GEOLOGIE EN MIJNBOUW VOLUME 56 (2), p. 168-181 1977

# BORING SPONGES (CLIONIDAE) AND THEIR TRACE FOSSILS FROM THE COAST NEAR ROVINJ (YUGOSLAVIA)

R.A. DE GROOT[1)]

## ABSTRACT

Groot, R.A. de (1977). Boring sponges (Clionidae) and their trace fossils from the coast near Rovinj (Yugoslavia). Geol. Mijnbouw, 56, p. 168-180.

Boring sponges of the genus *Cliona* were sampled by SCUBA-diving in the Adriatic Sea near Rovinj, Yugoslavia. Boulders of limestone and shells of molluscs, infested by clionids were collected. The sponges were identified and polyester casts were made of their bore-holes.

A description is presented of the spiculae of the sponges as well as their bore-holes. It appears that sponges with different spiculae excavate different borings. The borings in limestone are larger than those in shells.

## INTRODUCTION

Clionids show a wide geographic distribution and the clionid family has origins dating from at least the Silurian. Their usual habitats are excavations bored in calcareous hard substrates, such as limestone, coral and shells of molluscs. Warburton (1958) found that boring sponges can spread in two ways. "They may simply grow across the border between the shell they are living in and a new shell, with which the former is in contact. Or, they may spawn and produce swimming larvae which may settle on and infest new shells". When the sponge has settled on a calcareous surface, it begins to bore into the carbonate material.

The boring process is still little understood. According to Hancock (1849, 1867), the method of boring is mechanical excavation by the grinding action of spiculae. But Nassonov (1883) proved that larval clionids are boring actively before the development of spiculae. Nassonov also observed that active clionids produce small fragments of calcareous material. This phenomenon excludes boring by chemical etching alone. Warburton (1958) cultivated reconstituted clionids on calcite crystals. He found, that cells in contact with the substratum form a reticulum of fine filaments. The latter correspond with etched lines on the calcite crystals. The areas delimited in this way have the same size and shape as the fragments discharged by adult sponges. This proves that some (acid) solvent is secreted in minute quantities, and this solvent etches the calcite substratum.

The result of the boring process is a labyrinthine, anastomosing network of cavities within the carbonate material. The tissues of the ramified sponge colony line these cavities. Water currents, from which food is filtered, pass through perforations in the substratum surfaces, the papillae (Goreau & Hartman, 1963).

The modern taxonomy of recent clionids is based on the spiculae and on features such as: type of calcareous substratum, diameter and shape of individual papillae, number and distribution of papillae within one sponge colony and colour of living sponge tissue. Because the taxonomically important spiculae are not always preserved in the fossil record, paleontologists often study the cavities as trace fossil indications of ancient clionid presence (Fischer, 1868; Bromley, 1970).

Some recent clionid sponges were named on the strength of their cavity systems (for instance, Hancock, 1849). Such traces are best referred to as species of *Entobia*, the trace fossil generic name specially intended for such borings (Bromley, 1970).

Hartman (1958) and Hopkins (1962) found that different species of the genus *Cliona* have different tolerances for environmental factors such as the salinity of the water. Thus clionid distribution patterns may yield information on paleoenvironments.

This paper recounts some results of a study of recent clionid cavities, as a contribution to the status and taxonomy of trace fossils.

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1) Geologisch Instituut, Melkweg 1, Groningen, The Netherlands.

## AREA OF INVESTIGATION, COLLECTING METHOD, PREPARATION AND CASTING TECHNIQUES

The boring sponges were collected in 1975 in the vicinity of Rovinj, in the Yugoslavian Adriatic Sea. Rovinj was chosen because boring sponges are known to be in this area (Volz, 1939 and Rützler, 1965). The littoral terrace at Rovinj consists of limestone bedrock of the upper Cretaceous and loose limestone material to a depth of ± 18 meters. Below this depth an open sandy bottom is found, with a sparse collection of mollusc shells and small limestone pebbles.

All boring sponges described here were collected by SCUBA-diving near islands 500-1500 meters off the coast, at depths between 2 and 15 meters. Samples were taken close to the islands of Altyez, Frzital, Reverol, Tovarjez, Gusti Skolj, Figarola and Banjol (Fig. 1). It was not possible to take samples from other places of this region.

During diving, attention was paid to the depth at which the sponges were living. Nearly all the sponges collected were boring into loose limestone and shells. Sponges in firm bedrock were hard to collect, as the substratum is often overgrown with algae. Moreover, these were hard to cut out because the solid rock was crushed to pieces by hammer and chisel.

The collecting method was biased because only rather large colonies of boring sponges, in otherwise unaffected stones, were gathered. After collection the sponges were labelled; the locality and depth were noted, as well as the colour of the living sponge. The sponges were halved; one part was sun-dried, the other half was preserved in alcohol.

In the laboratory, microscopic slides were made for inspection under the light microscope. The length of the spronge spiculae was measured with an ocular micrometer. Scanning electron microscopy (JEOLCO-JSM-U3) was applied on a limited number of specimens, to observe the surface of the spiculae.

In order to study the trace fossils, casts were made. After determination of the sponge tissue, the excavated shells or limestone pebbles were put in a beaker with $H_2O_2$ (35%), until all organic material was removed. This took about two days. After drying of the substratum, its cavities were filled with polyester-resin.

It is necessary to make the casts in a vacuum, because otherwise the polyester-resin does not enter the cavities. It took 24 hours before the polyester-resin was completely solidified and another 24 hours to dissolve (HCl 35%( the calcareous matter of the substratum.

## THE SPONGES AND THEIR BORINGS

### *Introduction*

The taxonomic criteria as applied in the literature are not always consistent nor are the same criteria always regarded as significant. The type material of the different sponge species has not been inspected, it is not certain whether the species names applied by Volz, Rützler and this paper, are utilized according to the intentions of their original authors.

The shape and size of the spiculae and the combinations of skeletal elements in the different sponges are considered as major characteristics in this report. The boring sponges described here have a skeleton involving only three kinds of siliceous spiculae, namely tylostyles, amphioxi and spirasters. One or two of these spiculae may be lacking entirely. Features, such as colour of the living sponge, diameter and distribution of papillae are also recorded. The length of the spiculae is tabulated solely for the colonies in which the borings were also studied.

### *Descriptions of the sponge species*

#### *Cliona celata* Grant

*Cliona celata* Grant 1826, p. 78-81

*Papillella suberea* (O.Schim.), Lendenfeld 1898, p. 99-106, pl. III fig. 23-25. pl VII fig. 68

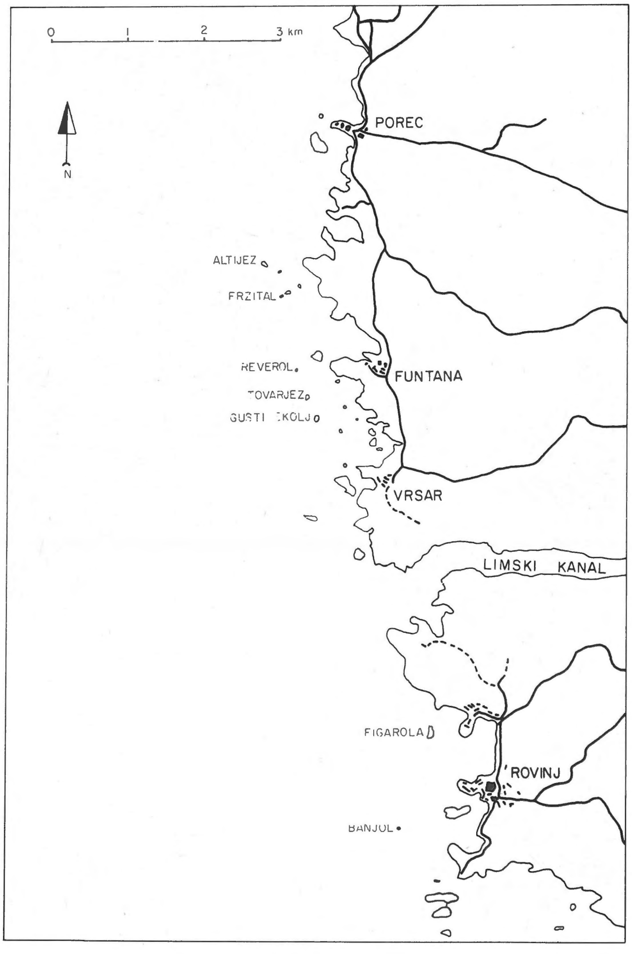

Fig. 1
Part of the western shore of Istria, showing the investigation area.

