).

Serpulid tube morphology and structure have rarely been investigated with modern techniques. Some more recent works insist on the importance of tube characters (Bubel et al., 1983; ten Hove & Zibrowius, 1986; Zibrowius & ten Hove, 1987; ten Hove & Smith, 1990; Nishi, 1993; Pillai & ten Hove, 1994; Aliani et al., 1995, Sanfilippo, 1996).

The study of *H. variorugosus* provides the opportunity to investigate the reliability of tube morphology and structure as diagnostic features for taxonomy.

Examined material.

Recent (Southern Tyrrhenian Sea) (Fig. 1):

- URANIA Cruise, July 1992, "del Thoro" canyon, Stn. DG03, 38°43.78'N, 8°20.59'E, 195 m: many empty tubes on fossil oyster shells of Würmian age; a few tubes and fragments free in the mud.
- EOCUMM 94 Exp., July 1994. Stn. 9, 38°34.39'N, 14°29.56'E, 359 m: a few tube fragments free in the mud. - Stn. 18, 38°31.59'N, 14°53.57'E, 300 m: a few

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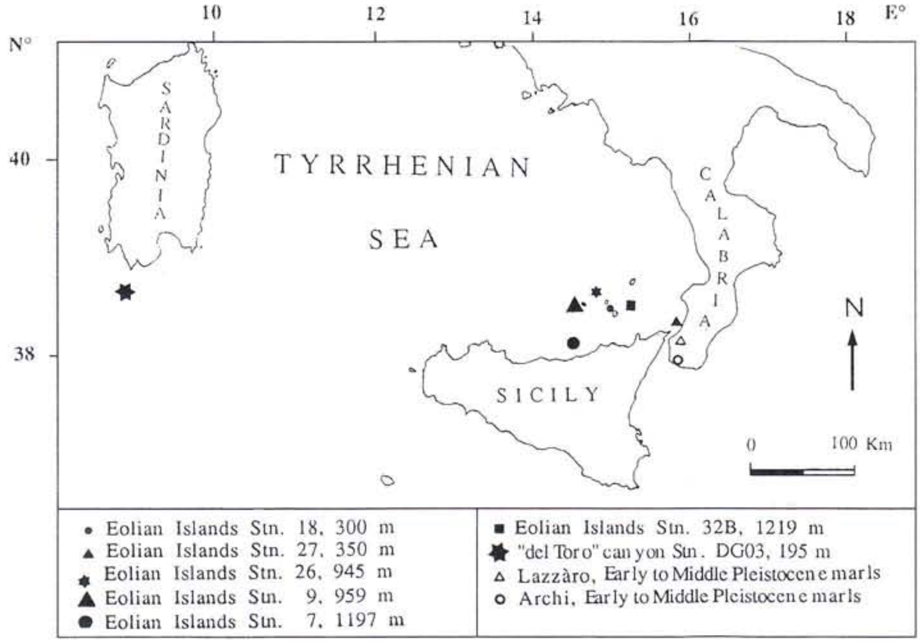


Fig. 1 - Location of samples.

tube fragments. - Stn. 27, 38°21.45'N, 15°46.55'E, 350 m: five tube fragments free in the mud.

- EOCUMM 95 Exp., June 1995. Stn. 7, 38°34.09'N, 14°25.01'E, 1197 m: one complete empty tube on a pteropod shell fragment; some broken tubes on pteropod shells and on pumice. - Stn. 26, 38°38.30'N, 14°57.53'E, 945 m: one broken tube on a pteropod shell fragment; one distal end. - Stn. 32B, 38°33.53'N, 15°05.33'E 1219 m: two complete empty tubes on a small piece of volcanic rock; one incomplete tube on a pteropod shell.

Pleistocene (Southern Calabria) (Fig. 1):

- Lazzàro, Early to Middle Pleistocene bathyal marls rich in scleractinians and isidid gorgonians, various samples: one tube on a scleractinian, some tubes inside *Lophelia pertusa* calices; one distal end of tube; many tube fragments.
- Archi, Early to Middle Pleistocene bathyal marls, various samples: many distal ends and tube fragments.

