BIOEROSION MICRO-PATTERNS AS DIAGNOSTIC CHARACTERISTICS IN BORING SPONGES

BARBARA CALCINAI*, GIORGIO BAVESTRELLO* & CARLO CERRANO**

*Dipartimento di Scienze del Mare, Università Politecnica delle Marche, Via Brecce Bianche, I 60131 Ancona, Italy
**Dip.Te.Ris., Università di Genova, Corso Europa 26, I 16132 Genova, Italy
E-mail: b.calcinai@univpm.it

ABSTRACT

Microscopic pitting patterns produced by different sponges, belonging to three orders and four different families, boring into various substrata have been examined. Different kinds of micro-erosion are characterised by various types of ornamentation and sculpturing patterns. *Pione, Cliona* and *Cliothosa* show smooth pits; *Holoxea* and *Spiroxya* produce pits that resemble fingerprints, *Thoosa* and *Delectona* have pits characterised by deep circular grooves that in *Alectona* overlap on radiating erosion lines. The pits of *Aka* have concentric, deep marks that reach the centre. Here we suggest that these differences are determined by the different erosion mechanisms of the various sponge groups and not by the features of the eroded substrata. In conclusion we propose the use of pitting patterns as a taxonomic tool for the identification of boring sponge groups.

KEY WORDS

Sponge micro-erosion, pit ornamentation, boring sponges, taxonomy.

INTRODUCTION

Boring sponges make a series of tunnels in the calcareous substrata where they live. Special cells produce the excavations by means of secreted chemical substances and through the mechanical removal of the substratum in the characteristic form of small fragments (chips) expelled through the oscula (RÜTZLER & RIEGER, 1973; RÜTZLER, 1975).

This boring activity results in typical scars (pits) on the wall of the excavations, these scars have been used as a tool in bioerosion studies to identify sponge erosion in recent and in fossil or sub-fossil substrata (BROMLEY & D'ALESSANDRO, 1984; PERRY & BERTLING, 2000).

In the past no taxonomic relevance has been attributed to the pitting pattern; differences were considered to be related to microstructures of the substratum rather than to the species (BROMLEY, 1970).

On the contrary VACELET (1999) showed that the unusual ornamentation of the pits produced by *Alectona* was different from any other. He also suggested that these microsculptures could be considered an additional taxonomic element. More recently CALCINAI *et al.* (2003) focused on the differences between the pit ornamentations of the two most common excavating genera: the hadromerid *Cliona* and the haploscerid *Aka.* The authors demonstrated that these two genera produce different pits ornamentations: smooth in *Cliona*, sculptured in *Aka.* These differences are always present and are not related to the substrate characteristics, making them useful as a tool for distinguishing the sponge erosion agents in both recent and fossil substrate.

The aim of this work is to extend these observations to other boring genera, controlling whether they use different pitting patterns, which could be employed as a taxonomic tool for genus determination.

MATERIALS AND METHODS

We have examined various substrata and species that come from different localities: *Pione* cf. *carpenteri* excavating into coralline algae from Juan Fernandez Archipelago (Pacific Ocean); *Pione* cf. *vastifica* excavating in a shell (*Cassis* sp.), of unknown origin; *C. varians* excavating into coral rock from Carrie Bow (Belize); *C. janitrix* and *Delectona ciconiae* excavating into *Corallium rubrum* from the Mediterranean Sea (Ligurian Sea and Alboran Sea); *Cliothosa hancocki* excavating into rock from Rovigno (Adriatic Sea); *Holoxea excavans, Thoosa bulbosa*, *Alectona triradiata, Spiroxya macroxeata* into *C. elatius* from the Pacific Ocean; *Cliona rhodensis* into coralline algae and rock from the Ligurian Sea; various species of the *Aka* genus and *Cliona mucronata* excavating into madreporian and *Heliopora* substrate from Bunaken (North Sulawesi, Indonesia); *C. vermifera* excavating into shell, algae and rock from the Ligurian Sea.

All these materials belong to authors' collection and were collected and classified at different times.