*Papillella quadrata* (Hancock), Lendenfeld 1898, p. 106-111, pl. III fig. 28-29, pl. VII fig. 76

*Cliona celate*, Topsent 1900, p. 32, 33, pl. I fig. 5a, b, d, fig. 6, pl. II fig. 1

*Cliona celata*, Volz 1939, p. 4-7, fig. 1

*Cliona celata*, Old 1941, p. 8, pl. VIII

*Cliona celata*, Hartman 1958, p. 16, 17

*Cliona celata*, Rützler 1965, p. 21, 22

The sponges have smooth, straight or slightly curved tylostyles. The head of these tylostyles is either asymmetrical, subterminal or may be lacking entirely (Fig. 2). The length of the tylostyles varies from 209 to 370 microns; the average is 277 microns (Table 1).

None of the sponges considered to be *Cliona celata* Grant by the present author, regardless of the size of the colony, carries spirasters. This is at variance with the descriptions of Volz (1939), Vosmaer (1933) and Hopkins (1956) of their *Cliona celata* Grant. The mostly yellow, less often red papillae have diameters between 0,3-10 mm. Most papillae are about 1,5 mm wide (Fig. 3, 4).

A free-living stage of *Cliona celata*, named $\beta$ – and $\gamma$ –stage by Vosmaer was not found. All the sponges were living in cavities, excavated in limestone rocks and shells. Some of these were so porous that less than 10% of the original calcareous substratum remained. The surface of the substratum, however, always remained intact (but for the perforations for the papillae) and also the partition walls between the individual spongelets. It is difficult to imagine any "free-living" *Cliona* colony.

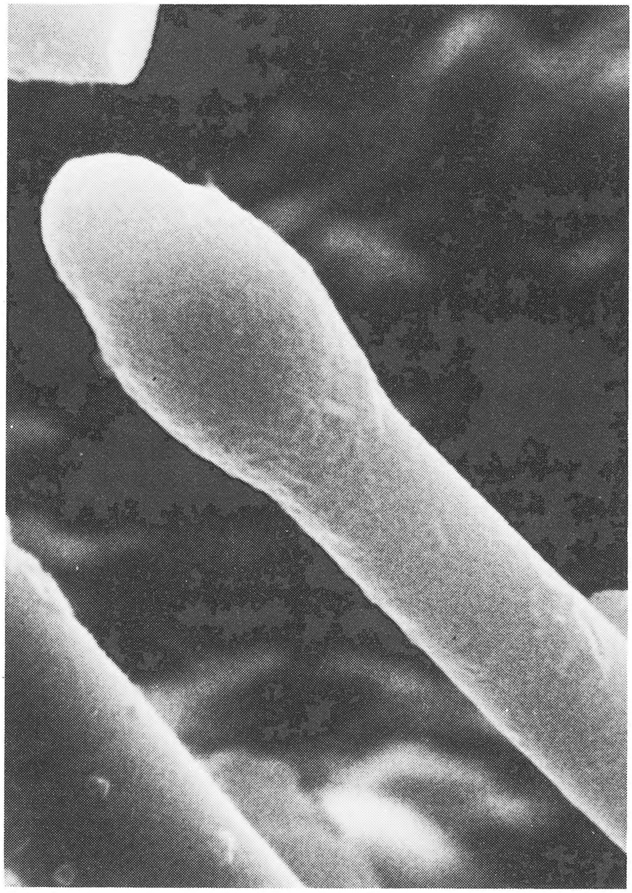

Fig. 2
S.E.M.-picture of a tylostyle (3700 ×) of *Cliona celata*, Reverol 9 m.

*Table 1.* Spicule length of *Cliona celata*. All measurements based on 30 spiculae per specimen.

| Substrate, locality and depth | Range and mean length-Tylostyles |
|---|---|
| Limestone: | |
| Tovarjez, 2m | 193 – 257 – 292 μm |
| Tovarjez, 10m | 247 – 294 – 370 μm |
| Tovarjez, 8m | 247 – 291 – 343 μm |
| Tovarjez, 12m | 245 – 277 – 310 μm |
| Gusti Skolj, 2m | 200 – 234 – 283 μm |
| Reverol, 6m | 241 – 312 – 362 μm |
| Reverol, 9m | 240 – 299 – 316 μm |
| *Pinna sp.*: | |
| Gusti Skolj, 10m | 209 – 251 – 287 μm |
| *Glycymeris sp.*: | |
| Tovarjez, 8m | 212 – 269 – 316 μm |
| Tovarjez, 14m | 224 – 282 – 316 μm |

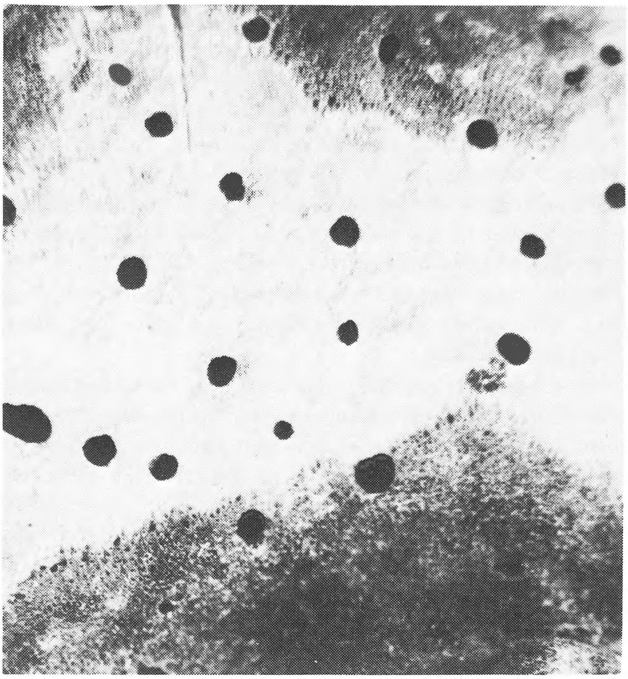

Fig. 3
Papillae of *Cliona celata* in limestone (3,1 ×), Tovarjez, 2 m.

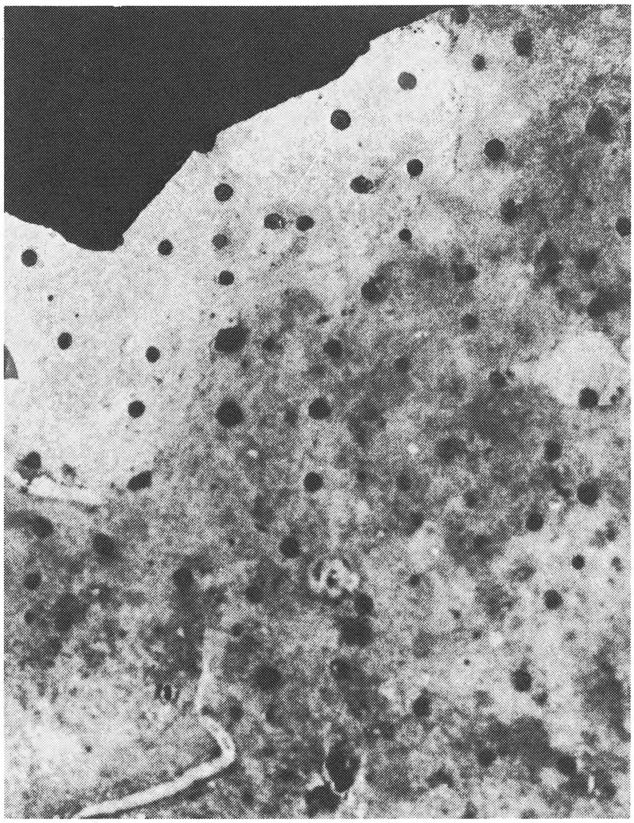

Fig. 4
Papillae of *Cliona celata* in a *Pinna* shell (3,0 ×), Gusti Skolj 10 m.

## *Cliona viridis* (O. Schmidt) Gray

*Cliona viridis* Schmidt, Gray 1867, p. 525

*Vioa viridis*, Lendenfeld 1898, p. 58-72, pl. II fig. 13-22, pl. VI fig. 49, pl. VII fig. 67

*Cliona viridis*, Topsent 1900, p. 84, 85, pl. II fig. 11, 12, 13, pl. III fig. 3a, b, c, fig. 4a, b

*Cliona viridis*, Volz 1939, p. 13-16, fig. 3

*Cliona viridis*, Rützler 1965, p. 22

The tylostyles have terminal heads; rarely subterminal or multiple or lacking entirely. The microscleres of this sponge are spirasters. These spirasters are rather large and distinctly twisted or angular. The spines on the spirasters are arranged more or less in a spiral pattern. These spines are more prominent at the angles and ends of the spicule (Fig. 5, 6). The mean length of tylostyles is 306 μm with a range of 190-460 μm. The mean length of spirasters is 28 μm, with a maximum of 96 μm (Table 2.)