Methods.

The deep water material was collected by means of dredge (Stn. DG03), grab (Stn. 27) or box corer (Stn. 7, 9, 18, 26, 32B). The fossil material was collected by means of bulk-samples (Di Geronimo & Robba, 1976).

Except for part of DG03, in which serpulids were found encrusting oyster shells, the samples were treated as routinely done for macrofauna studies, i.e. washed and sieved. *H. variorugosus* tube fragments were found in the fine fractions (500 µm and 250 µm).

Some tubes were broken, in order to show the inner structures. Before coating with gold palladium, tubes were treated with concentrated H_2O_2 to eliminate organic matter from the surface.

Results.

Tube morphology and structure.

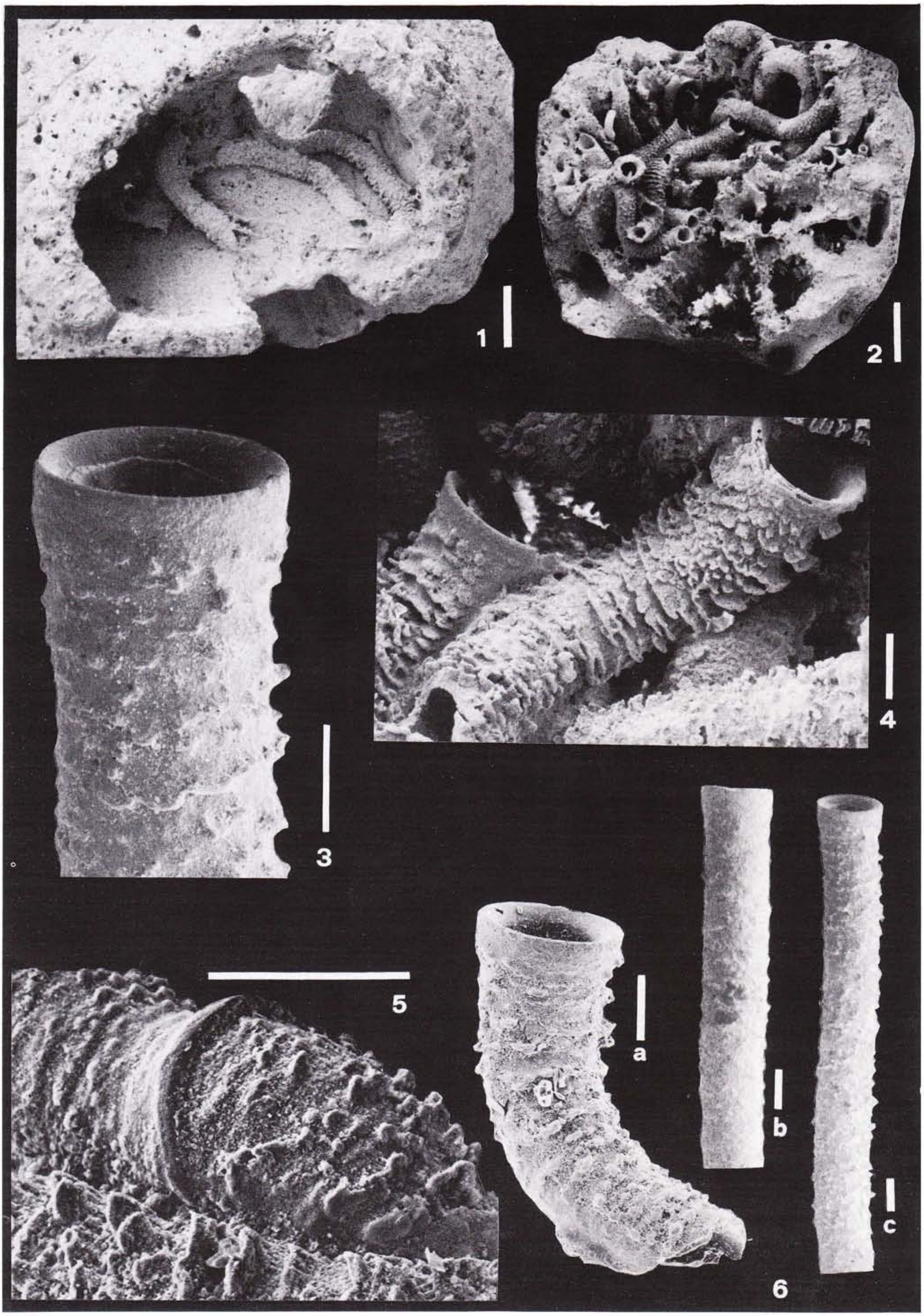
Whereas the original diagnosis of *H. variorugosus* was mainly based on the anatomy of the soft body (Ben-Eliahu & Fiege, 1996), the present description focuses on tube morphology and structure.

