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SMALL BATHYAL SPONGE SPECIES FROM EAST MEDITERRANEAN REVEALED BY A NON-REGULAR SOFT BOTTOM SAMPLING TECHNIQUE

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ABSTRACT

This first study of soft bottom sponges from the Levantine bathyal employed a device comprising a plankton net secured atop a Marinovich type semi-balloon trawl. All of the nearly 500 specimens collected were identified to four sponge species. All four species are of a very small body size. Sponges were not retained by the larger mesh Marinovich trawl net. The study describes a new polymastiid species *Tentorium levantinum* n. sp., and a new *Rhizaxinella shikmonae* n. sp. in addition to two Calcareans: *Sycon faulkneri* n. sp. and a *Plectroninia* sp. that appears to be a new species. These sponges, which inhabit soft bottom environments, have evolved morphological features such as unattached ground-based cones with a broad base (*Tentorium levantinum*), or a basal anchoring tuft (*Rhizaxinella shikmonae*). The absence of these species from previous records of the Mediterranean bathyal may have resulted either from overlooking the small sized species in soft bottom environments for lack of adequate collecting technique or scarcity of studies. It was thus impossible to confirm or reject the pattern of wide geographical distribution of deep-water sponges seen elsewhere, including the western Mediterranean. The new calcareous species was found at greater depths than most other calcareous sponges published so far, while *Plectroninia* sp. was found at greater depth than all but one record for this genus. It is expected that other small, benthic species may be discovered using the appropriate equipment.

Key Words: Porifera, Levant Basin, collecting devices, new taxa, nanism, deep-sea.

INTRODUCTION

Sponges are an important component of the oceans' bathyal benthos. Much of the bathyal consists of soft bottom environments whereas most sponges inhabit hard bottom environments. Records of deep-sea sponges therefore frequently show that the sponges attach in sites of hard substrate (like vertical walls), or to hard fragments within soft bottoms (e.g. Vacelet 1969; Boury-Esnault et al. 1994; Maldonado and Young 1996). Although the Mediterranean has been studied extensively, only a handful of reports relate to its deep-sea sponge fauna (Vacelet 1969, 1996; Uriz and Rosell, 1990; Boury-Esnault et al. 1994). The Levantine bathyal sponge fauna has received even less attention. With the exception of two studies that described one new species and new records (Ilan et al. 1994; Galil and Zibrowius 1998), it has not been studied at all. The deep-sea sponges described so far can be characterized as widely distributed, relatively large (<1 cm), hard bottom dwellers. Uriz and Rosell (1990) who studied western Mediterranean fauna reported that "the sponges found enjoy a broad geographical distribution…..as….pointed out for the deep Mediterranean fauna in general".

Monitoring deep-sea waste sites off the coast of Israel provided an opportunity to sample soft bottom benthos, at depths between 1200 and 1500 m. We therefore set to examine the soft bottom deep-sea sponges. The first aim was to collect, in addition to the large and moderate sized sponges, also the small sized specimens (<1 cm). Furthermore, we wanted to examine whether the sponges to be found will already be known from the East (or West) Mediterranean, validating the broad geographical distribution suggested for the West Mediterranean deep-sea sponges (Uriz and Rosell 1990).

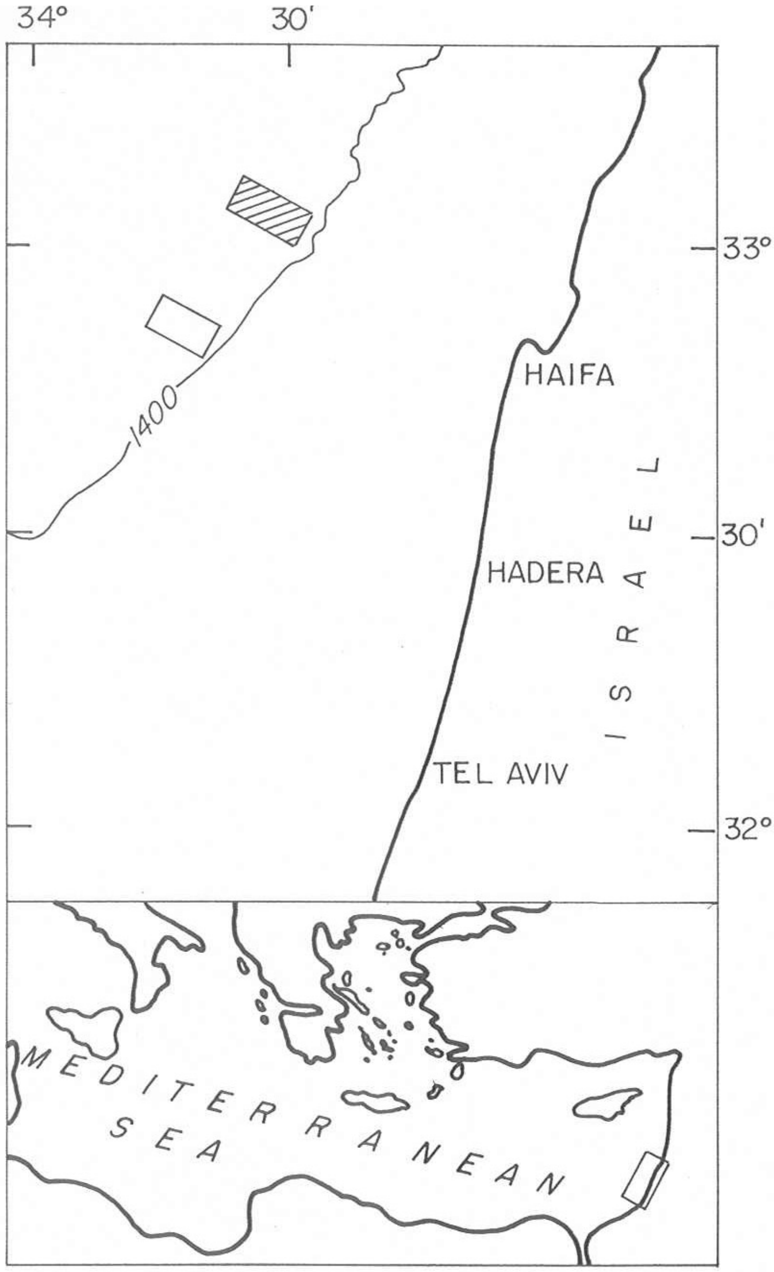

Fig. 1: Map of the region. The rectangles are the sampling sites.

RESULTS

Nearly 500 specimens were retrieved from 29 stations (Fig. 1). Two specimens were collected by box corer, the rest were caught by the plankton net set atop a Marinovich type semi-balloon trawl. The Marinovich type semi-balloon trawl itself failed to collect any sponge. All specimens were examined and identified to four sponge species, of which three new species are described here. The fourth species, although probably new, is only preliminarily described due to the fragmental preservation of the material.

Calcarea

Calcaronea

Leucosoleniida

Family Sycettidae Dendy, 1892

Sycon Risso, 1826

Diagnosis: Sycettidae with radial tubes partially or fully coalescent. Generally well-defined inhalant aquiferous system. Distal cones are decorated by tufts of diactines (modified from Borojevic et al. 2002).

Sycon faulkneri n. sp.

Material examined: Holotype: collected near Israel Off Hadera. Stn L15, 32°41.42'N, 34°13.95'E, 1243 m, 4.11.1998 (ZMTAU SP25188).

Paratypes: Four specimens collected near Israel Off Hadera. Stn L21, 32°29.30'N, 34°17.00'E, 1272 m, 10.09.1997 (ZMTAU SP25189); two specimens, Stn L15, 32°41.42'N, 34°13.95'E, 1243 m, 4.11.1998 (ZMTAU SP25190 and SMF no. 0006).

Additional material (spicule preparations): Israel, Off Hadera. Stn L52, 32°30.84'N, 34°19.34'E, 1269 m, 10.09.1997