Fusion of the mostly green papillae often occurs. The width of the papillae varies from 0,3 to 2,0 mm in limestone (Fig. 7) and from 0,1 to 1,1 mm in shells of molluscs. The usual diameter in limestone is 1 mm and in shells 0,5 mm.

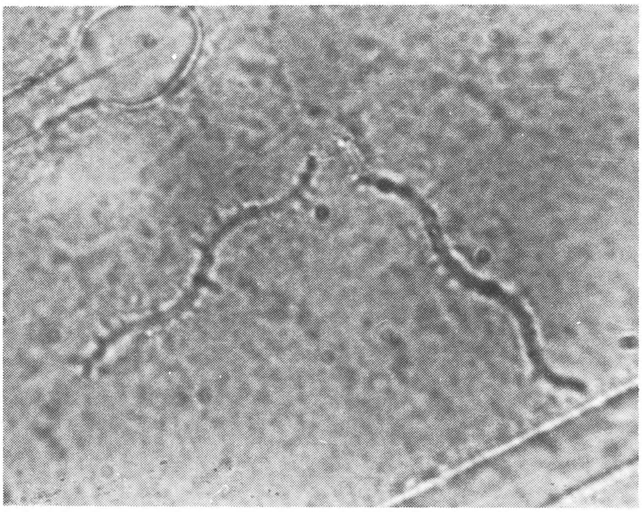

Fig. 5
Microphotograph of spirasters of *Cliona viridis* (758 ×), Gusti Skolj 5 m.

According to Volz (1939), *Cliona schmidti* Ridley contains the same type of spiculae. An important difference between *C. viridis* and *C. schmidti* would be the relation in length of the types of spiculae. The relation spirasters to tylostyles for *C. viridis* would be 1:20 and for *C. schmidti* it would be 1:4. None of these extreme relations were found when measuring length of spicules of the Rovinj clionids; intermediate values are consistently obtained. Another difference reported by Volz is colour. *C. viridis* sensu Volz would be yellow-green and *C. schmidti* sensu Volz would be violet-red. No spirasters would be evident in the papillae of the former. This last statement is not correct because sponges with green papillae with many spirasters were often found. Rützler did not record *C. schmidti* from Rovinj and in my opinion, *C. schmidti* sensu Volz is not a valid species. Possibly Volz identified young specimens of *C. viridis* which do not yet live in symbiosis (Sarà & Liaci, 1964) with green algae, as *C. schmidti*. Vosmaer (1933) places both *C. schmidti* and *C. viridis* in synonymy with *Cliona celata*, but this is lumping carried too far.

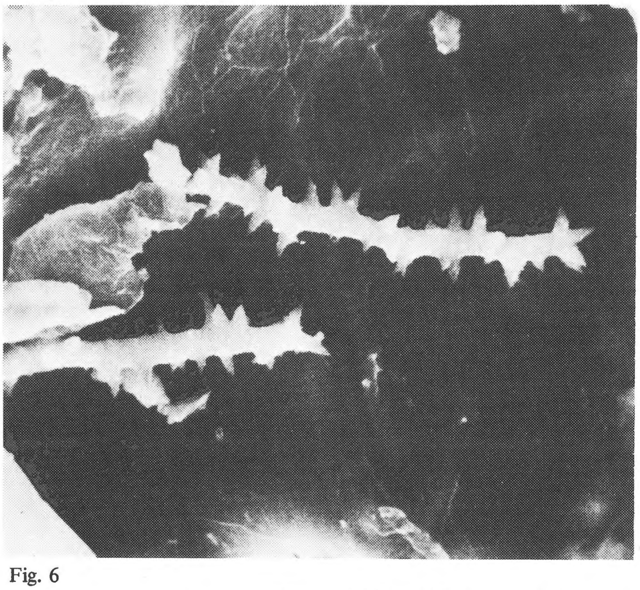

Fig. 6
S.E.M.-picture of spirasters of *Cliona viridis* (1230 ×), Tovarjez 2 m.

*Table 2.* Spicule length of *Cliona viridis* (in microns). The number of measured spiculae per specimen is placed in brackets.

| Substrate, locality and depth | Range and mean length- tylostyles | Mean and maximum length- spirasters |
|---|---|---|
| Limestone: | | |
| Tovarjez, 2m | (30) 243-281-316 | (30) 26,39 |
| Tovarjez, 12m | (30) 313-334-349 | (30) 26,50 |
| Tovarjez, 12m | (15) 225-339-385 | (30) 23,39 |
| Tovarjez, ? | (30) 247-345-410 | (30) 28,48 |
| Altyez, 5m | (30) 289-348-460 | (10) 18,96 |
| Gusti Skolj, 5m | (30) 241-286-297 | (30) 36,47 |
| Gusti Skolj, 5m | (30) 240-278-319 | (30) 38,67 |
| Gusti Skolj, 10m | (30) 245-301-337 | (30) 28,40 |
| Gusti Skolj, 7m | (30) 269-306-347 | (10) 21,33 |
| Reverol, ? | (10) 289-330-361 | (10) 45,51 |
| *Arca sp.* | | |
| Tovarjez, 9m | (30) 261-295-333 | (30) 45,68 |
| Tovarjez, 10m | (10) 217-257-289 | (30) 22,34 |
| Tovarjez, 10m | (15) 204-242-280 | (20) 20,28 |
| Tovarjez, 14m | (30) 274-324-360 | (10) 27,36 |
| Tovarjez, 10m | (30) 190-223-306 | (20) 22,31 |
| Reverol, 6m | (30) 228-267-302 | (10) 35,40 |
| *Astrea sp.* | | |
| Tovarjez, ? | (30) 226-277-327 | (20) 17,21 |

Fig. 7
Papillae of *Cliona viridis* in limestone (5,3 ×), Tovarjez 12 m.

### *Cliona vastifica* Hancock

*Cliona vastifica* Hancock 1849, p. 342, pl. XV
*Cliona vastifica* Hancock 1867, p. 237, pl. VII fig. 2
*Vioa vastifica*, Lendenfeld 1898, p. 86-94, pl. III fig. 33, 34 pl. VI fig. 60, pl. VII fig. 85
*Cliona vastifica*, Volz 1939, p. 8-12, fig. 2
*Cliona vastifica*, Old 1941, p. 11, 12, pl. XIII
*Cliona vastifica*, Hartman 1958, p. 21-23, pl. 5
*Cliona vastifica*, Rützler 1974, p. 15-17, fig. 12, 13; 1965, p. 22

The tylostyles are mostly straight and often show biterminal heads. Sometimes tylostyles are rare as compared with the number of amphioxi in the preparations. The average length is 263 µm, with a range of 161-361 µm. The spirasters are small, slightly bent, not angular and entirely spined. Their mean length is 18 µm with a maximum of 37 µm (Fig. 8, 9). The amphioxi are smooth or entirely microspined with a mean length of 107 µm and with a range of 63-164 µm (Fig. 10). The spines of the amphioxi are in fact small hooks

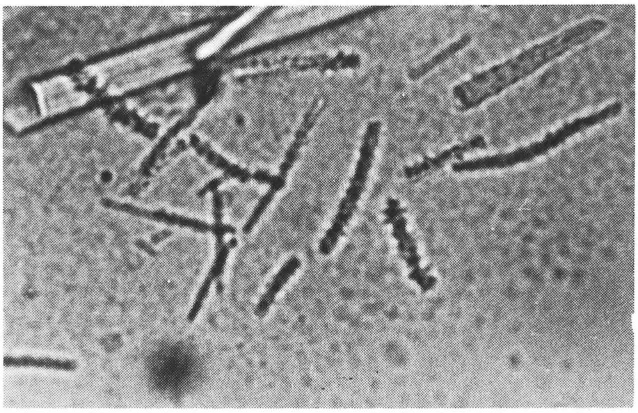

Fig. 8
Microphotograph of spirasters of *Cliona vastifica* (1000 ×), Tovarjez 2 m.