The tube is white, opaque and small-sized, up to 15 mm in length (Pl. 1, fig. 1, 2), often more or less coiled, folding on itself in the attached part and distally becoming straight and rising from the substrate (Pl. 1, fig. 6a, b, c).

PLATE 1

Hyalopomatus variorugosus Ben-Eliahu & Fiege, 1996. Scale bar = 500 µm (Figs. 1-2), 100 µm (Figs. 3-6).

Fig. 1 - Tubes cryptic in a small cavity of the substratum. Lazzàro.
Fig. 2 - Tubes gregarious in inner part of a scleractinian calice. Lazzàro.
Fig. 3 - Tube orifice with a circular smooth peristome. Eolian Islands, Stn.27.
Fig. 4 - Distal ends of tubes. Lazzaro.
Fig. 5 - Attached part of the tube with a smooth peristome directed towards the tube orifice. "del Thoro" canyon, Stn. DG03.
Fig. 6 - Distal erect parts of tubes, rising from the substratum, more (6a) or less (6b, 6c) rugose. Lazzàro (6a), Archi (6b, 6c).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The cross section is circular (Pl. 1, fig. 1, 2, 3), the outer diameter relatively constant along the tube, ca. 170 µm (Pl. 1, fig. 3), and the wall thickness reaching ca. 20 µm (Pl. 2, fig. 3, 5).

Sometimes there are peristome collar rings, slightly flaring and directed distally (Pl. 1, fig. 5). The tube orifice may be surrounded by a smooth peristome, slightly flaring (Pl. 1, fig. 4, 5. Pl. 2, fig. 3a).

Like in other serpulids, the early part of the tube, corresponding to the juvenile stage (Sanfilippo, 1993), is smooth. It is separated from the adult portion by a peristome (Pl. 2, fig. 1). Being very thin and fragile, the early portion is often lost in the adult specimens and in fossil material.

The outer surface of the tube is rugose. SEM examination shows the rugosity to consist of transverse flaps, more or less frayed out and posteriorly directed (Pl. 1, figs. 4, 5, 6; Pl. 2, fig. 2), roughly following the growth line pattern. Sometimes these flaps are few and weakly developed (Pl. 2, fig. 3c), the tubes appearing almost "smooth" (Pl. 1, fig. 4; Pl. 2, fig. 3b). In other cases, the flaps are well-developed and numerous (Pl. 2, fig. 2), giving the tube a "scaly" appearance. Both "scaly" and "smooth" tubes may occur in the same sample. The sculpture may also vary along the same tube, as already stressed by Ben-Eliahu & Fiege (1996).

SEM observations on transverse fractures of Recent material evidence a homogeneous composition for the tube wall, consisting of calcium carbonate crystals (Pl. 2, fig. 3, 6). In longitudinal section the crystals are arranged in layers that dip towards the opening at an angle of ca. 30° (Pl. 2, fig. 5). The layers overlay each other during growth, according to a conical plane. This type of microstructure and the layered pattern are common to most of the Mediterranean serpulids (Sanfilippo, 1993, 1996).