Additional material examined: Israel, Off Hadera. Stn L7, 32°41.70'N, 34°03.90'E, 1493 m, 11.09.1997: 9 spec. (TAU).- Stn L13, 32°41.80'N, 34°10.86'E, 1467 m, 9.09.1997: 1spec. (TAU).- Stn L14, 32°40.00'N, 34°13.70'E, 1415 m, 10.09.1997: 21 spec. (4 spec. on slides) (TAU).- Stn L51, 32°27.90'N, 34°04.90'E, 1362 m, 10.09.1997: 2 spec. (TAU).- Stn L52, 32°30.84'N, 34°19.34'E, 1269 m, 10.09.1997: 19 spec. (3 spec. dissolved for spicule preparation) (TAU).- Stn L4, 32°29.14'N, 34°15.03'E, 1296 m, 6.11.1998: 10 spec. (TAU).- Stn L15, 32°41.42'N, 34°13.95'E, 1243 m, 4.11.1998: 32 spec. (1 spec. on slide) (TAU).- Stn L19, 32°33.09'N, 34°03.08'E, 1462 m, 5.11.1998: 15 spec. (TAU).- Stn L20, 32°31.48'N, 34°03.99'E, 1344 m, 5.11.1998: 2 spec. (TAU).- Stn L21, 32°27.06'N, 34°15.05'E, 1276 m, 6.11.1998: 2 spec. (TAU).- Stn L22, 32°30.04'N, 34°02.67'E, 1450 m, 5.11.1998: 2 spec. (TAU).- Stn L24, 32°29.76'N, 34°03.22'E, 1391 m, 5.11.1998: 7 spec. (TAU).- Stn L25, 32°25.09'N, 34°06'E, 1351 m, 6.11.1998: 5 spec. (TAU).- Stn L26, 32°27.81'N, 34°16.82'E, 1277 m, 6.11.1998: 6 spec. (TAU).- Stn L27, 32°29.13'N, 34°19.79'E, 1251 m, 6.11.1998: 14 spec. (TAU).- Stn L28, 32°25.03'N, 34°5.09'E, 1319 m, 6.11.1998: 4 spec. (TAU). Off Haifa. Stn L1, 32°58.70'N, 34°37.11'E, 1299 m, 8.09.1997: 1 spec. (TAU).- Stn L3, 32°57.90'N, 34°34.80'E, 1349 m, 7.09.1997: 1 spec. (TAU).- Stn L4, 32°59.90'N, 34°33.20'E, 1389 m, 8.09.1997: 2 spec. (TAU).- Stn L7, 32°57.61'N, 34°40.30'E, 1227 m, 9.09.1997: 2 spec. (TAU).- Stn L8, 33°00.86'N, 34°36.60'E, 1313 m, 9.09.1997: 2 spec. (TAU).- Stn L9, 33°01.53'N, 34°28.56'E, 1439 m, 7.09.1997: 3 spec. (TAU).

External morphology

Tubular sponge, 4-9 mm long, 0.5-1 mm thick, always single tube, sometimes with a small to medium-sized stalk (Fig. 2A). The osculum is at the end of a collar surrounded by an apical fringe of protruding long oxea spicules, (Fig. 2A-C). The main body appears rather smooth at low magnification, but because of the lateral cones it is hispid under the microscope. Radial tubes are completely fused, with articulate choanoskeleton. Recently, additionally 3 specimens from ca. 1440 m depth were identified in a collection of deep-sea sponges from the Sea of Crete (Janussen et al. Unpubl. data).
Color in alcohol: light grey to light brown

Skeleton

Long easily broken diactine (type 1) surround the distal part of the collar, the apical fringe (Fig. 2A) and are sometimes found to be part of the stalk as well. The basal part of the collar also contains triactines, which all point with their unpaired rays in distal direction. Dermal wall consists mostly of regular triactines and few tetractines, numerous smaller diactine (type 2) are also part of the dermal wall, they protrude the surface of the outer wall and project from the cones in a fusiform arrangement. Gastral wall shows tetractines, commonly with unequal rays, and small diactines. The stalk is made up by a thin layer of triactines and diactines in different sizes (types 1 and 2).

Spicules

Sagittal triactines (Fig. 2D, E) paired rays not perfectly straight, unpaired ray perfectly straight, great size range, especially the unpaired ray is sometimes considerably longer than the other rays, all rays sharply pointed. The triactines are often almost regular (i.e. equal sized rays, Fig. 2D).

Sagittal tetractines (Fig. 2F) less abundant than the triactines, great size range, pointed rays, commonly irregular (i.e. unequal sized rays).

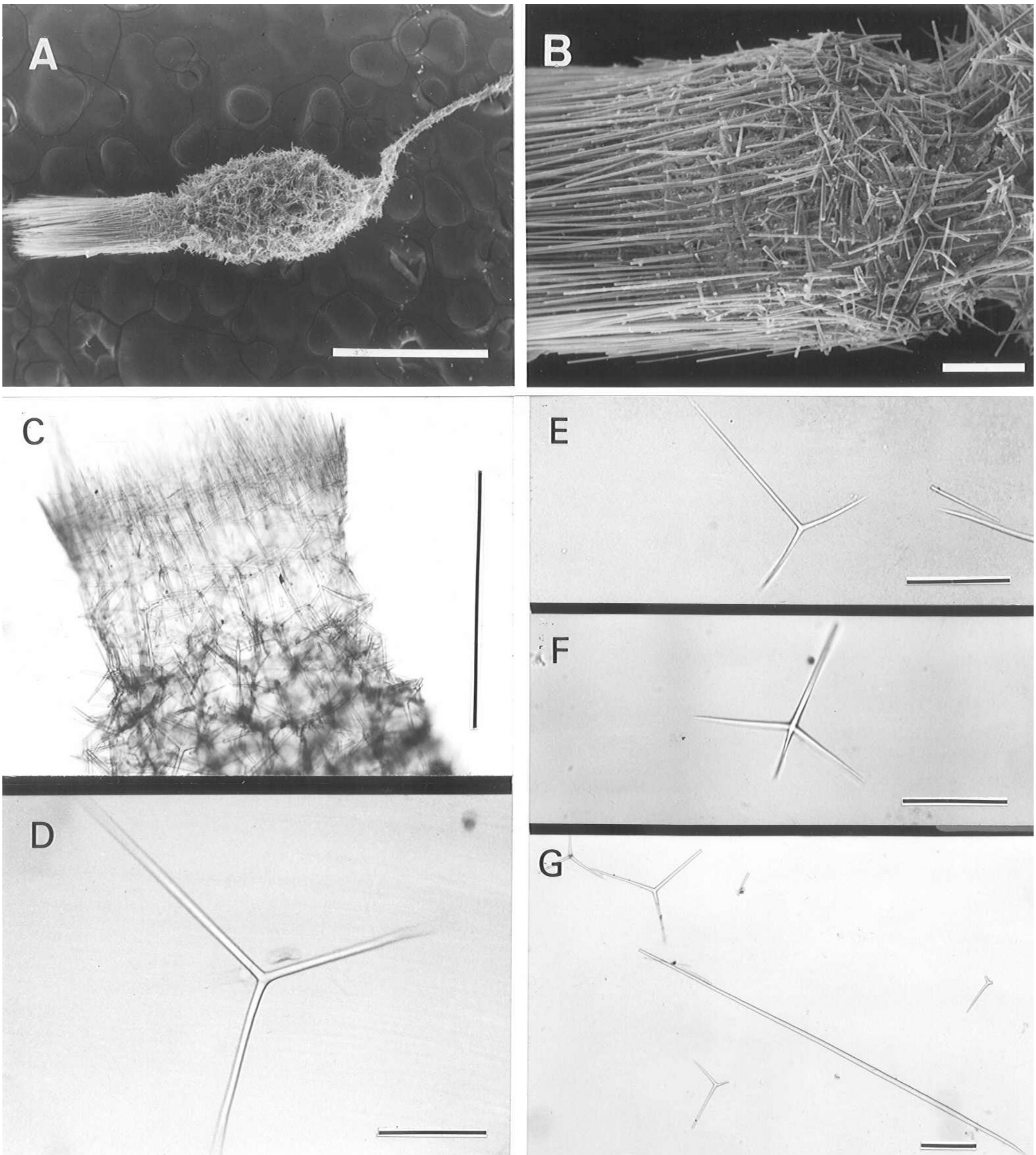

Fig. 2: *Sycon faulkneri* (A) A complete specimen with distinctive oscular tube, trunk and stalk. Scale bar = 1.0 mm; (B) Higher magnification of the oscular tube and connection to the trunk. Scale bar = 100 µm; (C) Apical spicule fringe. Most spicule types are evident. Scale bar = 500 µm; (D) Sagittal triactine (equal sized rays). Scale bar = 100 µm; (E) Sagittal triactine. Scale bar = 100 µm; (F) Sagittal tetractine. Scale bar = 100 µm; (G) Diactine 2. Scale bar = 500 µm.

Diactine 1 spicules (Fig. 2A-C) build the apical fringe and sometimes occur also in the stalk, straight, slowly tapering, sometimes with small tubercles in straight rows.

Diactine 2 spicules (Fig. 2G) occur everywhere in the skeleton (except for the apical fringe), and they project from the lateral cones in a fusiform (all directions) manner. Form is slowly tapering, straight, almost always broken when projected outwards. Spicule dimensions are given in Tab. 1.

Table 1: *Sycon faulkneri* spicule measurements

Spicule type	Length range (µm) (n=50)	Length mean (µm) ± s.d. (n=50)	Width range (µm) (n=10)	Width mean (µm) ± s.d. (n=10)
Sagittal triactines, unpaired ray	115-390	285 ± 67	7.5-12.5	9.5 ± 1.75
Sagittal triactines, paired ray	80-240	165 ± 45	7.5-12.5	9.5 ± 1.75
Diactine 1	290-370 n=10	330 ± 31 n=10	<1.9	
Diactine 2	When fully grown always > 750		7.5-22	13.25 ± 5

Etymology: The species is named after the late D.J. Faulkner in recognition of his contribution to the study of sponge chemistry and sponge-microorganisms interactions.