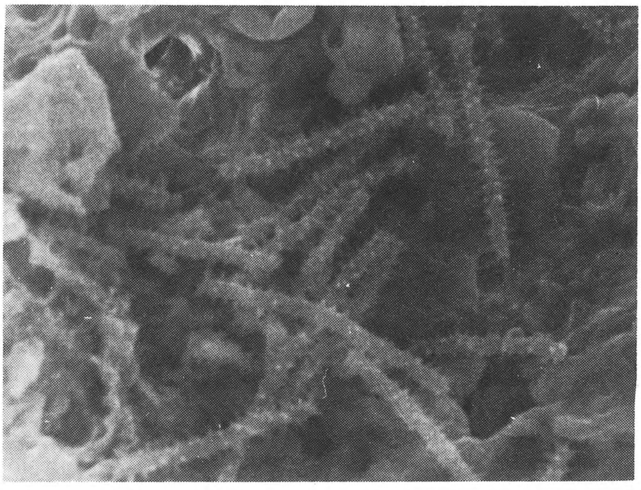

Fig. 9
S.E.M.-picture of spirasters of *Cliona vastifica* (1230 ×), Gusti Skolj 5 m.

*Table 3.* Spicule length of *Cliona vastifica* (in microns). The number of measured spiculae per specimen is placed in brackets. When less than 6 spiculae were measured only the mean length is reported.

| Substrate, locality and depth | Range and mean length | | Mean and max. length- spirasters |
|---|---|---|---|
| | tylostyles | amphioxi | |
| Limestone: | | | |
| Tovarjez, 2m | (3) 261 | (30) 79-108-150 | (30) 22,34 |
| Tovarjez, 6m | (5) 250 | (30) 70-114-145 | (20) 23,36 |
| Tovarjez, 6m | (3) 227 | (30) 96-124-155 | (30) 18,37 |
| Altyrez, 10m | (2) 338 | (15) 100-108-114 | (30) 18,34 |
| Banjol, 10m | (30) 225-252-269 | (30) 90-125-163 | (30) 19,22 |
| Gusti Skolj, 4m | (30) 207-250-296 | (25) 113-118-126 | (25) 24,28 |
| Gusti Skolj, 5m | (3) 270 | (30) 73-104-135 | (30) 17,27 |
| Gusti Skolj, 7m | (4) 267 | (30) 87-111-130 | (25) 21,26 |
| Gusti Skolj, 2m | (20) 161-205-241 | (20) 83-103-133 | (30) 17,25 |
| Gusti Skolj, ? | (15) 204-227-247 | (30) 72- 99-140 | (20) 16,20 |
| Gusti Skolj, ? | (3) 260 | (30) 87-111-121 | (20) 21,25 |
| *Arca sp.* | | | |
| Tovarjez, 8m | (5) 204 | (20) 89-109-125 | (30) 23,32 |
| *Pinna sp.* | | | |
| Gusti Skolj, 10m | (30) 202-250-295 | (30) 84- 98-116 | (30) 16,20 |
| *Spondylus sp.* | | | |
| Banjol, 12m | (25) 199-233-267 | (20) 86- 92- 96 | (10) 11,18 |
| *Venus sp.* | | | |
| Tovarjez, 10m | (10) 337-349-361 | (30) 89-122-164 | (20) 22,26 |
| Tovarjez, 11m | (20) 250-280-314 | (30) 80-100-126 | (30) 15,18 |
| Gusti Skolj, 14m | (30) 217-265-295 | (30) 84- 96-107 | (25) 14,17 |
| Gusti Skolj, 10m | (30) 204-243-283 | (30) 63- 90- 98 | (30) 20,27 |
| *Glycymeris sp.* | | | |
| Tovarjez, 13m | (30) 213-286-323 | (30) 89-112-127 | (25) 19,24 |
| Tovarjez, 13m | (20) 240-273-295 | (25) 84- 92- 96 | (20) 19,20 |
| Banjol, 9m | (25) 306-333-361 | (30) 78-104-115 | (30) 11,14 |

(Fig. 11). Sometimes the amphioxi show a central swelling or a trace of it. The length of the spiculae is reported in Table 3. The diameter of the orange-red papillae (seldom fused) is between 0,1-1,0 mm (Fig. 12). In young colonies the papillae are often arranged along a line in the substrata.

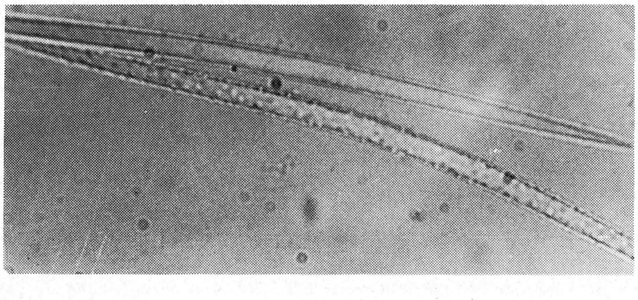

Fig. 10
Microphotograph of a smooth and a spined amphioxus of *Cliona vastifica* boring in *Glycymeris* (1500 ×), Tovarjez 13 m.

### *Cliona vermifera* Hancock

*Cliona vermifera* Hancock 1867, p. 239-240, pl. VIII fig. 2
*Vioa vermifera*, Lendenfeld 1898, p. 80, 81, pl. VI fig. 57, pl. VII fig. 81
*Cliona vermifera*, Volz 1939, p. 18-21 fig. 5
*Cliona vermifera*, Pang 1973a, p. 12-15 fig. 2
*Cliona vermifera*, Rützler 1974, p. 15-17 fig. 12, 13

The tylostyles are straight and sometimes show malformations near the apical end. The heads are mostly subterminal and sometimes biterminal. The average length of the tylostyles is 199 μm, with a range of 132-251 μm (Table 4). The characteristic, rather big, smooth, often slightly bent spirasters (Fig. 13) have a mean length of 51 μm, with a range of 32-107 μm.

Because the individual red papillae often fuse, these are found to be oblong (10 mm) and narrow (2 mm). *Cliona vermifera* was only found boring in limestone and not in the shells of molluscs.

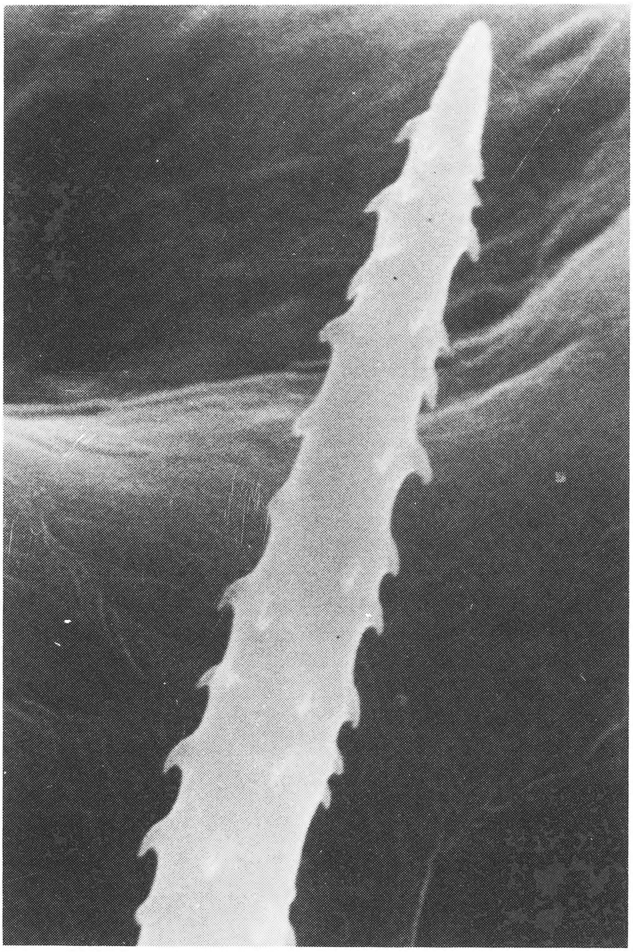

Fig. 11
S.E.M.-picture of an amphioxus with small hooks of *Cliona vastifica* boring in *Glycymeris* (7400 ×), Tovarjez 13 m.

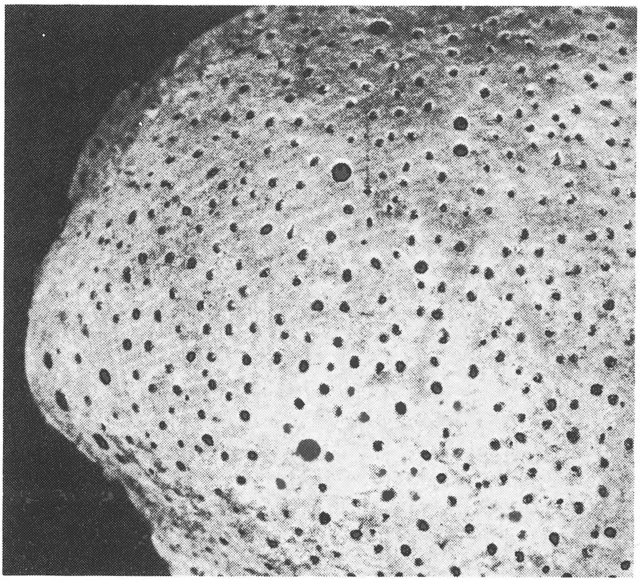

Fig. 12
Papillae of *Cliona vastifica*, boring in *Glycymeris* (2,7 ×), Tovarjez 13 m.