At higher magnification all crystals show a similar size (2-3 µm in length), and they have a prismatic habitus (Pl. 2, fig. 6). They are arranged in a criss-cross orientation, in a homogeneous granular microcrystalline structure (see Hall, 1980) (Pl. 2, fig. 6). The opaque appearance of the tube is due to the randomly arranged small crystals, as reported also for other serpulids (ten Hove & Zibrowius, 1986; Zibrowius & ten Hove, 1987).

Crystals and their arrangement are also visible on the outer surface of the tube. Rarely, the surface may be covered by a discontinuous film of very small crystals, organised in amorphous cryptocrystalline masses (Pl. 2, fig. 7).

The microstructure appears not to be affected by diagenetic modifications, being unchanged in fossil tubes.

Distribution and ecology.

In the Tyrrhenian stations (muddy bottoms, depth 200-2000 m) *H. variorugosus* occurs together with other small-sized serpulids, i.e. *Metavermilia multicristata* (Philippi), *Semivermilia agglutinata* (Marenzeller), *Filogranula stellata* (Southward) and *Filogranula gracilis* Langerhans.

In the Early to Middle Pleistocene marls of Lazzàro (Barrier et al., 1996), *H. variorugosus* co-occurs with *F. stellata, S. agglutinata* and *M. multicristata*. Boulders in these marls are encrusted by serpulids [(*Vitreotubus digeronimoi* Zibrowius, *Neovermilia falcigera* (Roule), *Placostegus tridentatus* (Fabricius)], isidid gorgonians and scleractinians. Many species of these palaeocommunities are no longer part of the Mediterranean fauna (e.g. *V. digeronimoi* and *N. falcigera*). Both the marl and the boulder faunas indicate a depth of about 600 m.

The Archi section (Di Geronimo et al., in press), consisting of a pelitic Early to Middle Pleistocene sequence, supplied several tubes of *H. variorugosus*. Benthic assemblages point to a depth of 500-1000 m and are marked by an Atlantic affinity. Among serpulids *N. falcigera* and *F. stellata* are common.

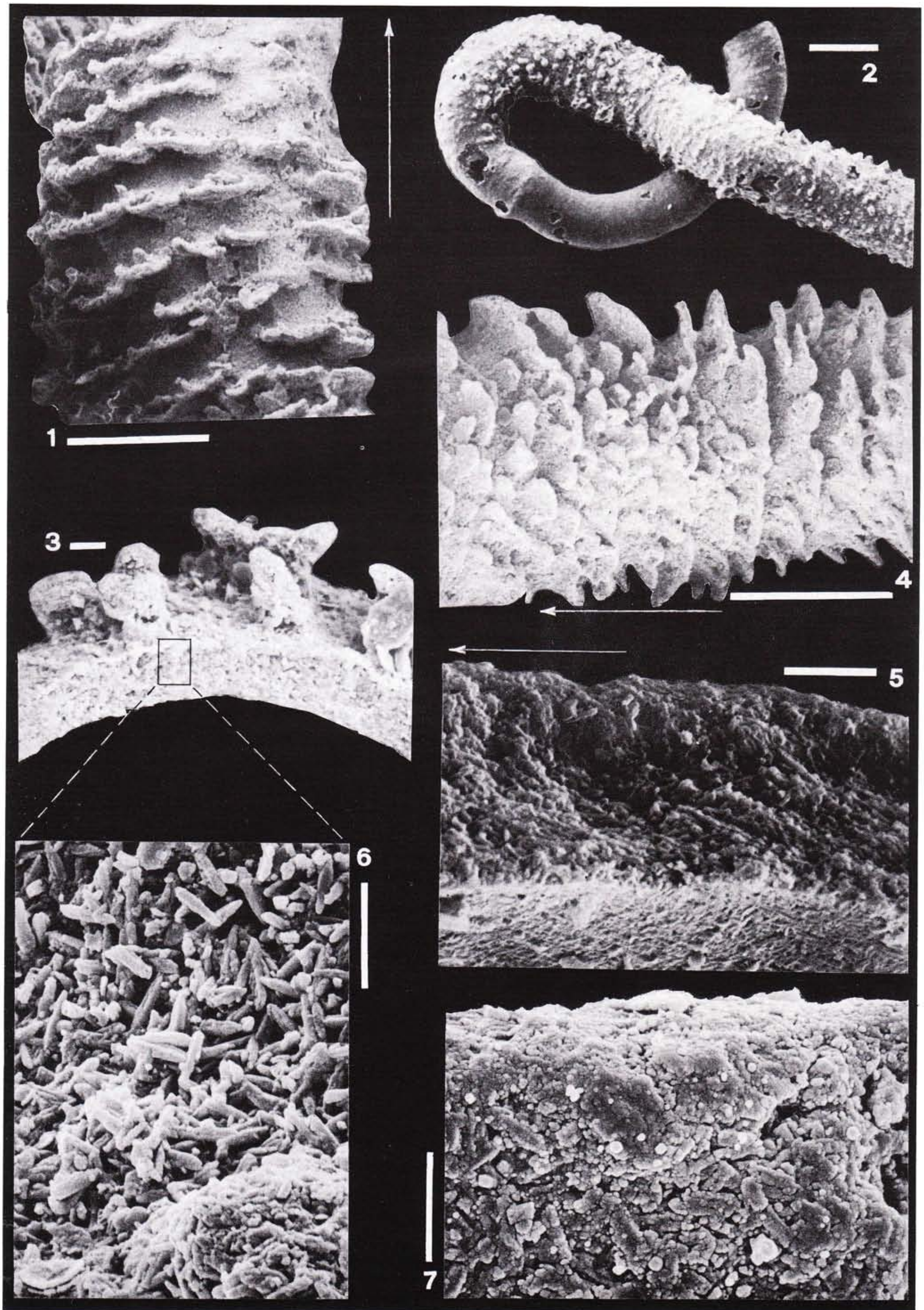
These new records of *H. variorugosus* extend its previously known geographical distribution.