Portions of the eroded substrata were cleaned from organic tissue by boiling in hydrogen peroxide (120 vol) and were then mounted on stubs and coated with gold for scanning electron microscope (SEM) analysis, using a Leo Stereoscan 440. Pit dimensions were taken with the ImageJ program; axes of 50 pits per species were measured. In taking SEM pictures, non-perpendicular and irregular surfaces were avoided.

RESULTS

Microscopic pitting patterns produced by different sponges, belonging to three different orders (Astrophorida, Hadromerida and Haplosclerida) and four different families (Ancorinidae, Clionaidae, Alectonidae, Phloeodictyidae) boring into various substrata have been examined.

The SEM observations show pits with different types of surface ornamentation. We believe it is possible to distinguish four groups of genera that show different micro-patterns.

1) Smooth pits (Fig. 1)

The surfaces of the pits of species of *Pione* (A-B)*, Cliona* (C-F) and *Cliothosa* (G-H) are smooth. These genera are indistinguishable on the base of the shape of the pits.

The other observed genera are characterized by ornamentations having different relief:

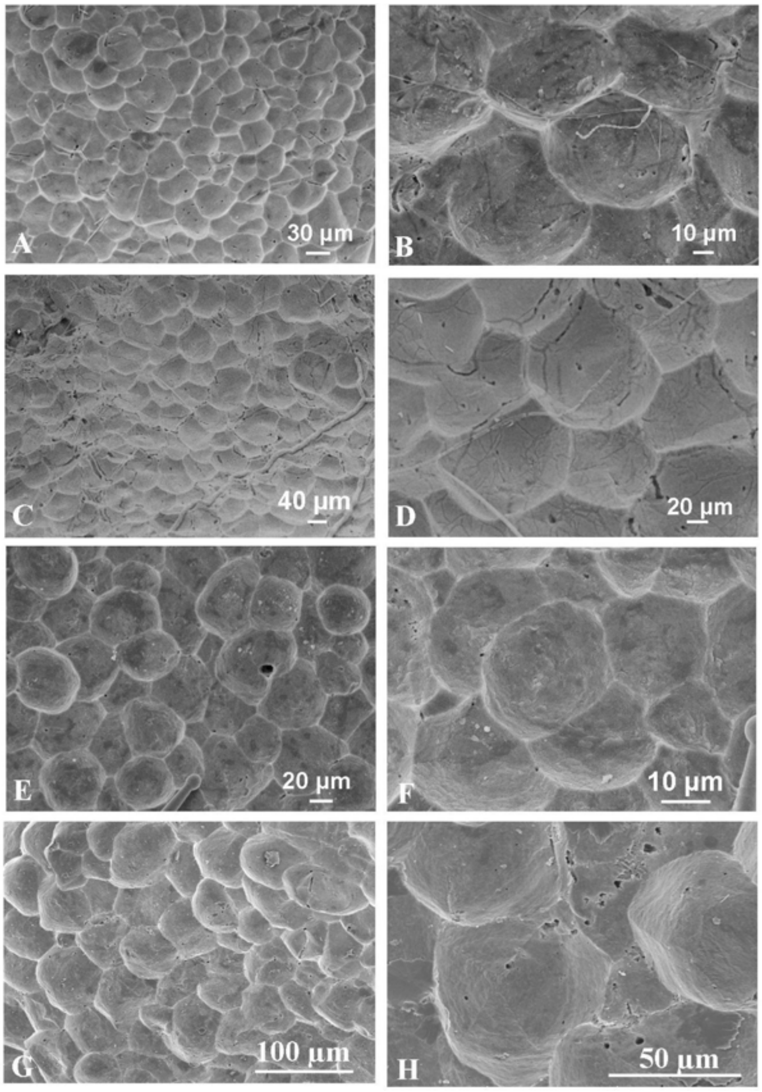

Fig. 1. Smooth pits produced by: *Pione* cf. *carpenteri* excavating into algae **(A-B)**, *Cliona varians* into coral rock **(C-D)**, *Cliona janitrix* excavating into red coral **(E-F)** and *Cliothosa hancocki* **(G-H)** excavating into rock.

2) Fingerprint-like pits (Fig. 2)

Concentric thin grooves characterize the pits of *Holoxea* (A-B) and *Spiroxya* (C-D). These two genera could be distinguished, given that the marks are more pronounced and continuous in *Spiroxya* than in *Holoxea*.