Remarks: Our specimens differ from *Sycon abyssale* Borojevic and Graat-Kleeton (1965), one of the two known deep-water *Sycon*, in its much smaller size (*S. abyssale* length is 10-18 mm, and diameter 3 mm) and lack of the oscular collar of long diactines. The tetractines and triactines of the two species resemble each other (subgastric triactines are lacking in the present *Sycon faulkneri*) but those of *S. abyssale* are larger (see Borojevic and Graat-Kleeton 1965). Thin diactine, like diactine 1, are lacking in *S. abyssale*, whose diactine are shorter and thicker (150-180 µm x 15-25 µm, compare with Tab. 1) than diactine 2 of the present *S. faulkneri*, which are slightly bent, and one tip is shaped like an arrowhead. The other deep-sea *Sycon* is *Sycon escanabensis* Duplessis & Reiswig 2000, found in the Northeast Pacific ocean (Escanaba Trough, off northern California). *Sycon faulkneri* differs from *S. escanabensis* by the combination of spicules and their size. Diactines are present in *S. escanabensis* only in one size class (Duplessis and Reiswig 2000). These are much shorter than diactine 1 and even diactine 2 of *S. faulkneri*. Moreover, unlike *S. escanabensis*, no lancet-head diactines were observed in *S. faulkneri*. *S. escanabensis* has very small triactines, which are absent from the Mediterranean species, and larger triactines with much thicker rays.

Of the shallow water Mediterranean Calcarea, which partly might have migrated into deeper water, *S. faulkneri* shows similarity to *S. raphanus* and *S. ciliatum*. However, the first species shows very irregular triactines, larger body size and much larger size of diactines. The latter species shows no lateral cones and no stalk, it is larger and the oscular collar is shorter compared to body size than in *S faulkneri*. The presence of spinose diactines sometimes observed in *S. faulkneri* is very unusual for calcareous sponges. The only *Sycon* species so far reported with this kind of ornamentation was described from the Atlantic Ocean by Carter (1876) as "*Grantia ciliata* Fleming, ? var. *spinispiculum*" to contain long spicules with "recurved spines like barbs, extended more or less in the same line for a certain distance up the shaft". Unfortunately, Carter figured only the sponge body, 22 mm long and 7 mm wide, and the barbed monaxons, so we do not know, what the other spicules of that sponge looked like.

Sycon faulkneri is the second *Sycon*-species to be reported from such deep water in the Mediterranean Sea. The other report, from Western Mediterranean (Vacelet et al. 1989), does not elaborate or describe the species, but states "The discovery of specimens of various *Sycon* sp. at great depth of the Western Mediterranean demonstrates that the occurrence of calcareous sponges in deep-water is in fact more common than was thought". These specimens were collected between 1500 and 2775m. *Sycon faulkneri* appeared in 23 out of the 27 stations sampled by net.

Lithonida

Minchinellidae

Plectroninia Hinde 1900

Diagnosis: Mincinellidae with a basal skeleton made up of two types of fused tetractines, a layer composed of large tetracines and a layer of small tetractines. Tetractines fused by their basal actins, with the apical actine remaining free and pointing outwards. Basal actins attached by simpler zygosis in small tetractine, zygosis reinforced by a cement layer in large tetractines. Cortical skeleton of free spicules tangentially arranged (Vacelet et al. 2002)

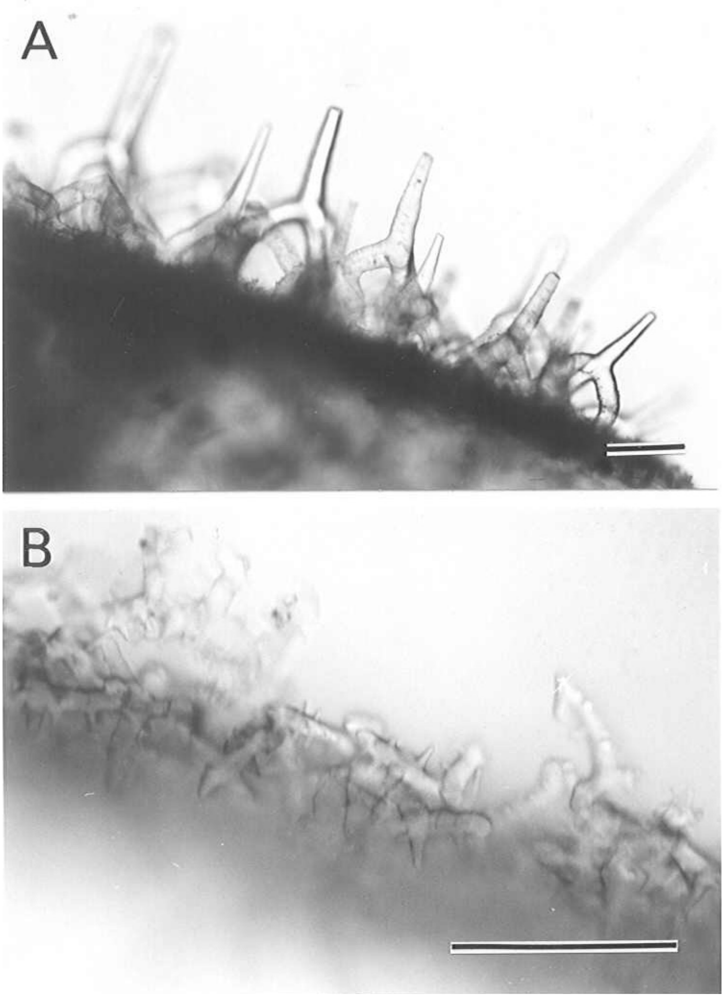

Fig. 3: *Plectroninia* sp. (A) Lateral view of a basal section with large tetractines; (B) Small tetractines. Scale bars = 100 μm.

Plectroninia sp.

Material examined: Stn L52, 32°30.84'N, 34°19.34'E, 1269 m, 10.09.1997: 1 spec. (on slide) (ZMTAU SP25152).- Stn L24, 32°29. 76'N, 34°03.22'E, 1391 m, 5.11.1998: 1 spec. (on slide) (ZMTAU SP25153).

External morphology

The sponge forms thin, small (0.7 x 0.2 mm) crusts.

Only two intact encrustations, and a number of single spicules (mixed with spicules of *Sycon* sp.) were found and identified as belonging to the genus *Plectroninia.*

Skeleton and spicules

The skeleton is composed of large tetractine spicules, in which basal actines are fused and the apical ray is free (Fig. 3A). These large triactines are accompanied by smaller tetractines (Fig. 3B).

Remarks: Most species of this genus are known from submarine caves (Vacelet 1970), with 12 recently described species (Borojevic et al. 2000). The geographical distribution of the genus extends from the Mediterranean (Vacelet 1967, 1970; Pouliquen and Vacelet 1970) to the Indo-Pacific (Burton 1963; Vacelet 1970). All species of *Plectroninia* appear as tiny encrustations.

Based on the key given by Vacelet (1981) the

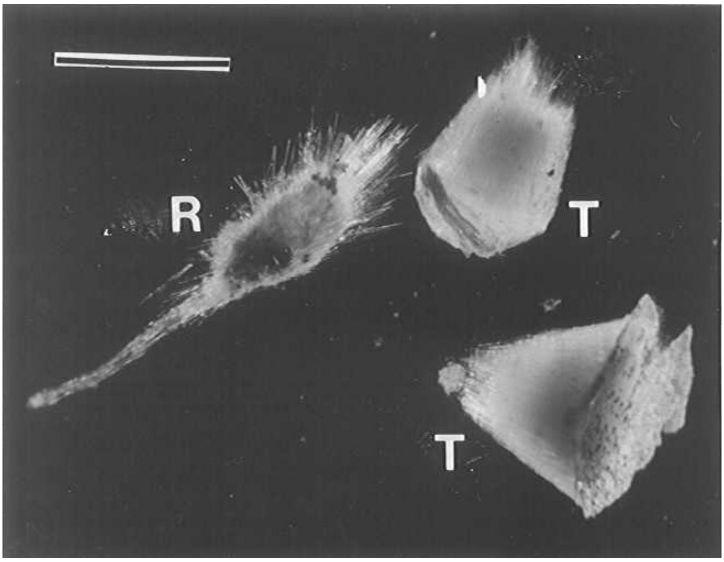

Fig. 4: *Tentorium levantinum* and *Rhizaxinella shikmonae*, total specimens. (T) *T. levantinum*, the exhalant process is obscured; (R) *R. shikmonae*. Scale bar = 500 µm.

present species differs from the Mediterranean *P. hindei* Kirkpatrick, 1900 in its complement of free spicules. *P. hindei* has "tuning fork" spicules together with spined microxea and spined "pin-shaped" spicules, which are not visible in the present specimens. The visible spicules are mostly tylostyles, smooth oxea and some irregular spicules. In addition the free actines of the fused tetractines of the present specimens are more blunt than those of *P. hindei* and other *Plectroninia* spp. (which are more pointed). The depth range of this "pharetronid" genus is from ca. 10 m to 1600 m (Burton 1963; Pouliquen and Vacelet 1970; Vacelet 1991; Borojevic et al. 2000). Our specimens were found in deeper water than most of the previous records of *Plectroninia*, but since only two small encrustations were collected, the material was deemed insufficient for full specific description. This species appeared in four out of the 27 stations examined.