*Table 4.* Spicule length of *Clione vermifera*. All measurements based on 30 spiculae of each category per specimen.

| Substrate, locality and depth | Range and mean length | |
|---|---|---|
| | tylostyles | spirasters |
| Limestone: | | |
| Banjol, 11m | 186 – 226 – 251 μm | 32 – 41 – 48 μm |
| Reverol, 6m | 132 – 204 – 249 μm | 44 – 79 – 107 μm |
| Tovarjez, 5m | 134 – 185 – 224 μm | 24 – 36 – 45 μm |
| Gusti Skolj, 4m | 163 – 179 – 241 μm | 36 – 58 – 80 μm |
| Gusti Skolj, ? | 164 – 203 – 241 μm | 34 – 40 – 46 μm |

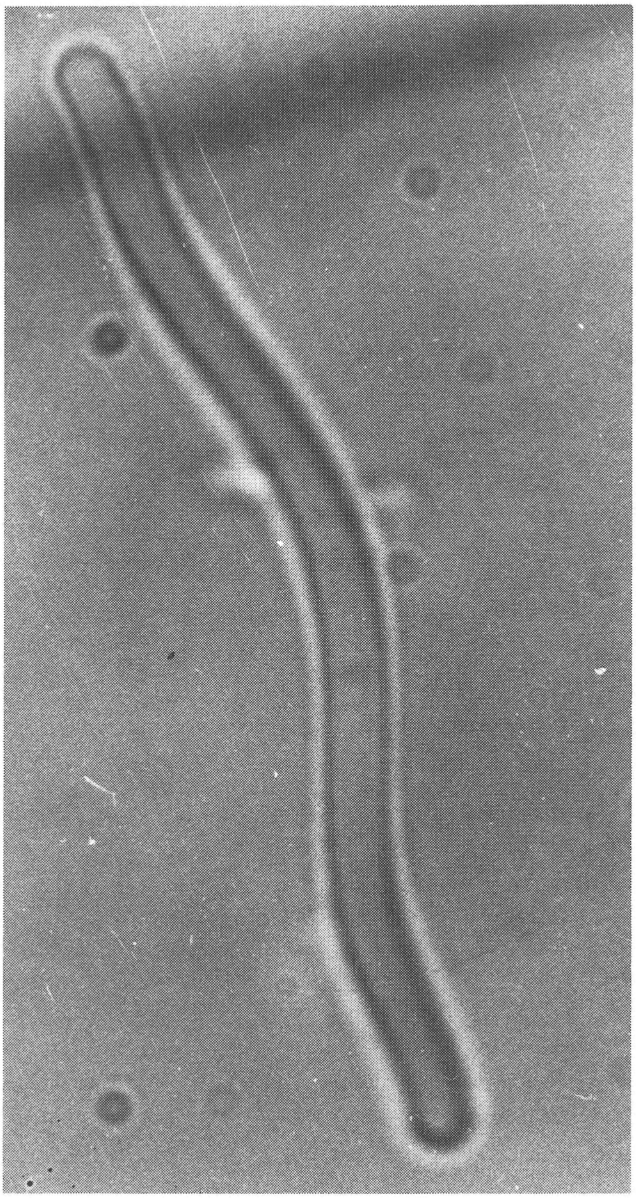

Fig. 13
Microphotograph of a spiraster of *Cliona vermifera* (1080 ×), Reverol 6 m.

### *Other clionids*

The sponges *Cliona albicans, Cliona rovignensis, Cliona copiosa, Cliothoosa hancocki* and *Thoosa mollis* were not found. A possible explanation is the difference in collecting methods with those of Volz and Rützler. For the present investigation only entire, isolated sponge colonies were collected. Heavily eroded pieces of limestone and shells, and very small sponge colonies were not collected because it is impossible to produce casts of their cavities. The small colonies of *Cliona rovignensis* and *Cliona copiosa* were described from walls of bore-holes of dead *Lithodomus;* this type of substratum was not studied by the present author.

### *Description of the trace fossils*

*Introduction* – When comparing cavities made by boring sponges, the substratum should have identical chemical and physical properties. One can imagine that a clionid produces different boreholes in soft and in hard limestone. This difficulty is avoided when different sponge colonies of roughly the same size in one homogeneous stone or shell are selected for inspection. If the sponge colonies are also of equal age, it is possible to compare their bore-holes. In the material studied these conditions were found in one stone bored by three different species of sponges, and one stone bored by two different species.

In all remaining single sponge species the properties of the limestone substratum are not necessarily the same, and this may cause variability in the cavities. One regularly finds several colonies of one single species of bore-sponge in one stone. This makes the study of intraspecific boring variability possible. Similar problems arise when one studies shell substrata.

Different species of molluscs may have shells of different constitution. A large series of shells of the same species, excavated by different species of sponges might circumvent these difficulties. But, as seen in tables 1-4, the habitation of one and the same shell by different species is seldom seen. We found that all but one *Arca* shell were inhabited by *Cliona viridis*. All *Venus* shells were inhabited by *Cliona vastifica*. *Glycymeris* was inhabited by both *Cliona vastifica* and *Cliona celata*, but these specimens were probably of a different age because of the size of the colonies and the erosion of the shells.

Whether these clear-cut substratum differences are caused either by preferences for distinct types of shell substrates, or by the availability of shells patterned by molluscan ecology, could not be decided. In only one *Pinna* was it possible to study different cavities, because two different colonies of the same size were found next to each other in the same shell. To describe the cavities, the following names will be used (Fig. 17):

Chamber: this is the cast of a more or less spherical cavity, excavated by the sponge.

Rootstock: usually the partition wall between a pair of cavities remains intact. These walls are penetrated by interconnecting canals. The casts of these canals are called rootstocks. Thus a rootstock connects two chambers.

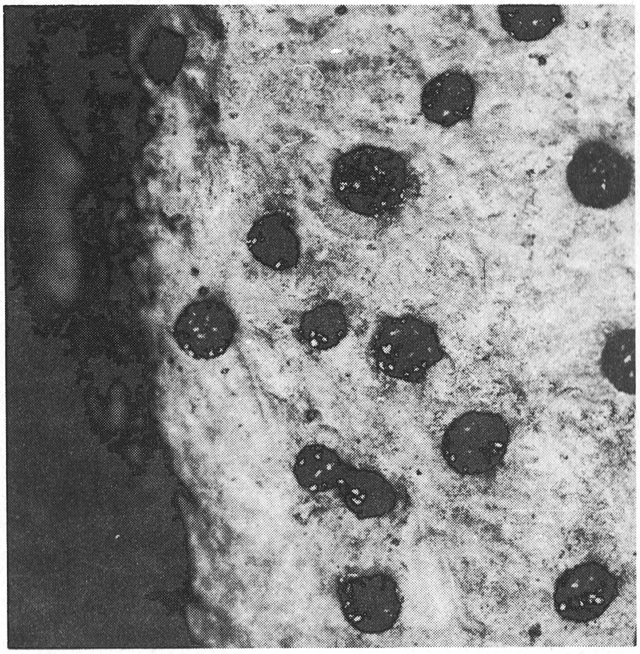

Fig. 14
Papillae of *Cliona celata* in a limestone boulder (4,6 ×), Tovarjez 10 m.

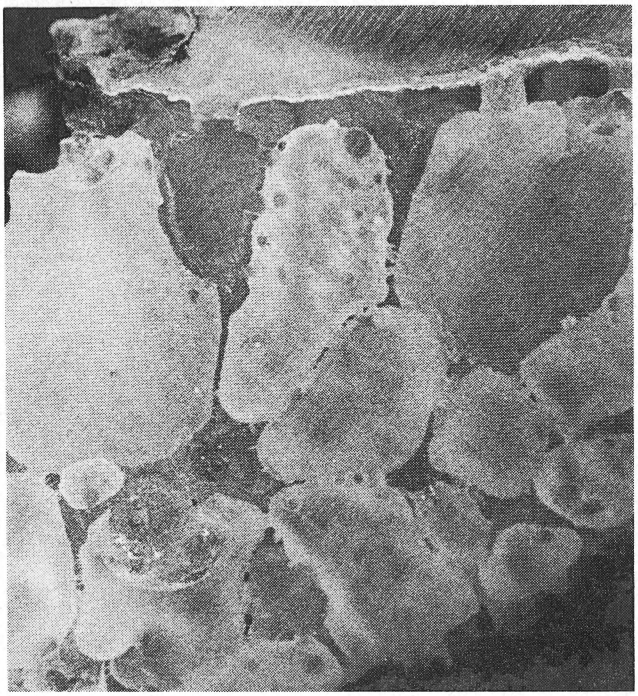

Fig. 15
Cross-section of a cast of *Cliona celata* in a limestone boulder (3,6 ×), Tovarjez 10 m.