Ben-Eliahu & Fiege (1996) reported living specimens of this species from the Levant Basin (S of Crete, S-SW of Cyprus, off Israel, off Egypt) and from the Ionian Sea (Gulf of Taranto), depths 792-2009 m, in crevices of hard substrates, such as coal, slag, hardened sediment crusts, and on pteropod shells.

PLATE 2

Hyalopomatus variorugosus Ben-Eliahu & Fiege, 1996. Scale bar = 100 µm (fig. 1, 2, 4), 5 µm (fig. 3, 5, 6, 7). Arrows indicating direction of growth.

Fig. 1 - Micromorphology of outer surface consisting of transverse flaps. Lazzàro.
Fig. 2 - Initial part of the tube, smooth, no ornamentations. Eolian Islands, Stn.7.
Fig. 3 - Transverse section of tube wall. Outer surface continued into flaps. Archi.
Fig. 4 - Crowded high transverse flaps, frayed out and turned. Lazzàro.
Fig. 5 - Longitudinal section of tube. Wall consisting of layers dipping towards tube mouth. Eolian Islands, Stn. 27.
Fig. 6 - Tube microstructure. Criss-cross arranged crystals of prismatic habitus, with a homogeneous microcrystalline structure. Eolian Islands, Stn. 27.
Fig. 7 - Outer tube surface, covered by an irregular film of very small crystals forming amorphous cryptocrystalline masses. Eolian Islands, Stn. 27.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Therefore, *H. variorugosus* can be regarded as a Mediterranean species, although a record from the Atlantic (halfway between Madeira and Gibraltar) (Zibrowius, pers. com.) should be noted, suggesting a possibly wider Atlantic distribution.

The new Recent material was found on a variety of both smooth and irregular substrates, e.g. pteropod shells, oyster shells, pumice and slag. In fact, its small size particularly enables the species to colonize interstices and microhabitats. The new fossil material was generally cryptic, within small crevices of hard substrates or inside the calices of scleractinians. Detached and fragmented tubes (especially distal ends), secondarily free, were found in muddy sediments.