Class Demospongiae

Sub-Class Tetractinomorpha

Order Hadromerida

Family Polymastiidae Gray 1867

Tentorium Vosmaer, 1882

Diagnosis: "Polymastiidae with columnar or globular growth form protected by a dense cylindrical sheath of longitudinally placed spicules which form a solid imperforate layer. The ectosomal skeleton contains bundles of smaller spicules arranged in a palisade and is limited to the upper surface of the cylinder. Ostia are present on the upper surface. The oscule at the tip of a small papilla is on center of the upper surface. Megascleres are subtylostyles and tylostyles" (Boury-Esnault 2002).

Tentorium levantinum n. sp.

Material examined: Holotype: Stn L24, 32°29.76'N, 34°03.22'E, 1391 m, 5.11.1998, 1 spec. (on slide) (ZMTAU SP25150);

Paratypes: Stn L20, 32°30.47'N, 34°6.948'E, 1374 m, 30.10.1996 (on slide) (ZMTAU SP25182).- Stn L21, 32°29.15'N, 34°16.67'E, 1281 m, 30.10.1996 (on slide) (ZMTAU SP25183).- Stn L24, 32°29.76'N, 34°03.22'E, 1391 m, 5.11.1998, 2 spec. (on slide) (ZMTAU SP25184) ; 8 spec. (NHM) and 3 spec. SMF no. 0005.

Additional material (spicule preparations): Stn L21, 32°29.30'N, 34°17.00'E, 1272 m, 30.10.1996.- Stn L52, 32°30.84'N, 34°19.34'E, 1269 m, 10.09.1997; (basal plate preparations) Stn L52, 32°30.84'N, 34°19.34'E, 1269 m, 10.09.1997 (two specimens).

Additional material examined: Israel. Off Hadera. Stn L7, 32°41.70'N, 34°3.90'E, 1493 m, 11.09.1997: 8 spec. (TAU).- Stn L14, 32°40.00'N, 34°13.70'E, 1415 m, 11.09.1997: 2 spec. (TAU).- Stn L19, 32°33.42'N, 34°4.43'E,

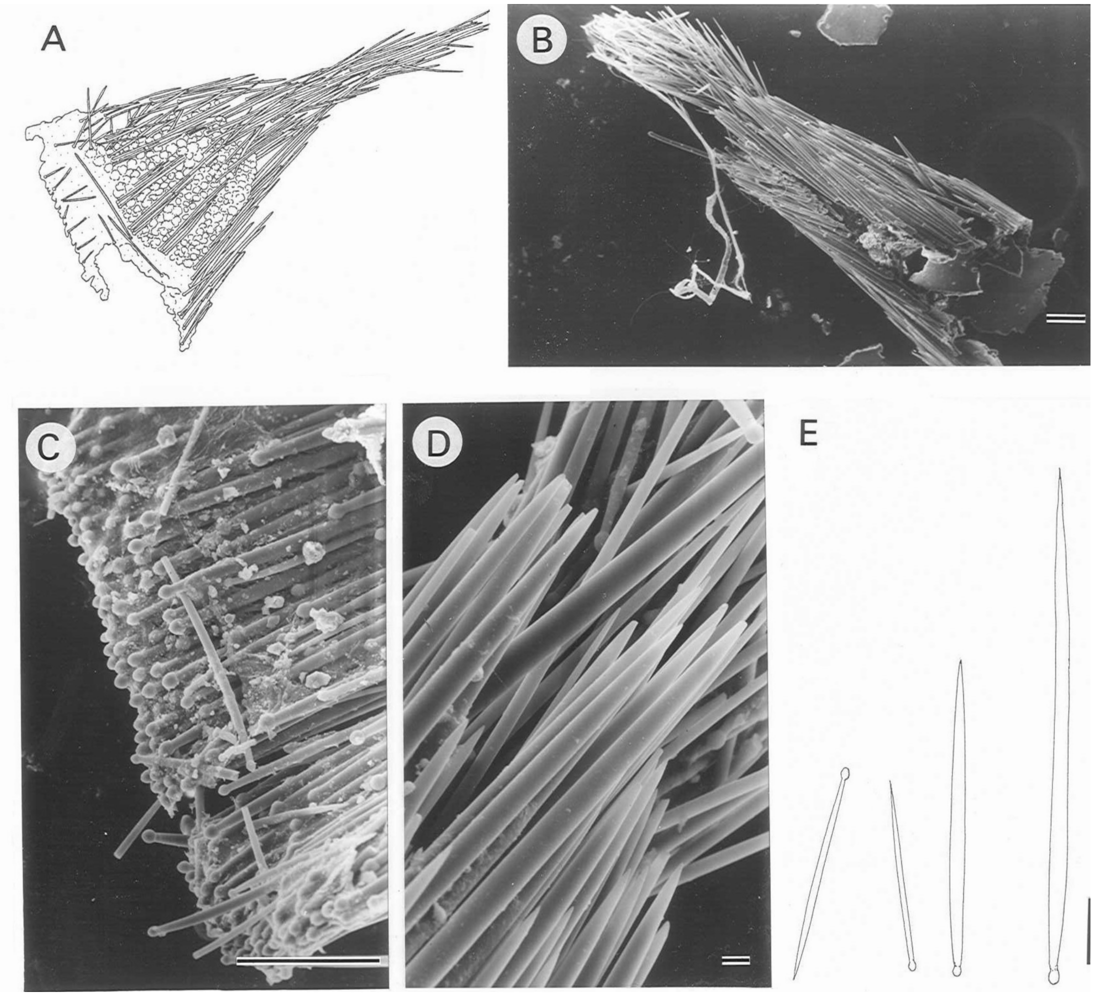

Fig. 5: *Tentorium levantinum.* (A) Longitudinal section through a specimen. Scale bar = 100 µm, (B) View on a specimen. Scale bar = 100 µm; (C) View from beneath on the spicule fringe, showing the orientation of the spicules with their heads down. Scale bar = 100 µm; (D) View from above on one of the vertical bundles, showing the orientation of the spicules, with their pointed ends directed above. Scale bar = 10 µm; (E) Tylostyles. Scale bar = 100 µm.

1421 m, 11.09.1997: 1 spec. (TAU).- Stn L21, 32°29.30'N, 34°17.00'E, 1272 m, 10.09.1997: 19 spec. (TAU).- Stn L51, 32°27.90'N, 34°04.90'E, 1362 m,10.09.1997: 2 spec. (TAU).- Stn L52, 32°30.84'N, 34°19.34'E, 1269 m, 10.09.1997: 19 spec. (TAU).- Stn P13, 32°42.49'N, 34°10.17'E, 1463 m, 17.09.1997: 1 spec. (TAU).- Stn L4, 32°29.14'N, 34°15.03'E, 1296 m, 6.11.1998: 15 spec. (TAU).- Stn L15, 32°41.42'N, 34°13.95'E, 1243 m, 4.11.1998: 27 spec. (TAU).- Stn L19, 32°33.09'N, 34°03.08'E, 1462 m, 5.11.1998: 14 spec. (TAU).- Stn L20, 32°31.48'N, 34°3.99'E, 1344 m, 5.11.1998: 12 spec. (TAU).- Stn L21, 32°27.06'N, 34°15.5'E, 1276 m, 6.11.1998: 9 spec. (TAU).- Stn L22, 32°30. 4'N, 34°02.67'E, 1450 m, 5.11.1998: 15 spec. (TAU).- Stn L25, 32°25.09'N, 34°06'E, 1351 m, 6.11.1998: 3 spec. (TAU).- Stn L26, 32°27.81'N, 34°16.82'E, 1277 m, 6.11.1998: 13 spec. (TAU).- Stn L27, 32°29.13'N, 34°19.79'E, 1251 m, 6.11.1998: 16 spec. (TAU).- Stn L28, 32°25.03'N, 34°05.09'E, 1319 m, 6.11.1998: 5 spec. (TAU).- Stn L19, 32°33.09'N, 34°03.08'E, 1462 m, 5.11.1998:

External morphology

Color in alcohol: whitish.
Growth form: extremely small conical sponges

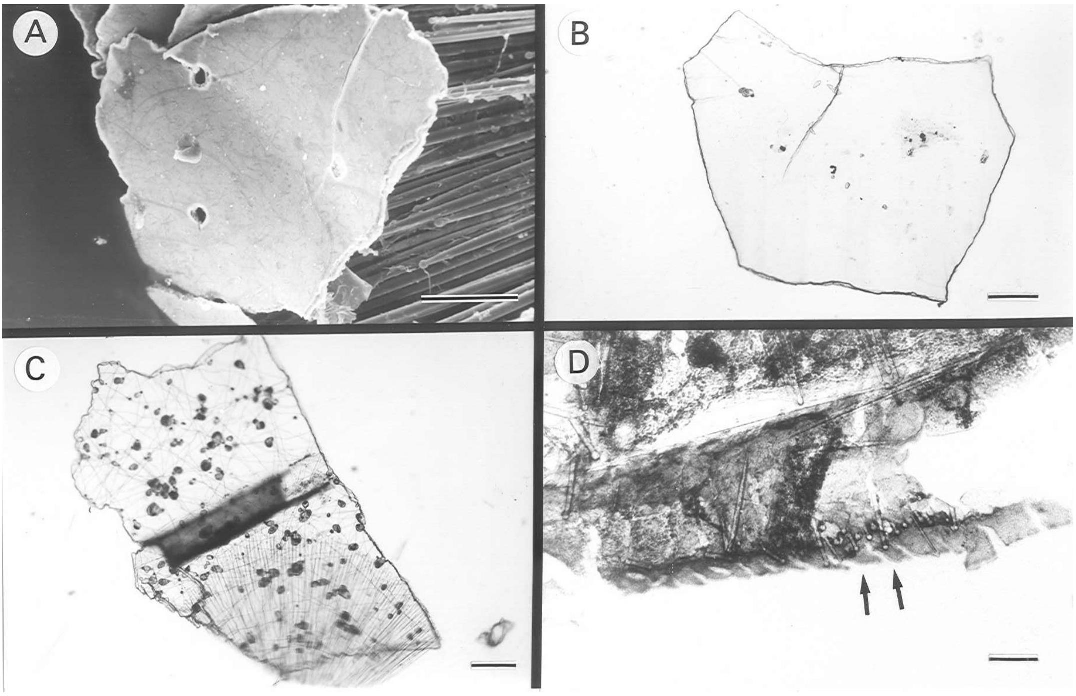

Fig. 6: *Tentorium levantinum*, basal plate. (A) SEM-view from beneath; (B) Fragment of the basal plate; (C) Fragment of a basal plate with part of the attached spicule fringe; (D) The "head" of the tylostyles (arrows) embedded within the basal plate. Scale bars = 100 µm.

(Figs. 4; 5A) with only a single exhalant process, always growing on a concave basal plate (Fig. 6). This basal plate is the outcome of the sponge deposition and not of a foreign origin as can be seen in Fig. 6D, where the embedded sponge spicules in the basal membrane are evident. In histological preparation using trichromic staining after MassonGoldner the basal plate was stained intensively blue, indicating high content of collagenous material. It was not affected by 2% hydrofluoric acid, but is dissolved in sodium hypochlorite (although not effected by the broad-spectrum protease pronase). Area of basal plate is 1-3.5 mm^2 (the plate's actual size varies, but it is larger than the sponge base). The basal plates are probably larger *in vivo* since all the plates in the sponges collected appear to have been broken during collection. Height of the cone is ca. 0.4-0.7 mm, and its top is flat to slightly concave. From this plateau arises the exhalant process of 0.2-0.7 mm, with a single oscule, invisible to the naked eye. The central space within the cone is filled with the choanosome. Seven additional specimens were found on hard rocky substrate collected from the Sea of Crete are 0.5-2.2 mm in cone height and 1.2-3.5 mm in diameter of the basal plate (Janussen et al. unpubl. data).

Skeleton

The sponge cone shape is the outcome of a fringe of long tylostyles in vertical position positioned tightly against one another. The tylostyles of the fringe converge upwards, so at the top the diameter of the cone is only about a quarter of the base. All spicules of the fringe are positioned with their heads on the basal plate and some even embedded in the plate (Figs. 5C, 6D) with the pointed ends towards the top of the cone (Fig. 5D). Several (generally four in each section) vertical bundles of tylostyles occur inside the cone. The spicules orientation in these bundles is the same as that of the surrounding fringe spicules. The heads touch the basal plate, and some are embedded but do not penetrate through it (Figs. 5C, 6D). Additional spicules are positioned horizontally just above the plate. The exhalant papilla is fringed by shorter tylostyles, placed more or

Table 2: *Tentorium levantinum*, spicule measurements

Spicule type	Length range (μm) (n=50)	Length mean (μm) ± s.d. (n=50)	Width range (μm) (n=10)	Width mean (μm) ± s.d. (n=10)
Tylostyles	190-820	455 ± 163	7.5-17.25, (at the widest point)	12.5 ± 3.3, (at the widest point)
Tylostyles, heads			7.25-10.25	9 ± 1

less vertically, diverging from one another. No visible spongin-fibers are observed, although the spicules of the outer spicule fringe are engulfed by a collagenous-layer.

Spicules

Straight fusiform (thickest in the middle and not at the head) tylostyles (Fig. 5E). The spicules have a broad size range without distinguishable size classes. Nevertheless the distal fringe almost entirely consists of long tylostyles, whereas the wall of the exhalant papilla contains only small spicules and the vertical bundles are constructed of small or intermediate sized spicules. Dimensions are given in Tab. 2. The seven specimens found by Janussen et al. in the Sea of Crete and Sporades Basin (unpubl. data) posses somewhat larger spicules (470 to 800μm) but otherwise show the same morphology as the specimens reported here.

Etymology: Known mainly from the Levantine basin of the Mediterranean where it was collected for the first time.

Remarks: Tentorium levantinum n. sp. has only straight tylostyles as megascleres without microscleres. Possible family assignments would be Suberitidae or Polymastiidae. Since the outer cone is a palisade of tylostyles and the upper periphery and the wall of the papilla are fringed by small ectosomal tylostyles in vertical to plumose orientation, we attribute this species to the Polymastiidae.

Within the Polymastiidae, the new species bears most characters of the genus *Tentorium* Vosmaer 1885, and there is also some resemblance with *Radiella* Schmidt 1870 (see Boury-Esnault and van Beveren 1982). However, the spicule arrangement and the different orientation of the spicule fringe, separate it from *Radiella* (Boury-Esnault 2002). Within the genus *Tentorium* there are currently two recognized species *T. semisuberites* Schmidt, 1870 and *T. papillatum* Kirkpatrick, 1907 (Boury-Esnault 2002). The new species does not conform to the description of any of these species. *T. semisuberites* general morphology is more globular, frequently with more than one exhalant papilla. It has much larger body size (10-30mm), and larger spicules. This species may attach itself to hard substrate particles (Barthel and Tendal 1993) but no mention has been given to structures as described here for the new species. In Addition, *T. semisuberites* was found in shallower water between 50 and 300m (recently reviewed by Boury-Esnault 2002) although Barthel and Tendal (1993) reported it from a wider range of 26-3193m. *T. papillatum* differs from the *T. levantinum* by the shape of the sponge surface, it has larger body and larger spicules size, and more than one papilla (Kirkpatrick 1907). The spicule bundles inside the cone diverge radially instead of the slightly convergent to vertical orientation seen in *T. levantinum. T. papillatum* is distributed not more than 1000m but usually shallower. This species, however, according to Kirkpatrick (1907) possesses a basal chitinous lamella comparable to the one found in *T. levantinum.* The present new species appeared in 18 out of the 27 stations sampled by net and in one out of the 36 sampled by box-corer.

Family Suberitidae

Rhizaxinella Keller, 1880

Diagnosis: Suberitidae with spherical or ovoid body carried on a long thin stalk. Skeleton radially arranged with ectosomal spicule brushes at the surface. Spicules tylostyles, and if present rhaphides arranged in trichodragmas (van Soest 2002).

Rhizaxinella shikmonae n. sp.

Material examined: Holotype: Israel. Off Hadera. 1 specimen Stn L1H, 32°46.41'N, 34°20. 02'E, 1427 m, 28.10.1996: (on slide) (ZMTAU SP25151),

Paratypes: Israel. Off Hadera. 2 specimens,

Table 3: *Rhizaxinella shikmonae*, spicule measurements

Spicule type	Length range (µm) (n=50)	Length mean (µm) ± s.d. (n=50)	Width range (µm) (n=10)	Width mean (µm) ± s.d. (n=10)
Tylostyles	365-945	700 ± 153	6.25-15.75	10.25 ± 2.8
Oxea	75-155	105 ± 12	2-2.5	2.25 ± 0.17

Stn L1H, 32°46.41'N, 34°20.02'E, 1427 m, 28.10.1996 (ZMTAU SP25185 and NHM).

Additional material (spicule preparations): Stn L2H, 32°54.89'N, 34°22.83'E, 1453 m, 28.10.1996