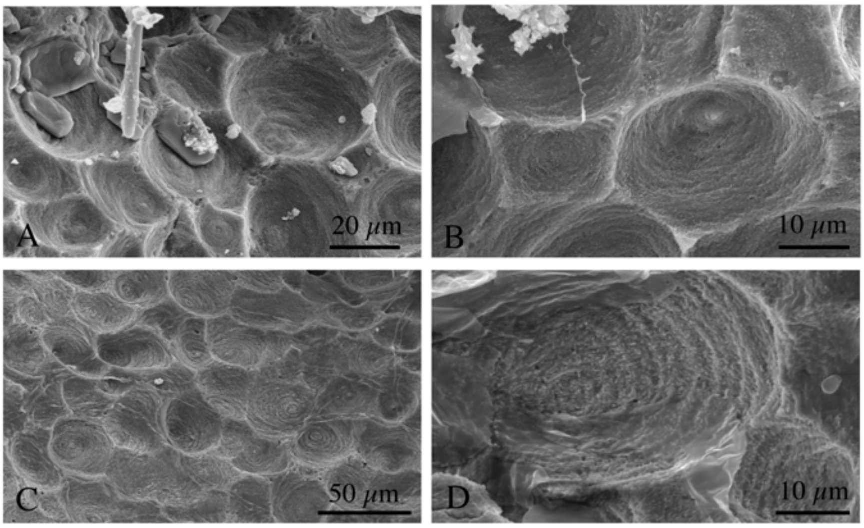

Fig. 2. Fingerprint like pits made by *Holoxea excavans* **(A-B)** and by *Spiroxya macroxeata* **(C-D)**.

3) Pits with deep concentric etching marks (Fig. 3)

Alectona (A-B), *Delectona* (C-D) and *Thoosa* (E-F) create pits with deep concentric, irregular erosion lines. While the two last genera are indistinguishable, *Alectona* shows a radial pattern that overlaps on the concentric bands, making the pits of this genus very distinctive (B). In *Delectona* and *Thoosa* the concentric grooves do not reach the centre of the pit, which appears to be eroded in a mild, irregular fashion.

4) Pits with deep, concentric etching marks reaching the centre (Fig. 4)

In the genus *Aka*, pits are generally regular, with the surface subject to deep grooves that extend to the pit centre. There is often an outgrowth in the centre of the pit.

Through SEM observation, we are able to conclude that the observed differences in the micro-patterns of the pits do not depend on substrate features. Different species of the genera *Alectona* (Fig. 5A), *Spiroxya* (Fig. 5B), *Cliona* (Fig. 5C) and *Holoxea* (Fig. 5D), which bore the same substratum (*Corallium* scleraxis) show their proper pit micro-patterns (Fig. 5), which are easily distinguishable. The same situation is found in the skeleton of the blue coral *Heliopora coerulea*, which is simultaneously bored by *Aka* (Fig. 5E) and *Cliona mucronata* (Fig. 5F).