Branching tubes are interpreted as a proof of scissiparity, as it had also been reported in other genera (*Filogranula* Langerhans, *Josephella* Caullery & Mesnil, *Rhodopsis* Bush, *Spiraserpula* Regenhardt, *Filograna* Berkeley; ten Hove, 1979; Ben-Eliahu & ten Hove, 1989; Pillai, 1993; Pillai & ten Hove, 1994).

Discussion.

The finding and description of *H. variorugosus* were carried out relatively late, owing to its ecological, biogeographical and stratigraphical range. Its scanty occurrence could be also due to the inadequate routine methods: the very small-sized tubes are not found until the finest granulometric fractions of sediment (250 and 500 μm) are examined.

The scarcity of deep-sea benthos in the Mediterranean Sea (Bellan-Santini et al., 1992) is another reason why *H. variorugosus* has seldom been recorded.

Records of other species of *Hyalopomatus* from deep Mediterranean waters are rare (Zibrowius, 1969; 1977) and of uncertain specific attribution (Ben-Eliahu & Fiege, 1996). The other nominal species of the worldwide distributed genus *Hyalopomatus* are morphologically close to each other, and also live in bathyal and abyssal depths. *H. variorugosus* is similar to some other *Hyalopomatus* species (Ben-Eliahu & Fiege, 1996). However, it markedly differs from all other species in its rugose sculpture.

In most descriptions of recent serpulid species no attention is paid to the tube structure. Nevertheless, it may provide useful characters for identification.

However, the knowledge of variability of these tube structures, for instance caused by external factors, is still insufficient for an optimum use. This might be corroborated by Bornhold & Milliman (1973) who mention a temperature-dependent mineralogy. In fact, the shape and size of the tube wall crystals seem not useful for generic nor for specific determination. These characters are not related to the size or to phylogenetic position of the worms; they seem to have evolved independently (Nishi, 1993).

A few occasional studies, especially when using SEM techniques, have shown a considerable diversity in the tube wall structure, such as homogeneously opaque one-layered tubes (e.g. *Vermiliopsis* Saint-Joseph, *Metavermilia* Bush, *Filogranula* Langerhans, *Filograna* Berkeley, *Protula* Risso) and two-layered tubes, the outer layer of which is transparent (*Ditrupa* Berkeley, *Laminatubus*, Regenhardt, *Galeolaria* Lamarck, *Neovermilia* Day, *Pseudochitinopoma* Zibrowius). Some other genera (*Placostegus* Philippi, *Vitreotubus* Zibrowius) are characterised by an entirely transparent tube. Small serpulids such as *Filogranula, Filograna, Protis* and *Josephella* possess tubes with thin and entirely opaque walls, as shown in this paper for *H. variorugosus*. In other genera tube characters may not be constant within the genus.

Thus, shape and other morphological features are available for determination at specific level but, till now, it has not been possible to find tube attributes characterising the various genera.

The same problem exists in *Hyalopomatus*. Although the tube of *H. variorugosus* has a morphological character distinctive at specific level, it is hardly possible to refer the tube to the genus *Hyalopomatus* without characters of the worms themselves. A morphological tube feature, diagnostic at a generic level, apparently has not yet been found for the genus *Hyalopomatus*. Thus, tubes lacking the specific rugosity, could be misidentified for *Protis* or *Filograna* species, wich have similar generic tube characters.

In the eyes of a paleontologist, this may be caused by the strong systematic weight given to characters of the worm by neontologists. The paleontological approach is clearly based on different morphological features which may lead to different systematic views.

The calcareous tubes are the fossilizable remains palaeontologists have access to whereas the classical taxonomy of serpulids by biologists is widely based on morphological features of the soft-bodied worm.

In view of a better coordination between the classical "soft-body" taxonomy and the palaeontological approach, it is necessary to carefully study the macro- and microstructures of the tubes of all Recent serpulid species.

In summary, despite the recent interest in tube taxonomy, with promising results, further studies in this field are needed.

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