Additional material examined: Israel. Off Hadera. Stn L7, 32°41.70'N, 34°3.90'E, 1493 m, 11.09.1997: 6 spec. (TAU).- Stn L13, 32°41.80'N, 34°10.86'E, 1467 m, 9.09.1997: 3 spec. (TAU).- Stn L14, 32°40.00'N, 34°13.70'E, 1415 m, 9-11.09.1997: 3 spec. (TAU).- Stn L19, 32°33.42'N, 34°4.43'E, 1421 m, 11.09.1997: 3 spec. (TAU).- Stn L21, 32°29.30'N, 34°17.00'E, 1272 m, 10.09.1997: 11 spec. (TAU).- Stn L51, 32°27.90'N, 34°4.90'E, 1362 m, 10.09.1997: 1 spec. (TAU).- Stn L52, 32°30.84'N, 34°19.34'E, 1269 m, 10.09.1997: 14 spec. (TAU).- Stn L4, 32°29.14'N, 34°15.03'E, 1296 m, 6.11.1998: 5 spec. (TAU).- Stn L19, 32°33.09'N, 34°03.08'E, 1462 m, 5.11.1998: 15 spec. (TAU).- Stn L20, 32°31.48'N, 34°03.99'E, 1344 m, 5.11.1998: 13 spec. (TAU).- Stn L21, 32°27.06'N, 34°15.05'E, 1276 m, 6.11.1998: 4 spec. (TAU).- Stn L22, 32°30.04'N, 34°02.67'E, 1450 m, 5.11.1998: 1 spec. (TAU).- Stn L24, 32°29.76'N, 34°03.22'E, 1391 m, 5.11.1998: 4 spec. (TAU).- Stn L25, 32°25.9'N, 34°06'E, 1351 m, 6.11.1998: 4 spec. (TAU).- Stn L26, 32°27.81'N, 34°16.82'E, 1277 m, 6.11.1998: 3 spec. (TAU).- Stn L27, 32°29.13'N, 34°19.79'E, 1251 m, 6.11.1998: 14 spec. (TAU).- Stn L28, 32°25.03'N, 34°05.09'E, 1319 m, 6.11.1998: 4 spec. (TAU).- Stn P26, 32°28.03'N, 34°17.06'E, 1271 m, 7-8.12.1998: 1 spec. (TAU). Off Haifa. Stn L1, 32°58.70'N, 34°37.11'E, 1299 m, 8.09.1997: 6 spec. (TAU).- Stn L2, 32°59.20'N, 34°33.70'E, 1374 m, 8.09.1997: 3 spec. (TAU).- Stn L3, 32°57.90'N, 34°34.80'E, 1349 m, 7.09.1997: 3 spec. (TAU).- Stn L4, 32°59.90'N, 34°33.20'E, 1389 m, 8.09.1997: 3 spec. (TAU).- Stn L6, 33°00.00'N, 34°30.90'E, 1434 m, 8.09.1997: 4 spec. (TAU).- Stn L7, 32°57.61'N, 34°40.30'E, 1227 m, 9.09.1997: 3 spec. (TAU).- Stn L8, 33°00.86'N, 34°36.60'E, 1313 m, 7-9.09.1997: 3 spec. (TAU).- Stn L9, 33°01.53'N, 34°28.56'E, 1439 m, 7.09.1997: 3 spec. (TAU).

External morphology

Body oval, globular above a peduncle with an elaborate root system, surface hispid (Fig. 4). The sponge body is about 0.5-2.5 mm long and 0.6-2 mm wide, with a 1-3 mm long hollow peduncle (in some cases the stalk may be more than 1 cm long). It contains a deep central cavity ending in a small round osculum, which may be invisible in smaller specimens. Larger specimens (up to 25mm long and 6 mm wide, Fig. 7D) were retrieved from different stations in the central and eastern Mediterranean Sea, e. g. Sea of Crete (Janussen et al. unpubl. data). Color in alcohol: grayish-brown.

Skeleton

Choanosome: axially condensed tracts of (sub)tylostyles (Fig. 7A), which extend into the hollow stalk. Subectosome with large extra-axial (sub)tylostyles similar to the axial ones and a few small oxea. Ectosome: dense tangential crust of fine oxea crossed by large extra-axial (sub)tylostyles, which protrude beyond the sponge surface (Fig. 7A, B).

Axial skeleton: (sub)tylostyles arranged along the axis of the peduncle with their heads in proximal direction and the tips pointing upwards and outwards in growth direction. Some of the (sub)tylostyles are longer and flexuous. The center of the peduncle is devoid of spicules. As in the body of the sponge, the peduncle's ectosome has a tangential layer of small oxea.

Microscleres are absent

No visible spongin fibers exist, but a spongin layer covers the entire sponge.

Spicules

Large (sub)tylostyles (Fig. 8b), usually straight, but some flexuous long spicules occur in the stalk (Fig. 7C). The (sub)tylostyle spicules have a wide range of dimensions (Tab. 3). Also present are thin, small straight, slightly tapering oxea (Fig. 8a).

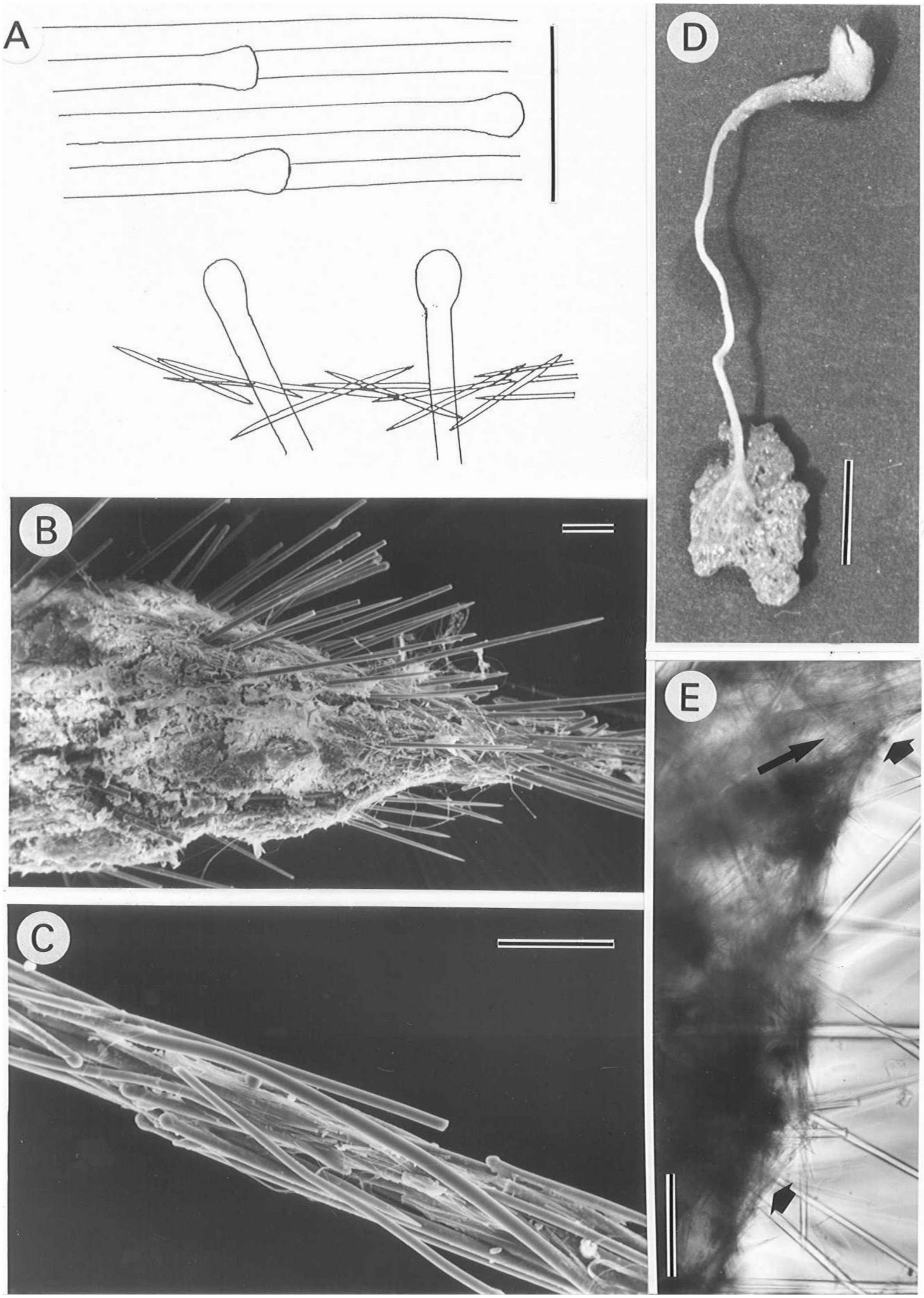

Fig. 7: *Rhizaxinella shikmonae.* (A) Skeletal organization; (B) Lateral view of a specimen cut in two; (C) "Stalk" with bent spicules. Scale bar = 100 µm; (D) A complete specimen collected in the Sea of Crete. Note the attachment root system. Scale bar = 1 cm; (E) The presence of tangential layer of small oxea is evident. Scale bar = 100 µm.

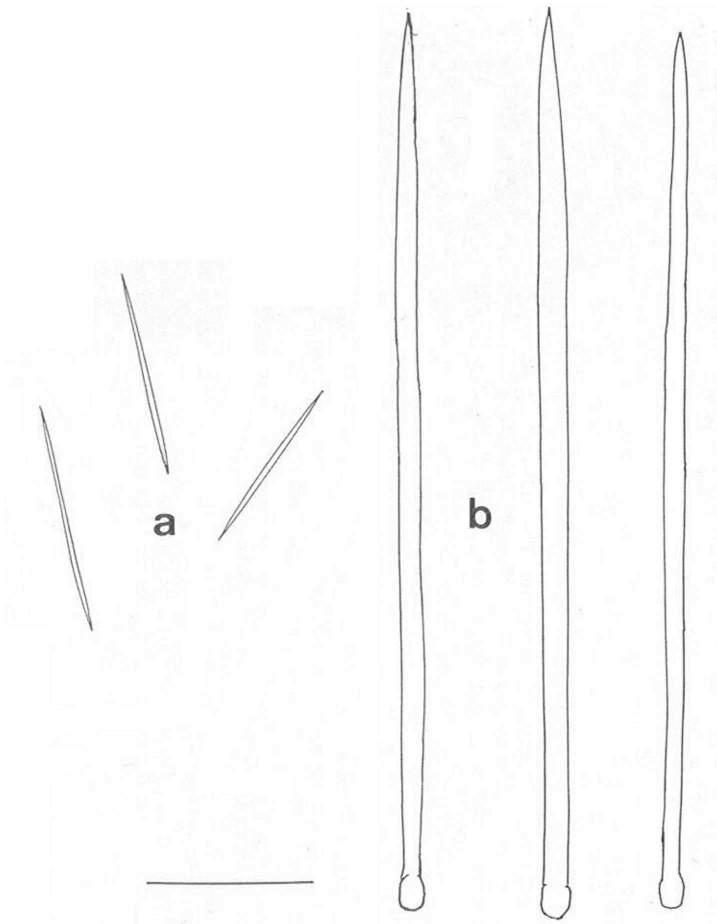

Fig. 8: *Rhizaxinella shikmonae*, spicules. (a) Oxea; (b) (Sub)tylostyles. Scale bars = 100 µm.