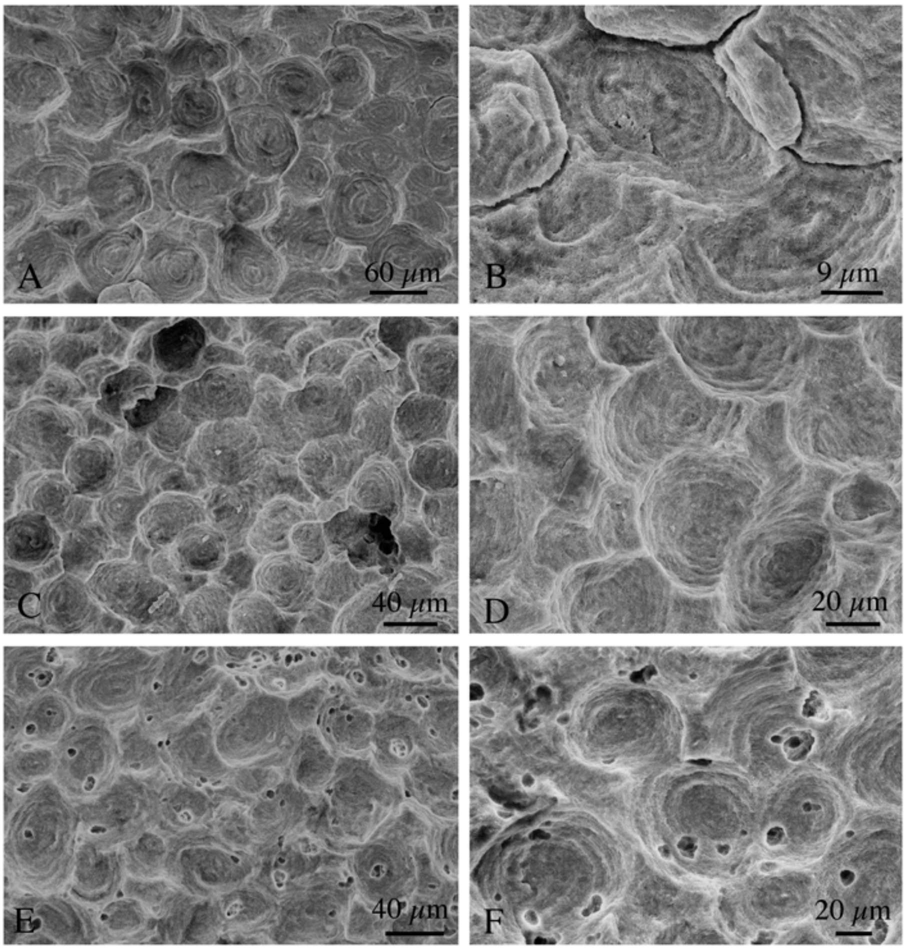

Fig. 3. Pits with deep concentric etching marks made by *Alectona triradiata* **(A-B)**, *Delectona ciconiae* **(C-D)** and *Thoosa bulbosa* **(E-F)**. In *Alectona* a radial pattern overlaps the concentric lines.

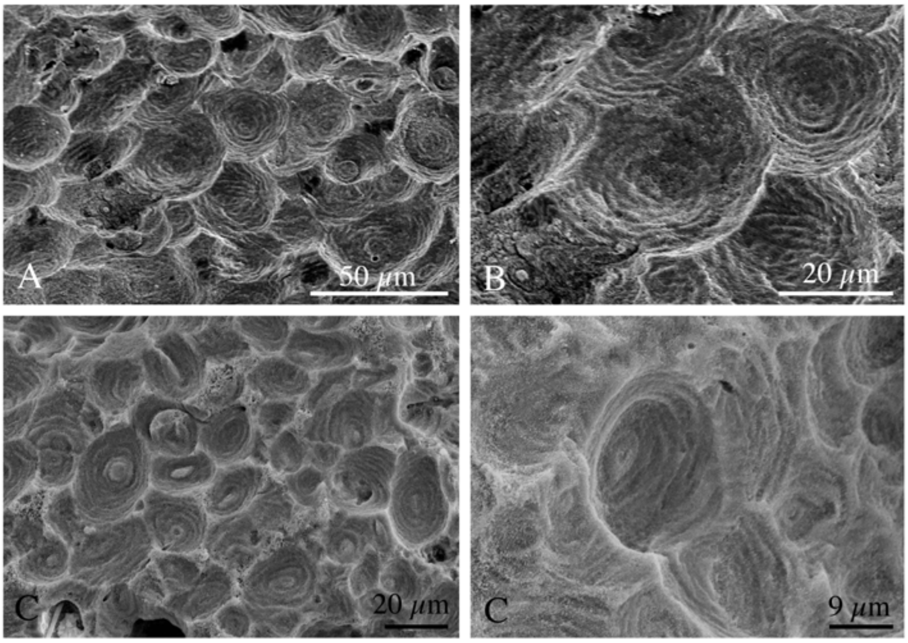

Fig. 4. Pits characterized by deep, concentric etching marks made by *Aka* spp.