Rootlet: the walls are not only penetrated by interconnecting canals, but also by pinprick-holes which appear in the casts as slender rootlike extensions of the chambers. From these rootlets, new chambers might be produced in the growing *Cliona* colony.

*Boring of Cliona celata Grant* – Of all these stages named by Vosmaer (α-, β- and γ-stage) only the α-stage, living in cavities which the sponges excavate in limestones and shells, is found. In the β-stage the sponge overgrows the calcareous substratum, and in the free-living γ-stage there is no trace of the original calcareous substratum, this is completely destroyed by the sponge. There was no indication that any of the 250 boring sponges near Rovinj were developing to a β- or γ-stage. On the contrary it seems that boring sponges stop growing when the calcareous substratum is completely scooped out. The completely cavernous limestone seen in Fig. 14 is a boulder of 8 x 8 x 4 cm, and no fusion of papillae has occured. Fig. 15 shows a cross-section of the cast of the same limestone boulder. The rather spherical chambers in this stone do not fuse either. A thin perforated wall of limestone between cavity and cavity as well as between cavity and surface always remains. Fusion of the chambers just below the surface of the limestone was observed sporadically but this does not lead to a fusion of the papillae. Coalescence of chambers is shown in Fig. 16. In this specimen the sponge colony has developed in one level just below the surface of the limestone, but the papillae remained autonomous.

The width of the chambers varies from 2-8 mm, the average width is 6 mm. In the case where papillae are arranged in a linear (sometimes branched) pattern, fusion of the spherical chambers is often seen, but the originally spherical chambers are, as a rule, still recognisable. The width in cross-section of these chambers varies from 2-6 mm. The chambers show many rootstocks and rootlets (Fig. 16, 17). Average rootlets are 2 mm long. Some rootlets of more than 8 mm were observed, but these were rare.

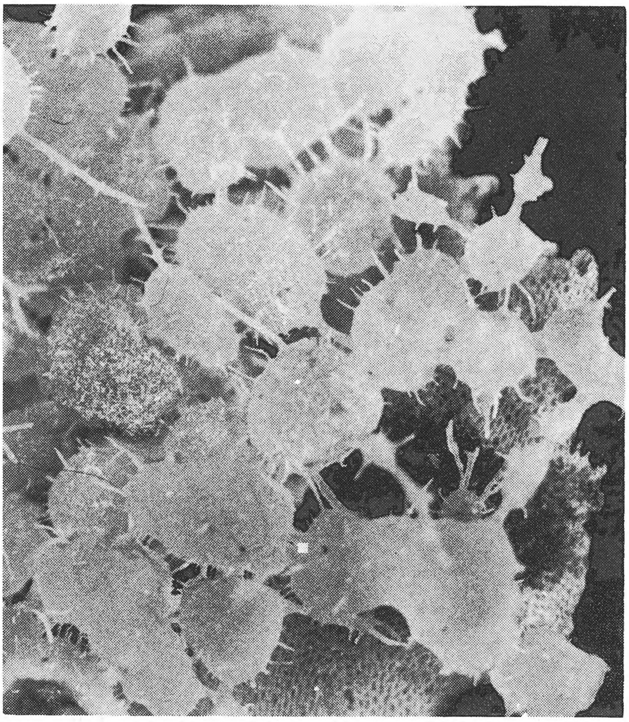

Fig. 16
Cast of *Cliona celata* (2,9 x). In the same boulder *Cliona viridis* (Fig. 21) and *Cliona vastifica* (Fig. 24) were found boring, Tovarjez 2 m.

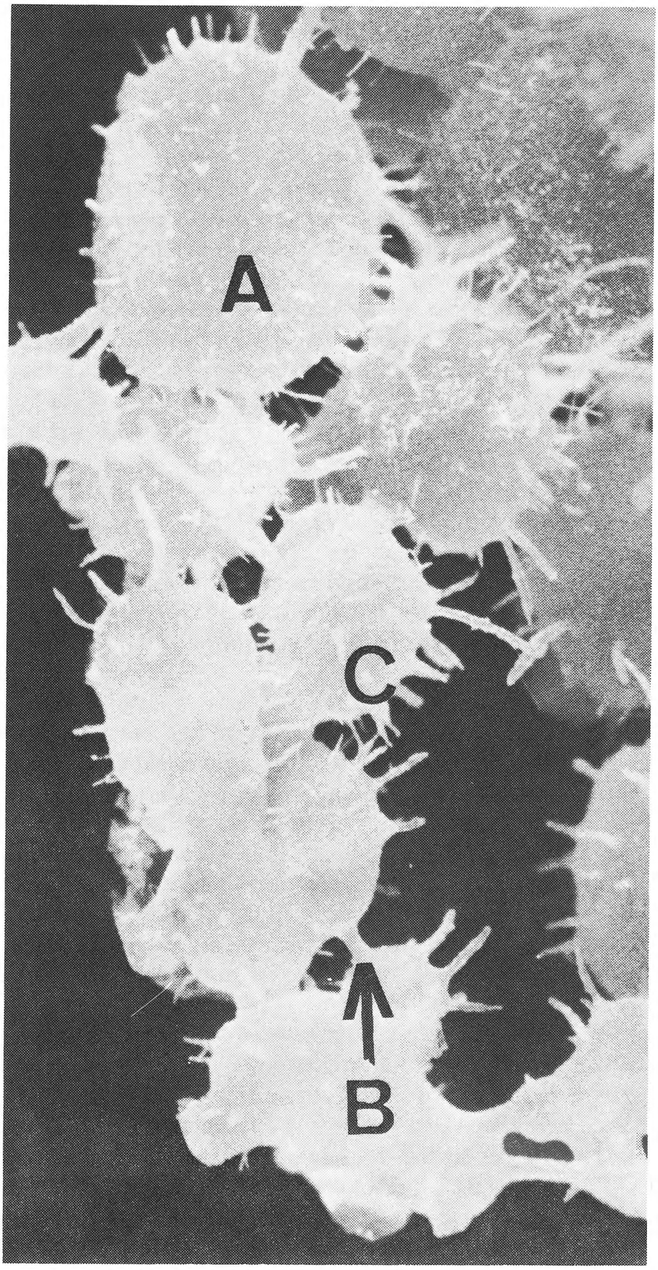

Fig. 17
Cast of *Cliona celata* in limestone (4,7 x), Tovarjez 2 m. A. Chamber; B. rootstock; C. rootlets.

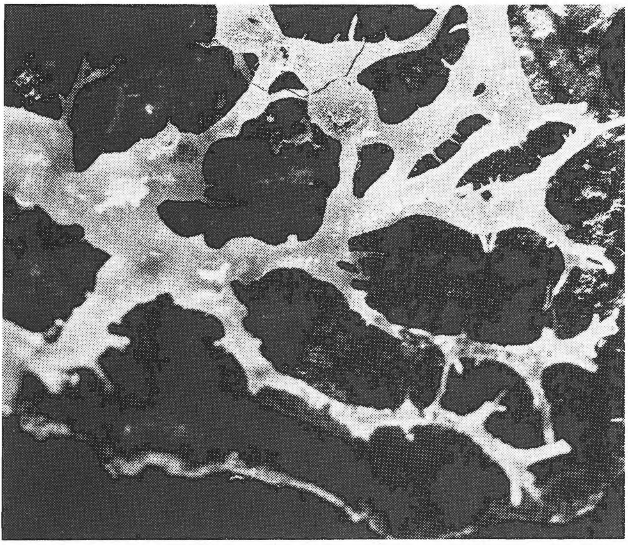

Fig. 18
Cast of *Cliona celata* boring in *Glycymeris* (3,5 ×), Tovarjez 8 m.