Etymology: After R.V. Shikmona from which the collections were made.

Remarks: The skeleton of *R. shikmonae* is axially compressed and has a specialized ectosomal skeleton consisting of protruding large tylostyles and tangential crust of thin oxeote spicules (Figs. 7A, 8a). According to Pulitzer-Finali (1983), in the Mediterranean there are three *Rhizaxinella* species: *R. pyrifera* (Delle Chiaje 1928), *R. gracilis* (Lendenfeld 1896), and *R. elongata* (Riedly & Dendy, 1886). The present species differs from the two latter species since they do not possess any oxeote or raphid spicules. *R. pyrifera* is the most closely related species, although it usually has tylostyles much larger than in the species reported here where the largest spicule measured was 945µm compared with 2100µm and 2500µm by Pulitzer-Finali (1983) and Boury-Esnault et al. (1994) respectively. *R. pyrifera* also possesses raphids of similar size as the *R. shikmonae* oxea. Moreover, also Boury-Esnault et al. (1994) recognized that the small spicules of their collected *R. pyrifera* are like microxea and do not form trichodragmas. However, *R. shikmonae* differs from all other *Rhizaxinella* species, including *R. pyrifera*, by having a prominent tangential layer of the small oxea (Fig. 7E). This layer is less dense in larger specimens, but still clearly visible in histological sections (Janussen et al. unpubl. data). Such a layer is more typical of members of the family Stylocordylidae. However, this family is also characterized by having two sizes of oxeote spicules, long centrotylote spicules and unusual short, terminally curved spicules. Therefore the new species is positioned within the *Rhizaxinella*, although its generic affiliation does not entirely comply with the current genus definition (van Soest, 2002).

Rhizaxinella shikmonae is attached to a hard substrate by means of its root system, even when found in soft bottom environment (Fig. 7D). It is not clear if the species can attach itself in the soft bottom also in the absence of an initial hard substrate. *Rhizaxinella shikmonae* appeared in 26 out of the 27 stations sampled by net and in one out of 36 sampled by a box corer. It was also found to be quite common in the Sea of Crete and Sporades Basin at depths between 1875 m and 4300 m (Janussen et al. unpubl. data) and West Mediterranean (Vacelet *in litt.*).

DISCUSSION

It is commonly thought that most sponges are dependent for attachment on hard substrate. Maldonado and Young (1996) have shown that the highest abundance of sponges, from the littoral to the deep-sea, occurs on vertical walls. However, in the Western Mediterranean interesting fauna has been collected from argillaceous mud (Uriz and Rosell 1990). Our own previous work concentrated on hard substrate (Ilan et al. 1994). In the current study, we set out to investigate the bathyal mud-inhabiting sponges off the Mediterranean coast of Israel. The use of a box-corer as a sampling device is appropriate only if the species is relatively abundant. In our case, however, the sponges often eluded samplings by box-corer probably because of their scarcity. On the other hand, nearly 500 specimens were collected in the plankton net, whereas none was collected in the larger Marinovich type semi-balloon trawl. It would appear that small sized sponges are not retained by the larger nets or dredges used in previous expeditions. We are convinced that the future use of small-mesh nets would greatly contribute to enriching our knowledge of the deep-sea sponge fauna (Janussen et al. 2003).

In 29 stations where sponges were found, we identified four sponge species: *Tentorium levantinum,* n. sp., *Rhizaxinella shikmonae* n. sp., *Sycon faulkneri* n. sp. and *Plectroninia* sp. *Tentorium levantinum* is probably a free-living species, with a special adaptation for life on soft substrate: a broad basal plate that prevents it from sinking into the fine mud. When it grows on hard substrate environment (as is the case with the Sea of Crete specimens) this plate is smaller compared to body diameter, but yet evident (Janussen et al. unpubl. data). *Rhizaxinella shikmonae* is anchored in the soft substrate using a special basal anchoring root system that may attach to hard pieces in such an environment. Similarly, although a resident of bathyal fine mud, *Plectroninia* sp., an encrusting sponge, still needs a foothold of small (about 1 mm^2) hard substrate.

The presence of two calcareous species within our collection is unusual since most Calcarea are reported from water not deeper than 100 m (Bergquist 1978), although especially in the North Atlantic this is not always the case (e. g., Hansen 1885; Koltun 1964; Tendal 1989, Janussen et al. 2003). The most notable example of a bathyal calcareous sponge is *Sycon abyssale,* which was found between 2400 and 3900 m (Borojevic and Graat-Kleton 1965) and *Pericharax* n. sp. Collected from 4000 m in the Antarctic Weddell Sea (Janussen et al. 2003) . Hartman (1982) cites for most sponge families at least one species that occurs deeper than 100 m but only a third of the families have bathyal representatives. Borojevic and Boury-Esnault (1987) recorded several N.E. Atlantic deep-water calcareous sponges (down to 760 m for one species). The rarest of the four species found in the present study was *Plectroninia* sp. It belongs to a family (Minchinellidae) usually found in coastal habitats (Vacelet 1991). The present finding of *Plectroninia* sp. at such depths (1269-1391 m) is one of the deepest records for this genus that is known to exist from ca. 10 to 1600 m (Burton 1963; Pouliquen and Vacelet 1970; Vacelet 1991). This observation confirms a trend we noticed in a previous work (Ilan et al., 1994) and observation of specimens from the Sea of Crete and Sporades Basin (Janussen et al. unpubl. data) that even within a species, the Eastern Mediterranean specimens sometimes live at greater depths compared with the Western Mediterranean.

Generally the sponge specimens of each species are bigger in the western than in the eastern part of the Levant Basin, and this tendency is independent of water depth. The diversity might be somewhat higher at the deep Sea of Crete, because here we find the three new species described herein and furthermore two demosponge species, which we did not collect at the localities off Israel. Only *Plectroninia* has so far not been found in the "Meteor" collections (Janussen et al. unpubl. Data). The small number of sponges, their small size, and their overall low biomass in the samples, attest to the inability of the deep-sea soft bottom environment in the Eastern Mediterranean to carry large sized sponges. This is probably due to the scarcity of water-borne particles in deep-sea environments, leading to suspension feeding being less important in deep-sea compared with shallower depths (Witte et al. 1997). This might explain the evolution of the recently discovered carnivorous deep-sea sponges (Vacelet and Boury-Esnault 1995; Vacelet et al. 1996). In addition to the general scarcity of organic particles in deep-sea, the absence of input from large Eastern Mediterranean rivers (especially since the damming of the Nile) also reduces particle influx of terrestrial origin.

Mediterranean deep-sea sponges are believed to be widely distributed (Uriz and Rosell 1990). Of the four taxa described in the present work three are new to science, and one may be new. Of the five species recorded in our previous studies in the Levantine bathyal, one was new to science (Ilan et al., 1994; Galil and Zibrowius 1998). The high degree of perceived endemism found among the Levantine bathyal sponges might be attributed to the use of a new technique for collecting the hitherto neglected small sized soft bottom sponges. In addition, such endemism may also be attributed to the unique history of the basin and its special physical conditions (Fredj and Laubier 1985). It should be noted that within the region, except for *Plectroninia* sp., the sponges were found in most of the stations sampled. So even if there are no dense populations, they are still quite ubiquitous.

In conclusion, we concur with Vacelet (1996) "Il est certain que l'inventair des éponges profonde de la Méditerranée est encore tres incomplet". We hope that the findings in this study will stimulate further surveys and that the use of various devices, like that described in this article, will reveal additional deep-sea species.

MATERIAL AND METHODS

The material for this study was collected during monitoring of two deep-water waste disposal sites off the northern coast of Israel. One site, 70 kms off Hadera, is for coal fly ash produced by two coal fired power plants; the other, 50 kms NW of Haifa, is for acidic industrial sludge from the production of fertilizers (Fig. 1). At the coal ash site epibenthic fauna were collected from 9-11 September 1997 and 11 sediment samples from 16-18 September 1997. The following year, epibenthic fauna were collected from 4-7 November 1998, and 18 sediment samples from 7-8 December 1998. At the acidic sludge site epibenthic fauna and 7 sediment samples were collected from 7-9 September 1997.