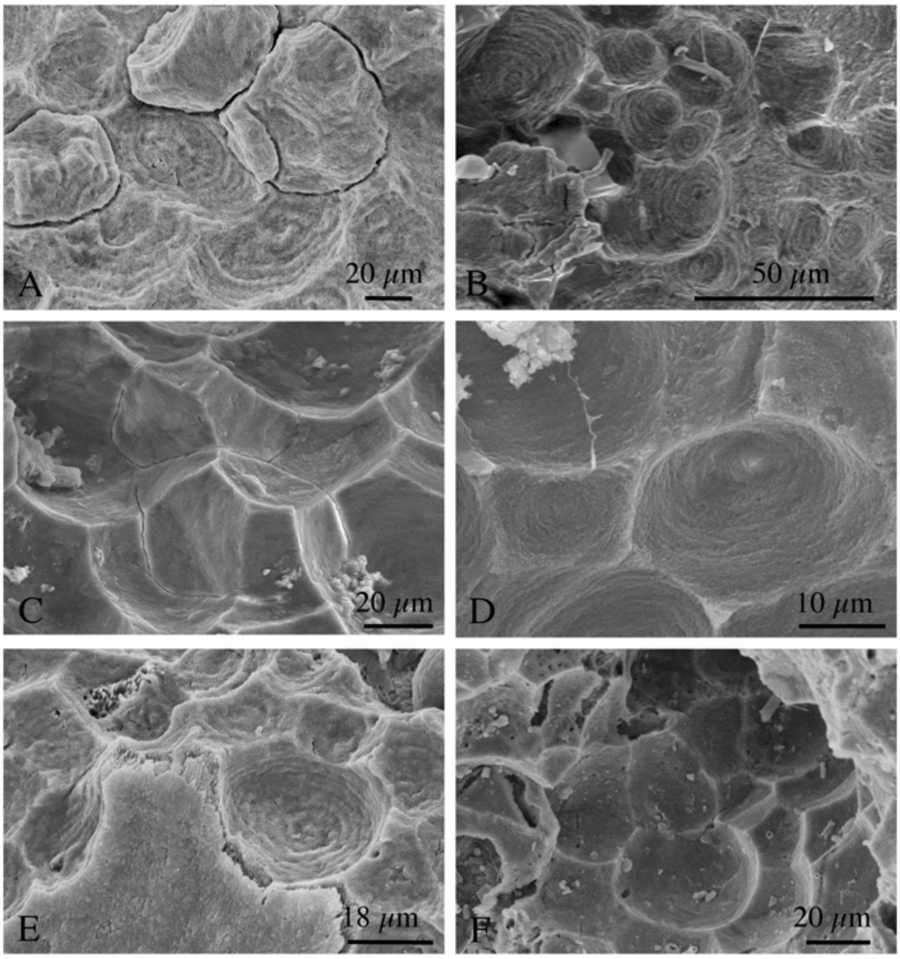

Fig. 5. Comparison among different sponge species that excavate in the same kind of substratum showing their own pitting pattern: *Alectona* **(A)**, *Spiroxya* **(B)**, *Cliona* **(C)** and *Holoxea* **(D)** into *Corallium* scleraxis and *Aka* sp. **(E)** and *Cliona mucronata* **(F)** into *Heliopora coerulea*.

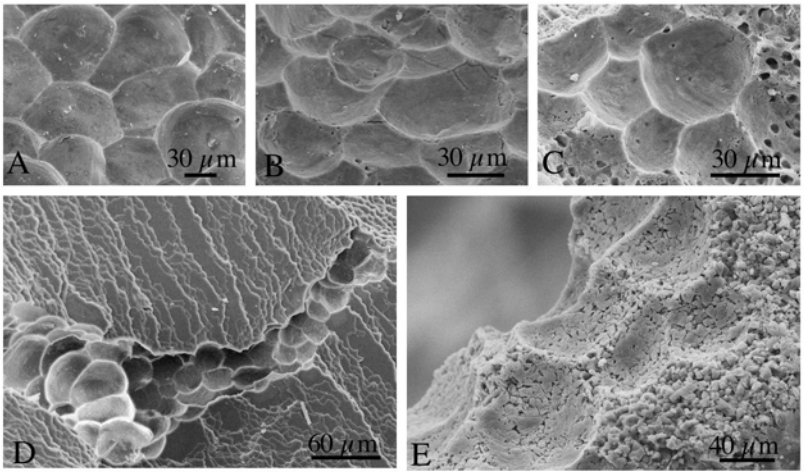

Fig. 6. Smooth pits are produced by *C. vermifera* even when it excavates in different substrata: shell **(A)**, rock **(B)**, algae **(C)**. Pits produced by *Pione* cf. *vastifica* show a highly variable size range. In particular they decrease their size inside the pioneer canals **(D)**. In some cases the pitting pattern may be obscured by the rock porosity **(E)**.