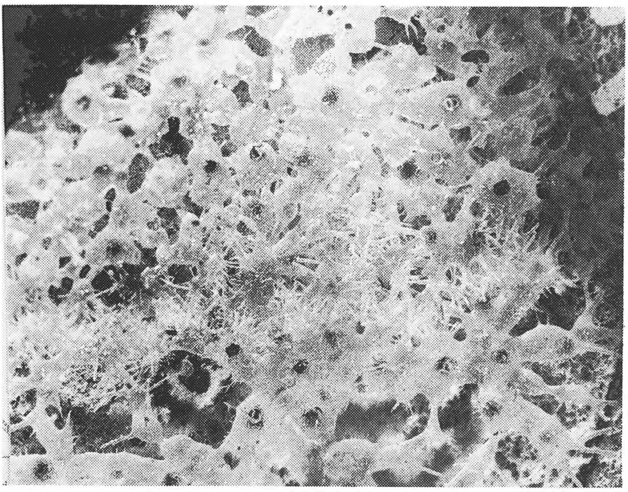

Fig. 19
Cast of two colonies of *Cliona celata* boring in a *Pinna* shell (4,5 ×), Gusti Skolj 10 m. Between the two individual colonies there is a 'zone of proximity' of very fine rootlets.

Casts of borings in shells are shown in Fig. 18. The chambers are smaller (up to 3 mm). The chambers are arranged in linear, sometimes branched structures, with diminutive rootlets.

Fig. 19 shows an example of substratum competition between two sponges of the same species in a *Pinna* shell. The two individual colonies show strict avoidance of coalescence. Instead, the space between the two sponges is riddled with very fine, branching rootlets. Possible reasons for this non-coalescence are sexual difference, age discrepancy or difference in strains (Bromley & Tendal, 1973).

*Borings of Cliona viridis (O. Schm.) Gray* – The free-living stage of this sponge, reported as common by Volz (1939), was never found. Almost every colony of *C. viridis* shows many fused papillae (Fig. 20). The casts of cavities in stones reveal a very compact maze of small chambers (Fig. 21),

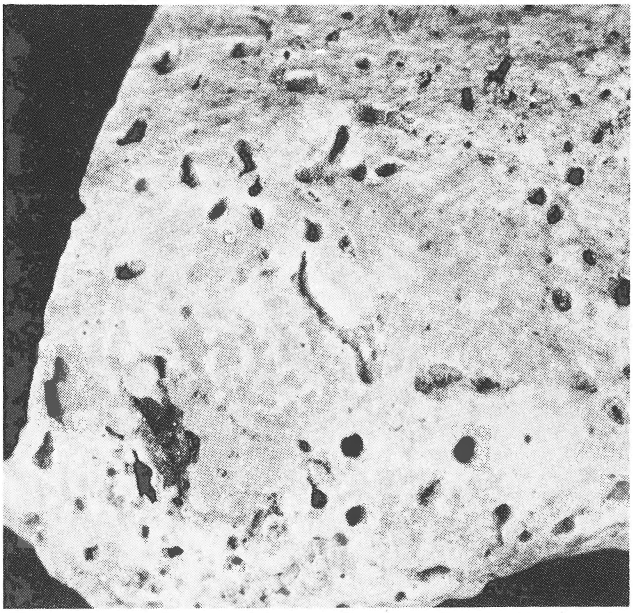

Fig. 20
*Cliona viridis* boring in a *Arca* shell (3,3 ×), Tovarjez 14 m. The papillae often fuse.

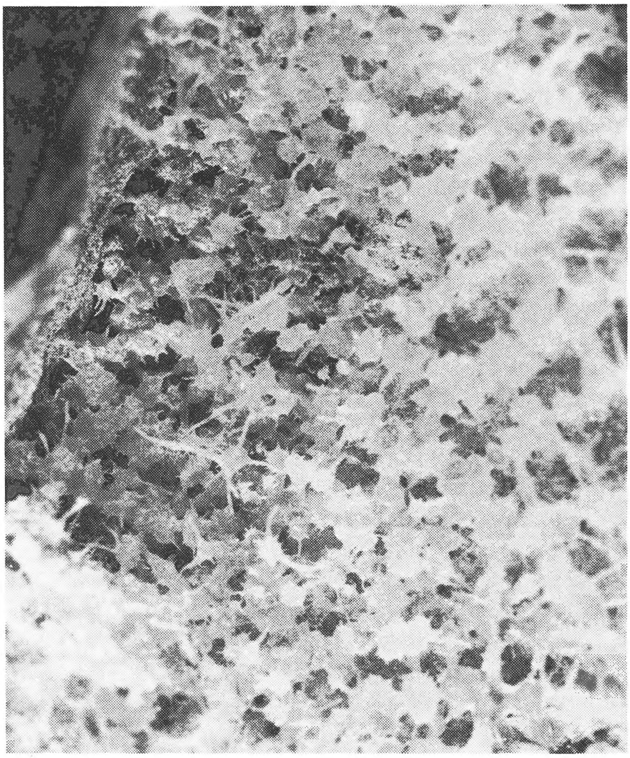

Fig. 21
Cast of *Cliona viridis* boring in limestone (2,9 ×), Tovarjez 2 m. In the same boulder *Cliona celata* (Fig. 16) and *Cliona vastifica* (Fig. 24).

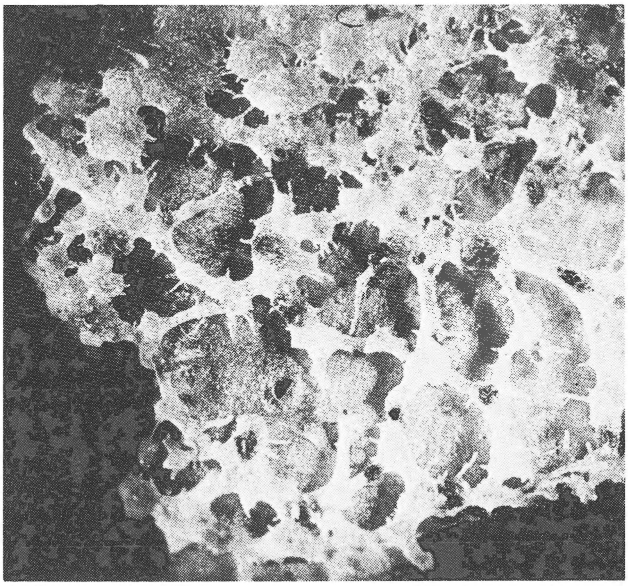

Fig. 22
A cast of *Cliona viridis* boring in an *Astrea* shell (5,4 ×), Tovarjez 12 m.

interconnected by rootstocks in all directions. The polyester casts are sometimes so massive that the calcareous substratum between the chambers cannot be dissolved, because the hydrochloric acid cannot enter the polyester-limestone conglomeration. Borings, branching at only one level (as commonly found in all other clionids) were not observed. The average chambers are 2 mm in cross-section. Coalescence of these chamberlets is predominant, but individual chambers remain recognizable. The chamberlets are very irregular (Fig. 21, 22), not globular as in the other species. The chambers show small rootlets too, but not as many as in *Cliona celata.* The rootlets must be considered as small trumpet-like extensions of the chambers rather than as discrete parts of the structure. The casts of cavities in shells are of the same type as those from limestones, but the chambers are much smaller (Fig. 22). The chambers are restricted to one level in this case.

*Borings of Cliona vastifica Hancock* – Although fusion of the papillae is sometimes observed (Fig. 23) it is not often seen. The casts from limestone consist of a network of chambers (Fig. 24) just below the surface of the stone. The chambers are often arranged in strings. In these strings the globular or oval chambers are not completely fused; a constriction always remains in between (Fig. 24, 25). The width in cross-section of the usually smooth chambers ranges from 1,0 to 3,0 mm.

In Fig. 25, a cast from a *Venus* shell, a network of rather smooth chambers is seen. The chambers are smaller in cross-section. In older specimens the string-pattern is extended into a spatial network in which coalescence of the chambers just below the surface often occurs. Fusion of the chambers does not lead to fusion of the papillae.

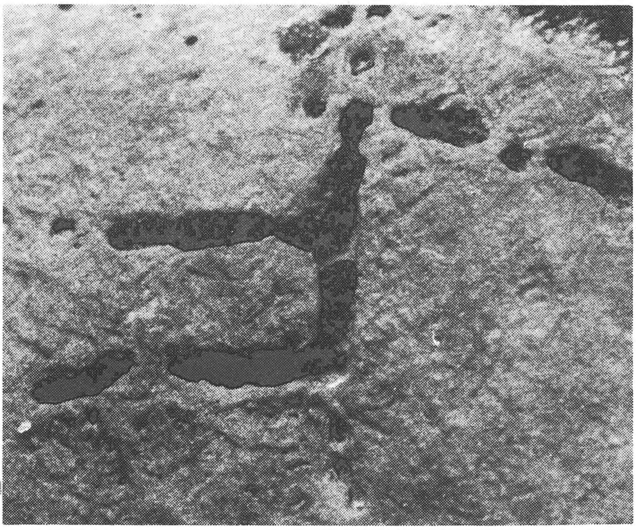

Fig. 23
Papillae of *Cliona vastifica* boring in limestone (5,1 ×), Tovarjez 2 m.