Epibenthic fauna was collected by 0.5 mm plankton net set atop a Marinovich type semi-balloon trawl. Sediment was sampled by 0.062 m^2 box corer (Ocean Instruments, BX 700 A1). Net collected samples (n=27) are identified by the letter L, and box-corer samples (n=36) by the letter P. Samples were initially fixed in 10% formalin. Following sieving and preliminary sorting they were preserved in 70% ethanol. Several specimens of each species were dried on a microscope slide and mounted with Permount (Fisher Scientific). Other specimens were dissolved in sodium hypochlorite, and washed in distilled water followed by ethanol (70%) for spicule preparations; the isolated spicules were dried on a glass slide and mounted with Permount. Spicule dimensions are based on 50 length and 10 width measurements, unless otherwise stated. Several entire specimens of *Tentorium levantinum* and *Rhizaxinella shikmonae* were cut in half, critical-point-dried, mounted on a stub and coated with gold for scanning electron microscope (SEM) examination. Other specimens were treated with common histological preparations using Masson gold as the staining procedure for 30 µm thick sections.

The material is deposited in the National Zoological Collection, Tel Aviv University (TAU), the Natural History Museum, London (NHM) and at The Naturmuseum Senckenberg, Frankfurt am Main (SMF).

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REFERENCES

Barthel, D., & O. Tendal 1993. The sponge association of the abyssal Norwegian-Greenland Sea: species composition, substrate relationship and distribution. – *Sarsia* **78:** 83-95.

Bergquist, P.R. 1978. *Sponges*. University of California Press, Berkeley.

Borojevic, R., & N. Boury-Esnault 1987. Calcareous sponges collected by N.O. *Thalassa* on the continental margin of the Bay of Biscaye: 1.Calcinea. *In* Vacelet, J. & N. Boury-Esnault (eds) *Taxonomy of Porifera from the N.E. Atlantic and Mediterranean Sea*. Springer Verlag, Berlin, pp. 1-27.

Borojevic, R. & G. Graat-Kleeton 1965. Sur une nouvelle espèce de *Sycon* et quelques Demosponges recoltées par le "Cirrus" dans l'Atlantique Nord. - *Beaufortia* **13:** 81-85.

Borojevic, R., N. Boury-Esnault & J. Vacelet 2000. A revision of the supraspecific classification of the subclass Calcaronea (Porifera, Class Calcarea). - *Zoosystema* **22:** 203-263.

Borojevic, R., N. Boury-Esnault, M. Manuel & J. Vacelet 2002. Order Leucosolenida Hartman, 1958. *In* Hooper J. & R.W.M. van Soest (eds) *Systema Porifera*. Kluwer Academic, New York, pp. 1157-1184.

Boury-Esnault, M. 2002. Polymastiidae Gray, 1867. *In* Hooper J. & R.W.M. van Soest (eds) *Systema Porifera*. Kluwer Academic, New York, pp. 201-219.

Boury-Esnault, N., M. Pansini & M.-J. Uriz 1994. Spongiaires bathyaux de la mer d'Alborean et du golfe Ibéro-Marocain. - *Mém. Mus. Nat. d'Hist. Naturelle, Zool.* **160:** 1-173.

Boury-Esnault, N., & M. van Beveren 1982. Les Démosponges du Plateau continental de Kerguelen-Heard. - *Comité National Français des Recherches Antarctiques* **52:** 1-132.

Burton, M. 1963. *A revision of the classification of the calcareous sponges*. British Museum (Natural History), London.

Duplessis, K. & H.M. Reiswig 2000. Description of a new deep-water calcareous sponge (Porifera: Calcarea) from northern California. - *Pacific Science* **54:** 10-14.

Fredj, G. & L. Laubier 1985. The deep Mediterranean benthos. *In* Maraitou-Apostolopoulu, M. & V. Kiortsis (eds) *Mediterranean Marine Ecosystems*. Plenum Press, New York, pp. 109-145.

Galil, B.S. & H. Zibrowius 1998. First benthos samples from Eratoshenes Seamount, Eastern Mediterranean. - *Senck. Mar.* **28:** 111-121.

Hansen, G.A. 1885. Spongiadae. - The Norwegian North-Atlantic Expedition 1876-1878. Zoology. 25 pp.

Hartman, W.D. 1982. Porifera. *In* Parker, S.P. (ed) *Synopsis and classification of living organisms*. McGraw-Hill, New York, **1:** 640-666.

Ilan, M., M.N. Ben-Eliahu & B.S. Galil 1994. Three deep water sponges from the Eastern Mediterranean and their associated fauna. - *Ophelia* **39:** 45-54.

Janussen, D., H. T. Rapp & O. S. Tendal (2003). A myth vanished: Calcareous sponges are alive and well at abyssal depths.- *Deep-Sea Newsletter*, **32**: 17-19.

Koltun, V.M. 1964. Porifera. - Pp. 143-166 in "Scientific results from higher latitudes. Oceanographic investigations in the northern part of the Greenland Sea and the adjacent Arctic Basins". Trudy arkt. antarkt. nauchno-issled. Inst. 259 (In Russian)

Maldonado, M. & C.M. Young 1996. Bathymetric patterns of sponge distribution on the Bahamian slope. - *Deep Sea Res. I* **43:** 897-915.

Meteor-Berichte 94-3: Mittelmeer 1993 Cruise No. 25, 12 May – 20 August 1993.- W. Hieke, P. Halbach, M. Türkay & H. Wiekert, (eds), 243 p.p., Institut f. Meereskunde, Univ. Hamburg.

Meteor-Berichte 99-2: Mittelmeer 1997/98 Cruise No. 40, 28 October 1997 – 10 February 1998.- W. Hieke, C. Hemleben, P. Linke, M. Türkay & H. Weikert (eds.), 286 p.p., Institut f. Meereskunde, Univ. Hamburg.

Pouliquen, L. & J. Vacelet 1970. Nouvelles observations sur des éponges pharétronides, Minchinellidae de Mediterranée. - *Tethys* **2:** 437-442.

Pulitzer-Finali, G. 1983. A collection of Mediterranean Demosspongiae (Porifera) with, in appendix, a list of the Demospongiae hitherato recorded from the Mediterranean Sea. - *Annali del Museo civico di storia naturale Giacomo Doria* **84**: 445-621.

Tendal, O.S. 1989. Calcareous sponges in the abyssal Norwegian and Greenland Seas. - *Deep-Sea Newsletter* **l5**: 22-23.

Uriz, M.-J. & D. Rosell 1990. Sponges from bathyal depths (1000-1750m) in the Western Mediterranean Sea. - *J. Nat. Hist.* **24:** 373-391.

Vacelet, J. 1967. Quelques éponges Pharétronides et "Silico-Calcaires" de grottes sous-marins obscures. - *Rec. Trav. Stat. Mar. d'Endoume* **42:** 121-132.

Vacelet, J. 1969. Éponges de la Roche du Large et de l'étage bathyal de Méditerranée (Récoltes de la soucoupe pologeante Cousteau et dragages). - *Mém. Mus. Nat. d'Hist. Naturelle, Zool.* **A59:** 145-219.

Vacelet, J. 1970. *Les éponges Pharétronides actuelle. In* Fry, W.G. (ed) *Biology of the Porifera*. Academic Press, London, pp. 189-204.

Vacelet, J. 1981. Éponges hypercalcifiées ("Pharétronides", "Sclérosponges") des cavités des récifs coralliens de Nouvelle-Calédonie. - *Bull. Mus. Nat. d'Hist. Naturelle, Zool.* **3A:** 313-351.

Vacelet, J. 1991. Recent Calcarea with a reinforced skeleton. *In* Reitner J. & H. Keupp (eds) *Fossil and recent sponges*. Springer-Verlag, Berlin, pp. 252-265.

Vacelet, J. 1996. New records of deep-sea sponges from the Mediterranean Sea. - *Mésogée* **55:** 107-114

Vacelet, J., R. Borojevic, N. Boury-Esnault & M. Manuel 2002. Order Lithonida Vacelet, 1981 Recent. *In* Hooper J. & R.W.M. van Soest (eds) *Systema Porifera*. Kluwer Academic, New York, pp. 1185-1192.

Vacelet, J. & N. Boury-Esnault 1995. Carnivorous sponges. - *Nature*, **373:** 333-335.

Vacelet, J., N. Boury-Esnault & H. Zibrowius 1989. Unexpected deep-water records of calcareous sponges (Calcarea). - *Deep-sea Newsletter* **15:** 24-25.

Vacelet, J., A. Fiala-Medioni, C.R. Fisher & N. Boury-Esnault 1996. Symbiosis between methane-oxidizing bacteria and a deep-sea carnivorous cladorhizid sponge. - *Mar. Ecol. Prog. Ser.* **145:** 77-85.

van Soest, R.W.M. 2002. Suberitidae. *In* Hooper J. & R.W.M. van Soest (eds) *Systema Porifera*. Kluwer Academic, New York, pp. 227-244.

Witte, U., T. Brattegard, G. Graf & B. Springer 1997. Particle capture and deposition by deep-sea sponges from the Norwegian-Greenland Sea. - *Mar. Ecol. Prog. Ser.* **154:** 241-252.

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