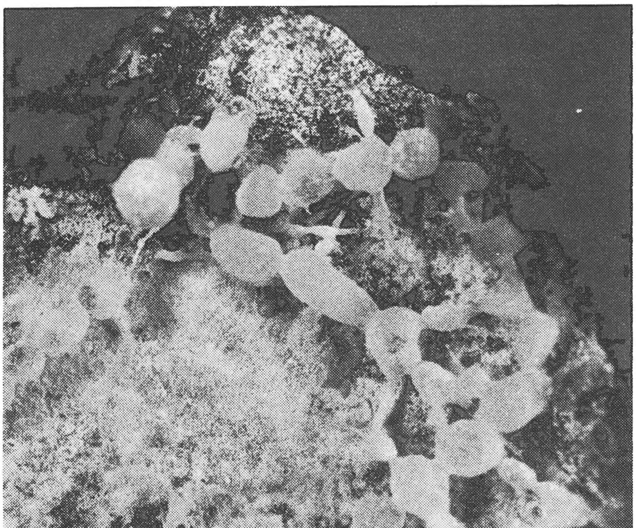

Fig. 24
Cast of *Cliona vastifica* boring in limestone (2,9 ×), Tovarjez 2 m. In the same boulder *Cliona celata* (Fig. 16) and *Cliona viridis* (Fig. 21) were found boring.

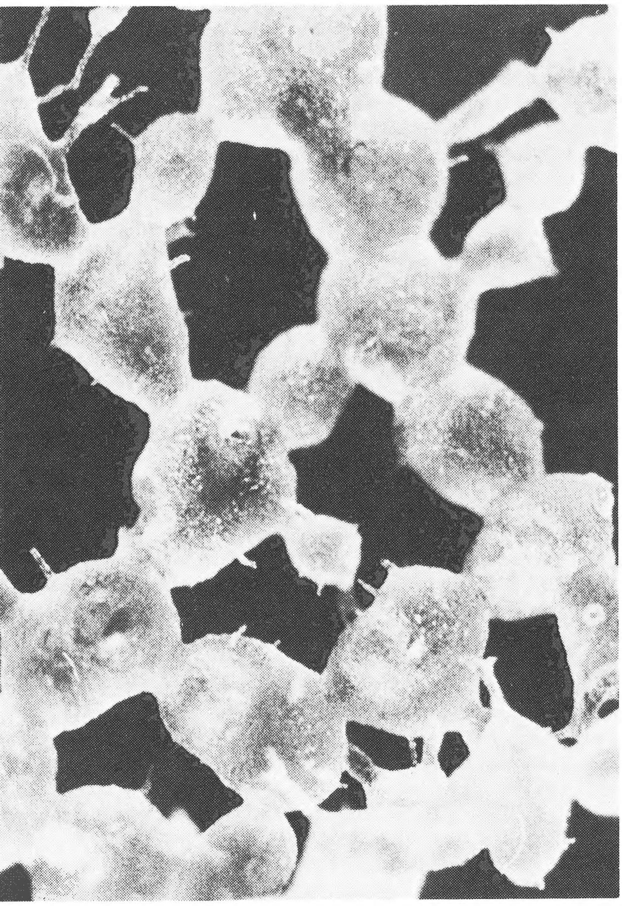

Fig. 25
Cast of *Cliona vastifica* boring in a *Venus* shell (12,1 x), Tovarjez 10 m.

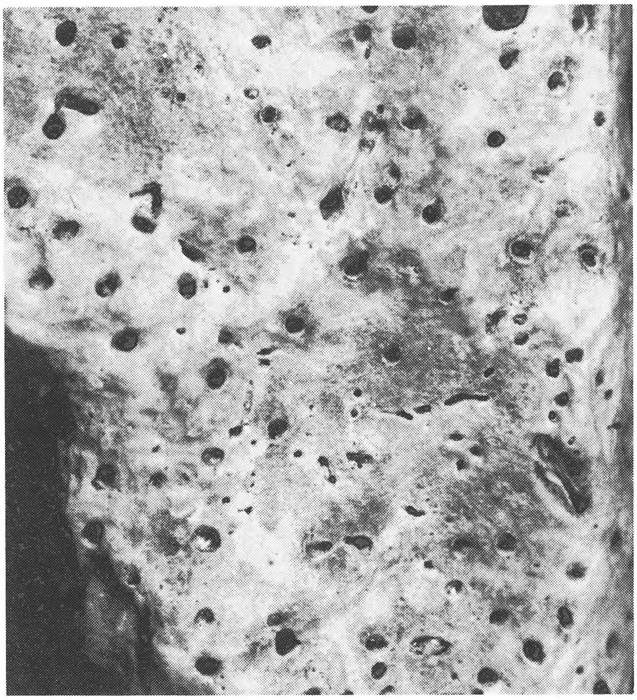

Fig. 26
*Cliona vermifera* boring in limestone (4,0 x), Gusti Skolj 4 m.

*Borings of Cliona vermifera Hancock* – Fusion of the small papillae occurs rather commonly in colonies of *Cliona vermifera* (Fig. 26). It is rather difficult to study the chambers, because in colonies of *Cliona vermifera* one often also finds small colonies (a few papillae) of *Cliona vastifica*. The growing habit is open and the rather small chambers are not arranged in a regular pattern. For the greater part they are found directly under the surface of limestone. Although globular chambers occur, the usual boring consists of oblong cavities ± 12 mm in length and 2 mm wide. At intersections the chambers coalesce (Fig. 27). *Cliona vermifera* was not found boring in shells.

*Conclusion* – From the preceding descriptions it is obvious that different species of clionids produce different excavations, at least in limestone substrata. That this does not apply to old sponges, boring in shells, is explained by the small range of differentiation within the limited space of a shelly substratum.

The present study proves that taxonomic subdivision of different types of the trace fossil genus *Entobia* is warranted.

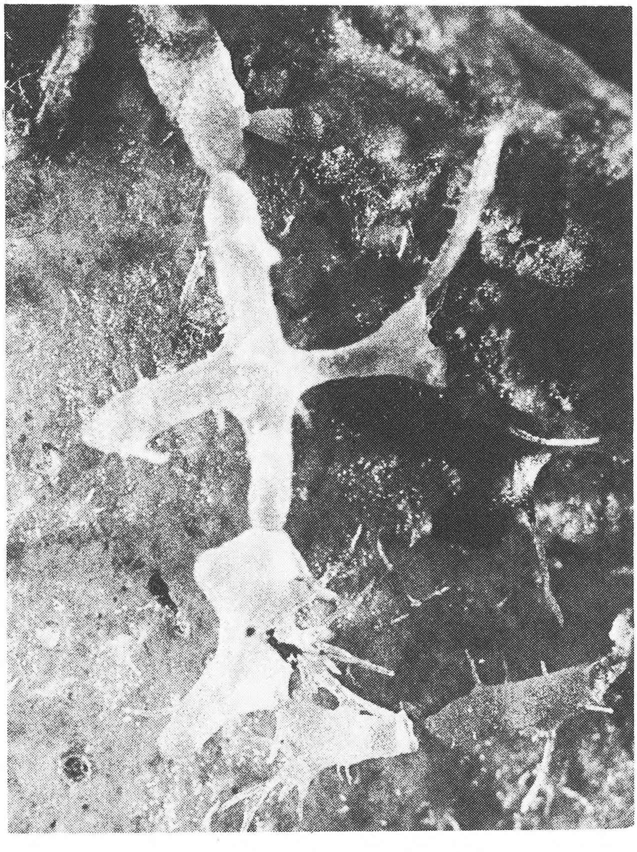

Fig. 27
Cast of *Cliona vermifera* boring in limestone (4,2 x), Reverol 6 m.

## ACKNOWLEDGEMENTS

The author would like to thank the following people: Dr. G.J. Boekschoten for the suggestion of the theme and the guidance of the research; Mr. K.J.M. Ververgaart for acting as buddy during diving and for his cooperation during the sampling periods; Dr. W.L. Jongebloed for the production of Stereoscan pictures; and Mr. M.H. Huizinga for making the remaining pictures.

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