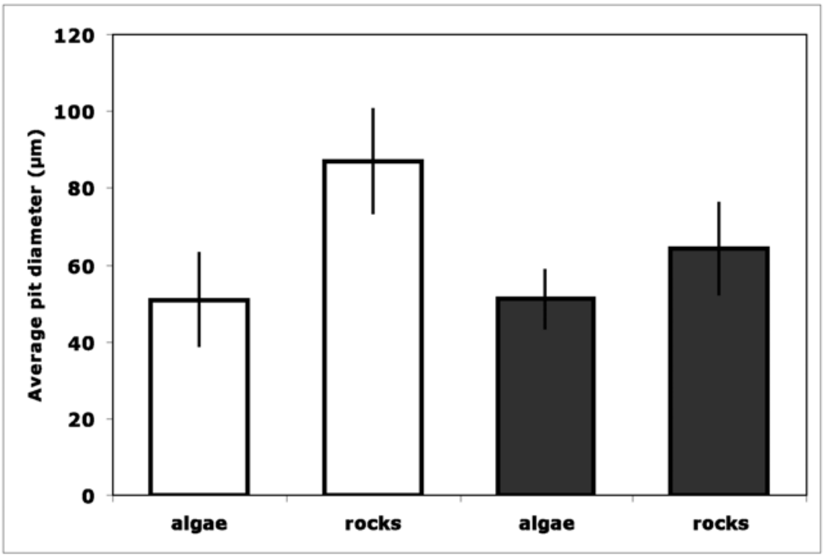

Fig. 7. Average size (± sd) of the pits produced by *Cliona rhodensis* (empty bars) and *Cliona vermifera* (black bars) excavating into coralline algae and rock. All the shown differences are significant ($p < 0.01$; t-test).

Further evidence is provided by observation of the micro-erosion pattern produced by the same species in different substrata. The different texture of the substrate does not influence the erosion pattern, as *Cliona vermifera* produces smooth pits in shells, rock, or coralline algae (Figs 6A-C).

While pit ornamentation is constant in different genera, pit size can vary within a single species, meaning that it is not suitable for use as a taxonomic tool. SEM observations show that pits overlap, resulting in changes in size. Moreover, pits are different in different parts of the excavations; for example, the pits of explorative canals are smaller that those of the normal chambers (Fig. 6D). This means that younger specimens probably present, on an average, smaller sized pits. What is more, substrata may play a role in determining the size of pits. *Cliona rhodensis* and *C. vermifera* produce pits that are significantly larger in rocky substrata than in coralline algae (Fig. 7).

DISCUSSION AND CONCLUSIONS

Comparison of the micro-pattern of excavations in different genera has shown that they may be used as a diagnostic character in the diagnosis of super-specific groups; it may be usefully applied in the establishment of the taxonomic status of critic genera such as *Aka-Siphonodictyon* (DESQUEYROUX-FAUNDEZ & VALENTINE, 2002).

Even though we have demonstrated that substrate does not influence the specific micro-erosion pattern, at times the substrate may alter it. For example, rock texture or coralline algae porosity may obscure the original pitting pattern, making it difficult to recognize it (Fig. 6E). In this case it is necessary to study different part of the specimen, where the porosity or the rock texture is orientated in a favourable way. In addition, erosion by biological, physical or chemical agents may overlap the original erosion, modifying the pitting pattern (Figs 3E-F).

Our data clearly indicate that the microtopography of the pits is not due to the physical features of the substrate, and we hypothesize, therefore, that the structure and the physiology of the etching cells are involved. POMPONI (1977) also observed microterracting on the pit walls and speculated that a gradual process of chemical etching may cause it. It is also likely that a different mechanical action is at work in the different genera, and that the visible differences may be caused by the etching cells' alternating phases of chemical and mechanical attack and pause.

ACKNOWLEDGEMENTS

We are grateful to Dr. Michetti for his technical assistance during the Scanning Electron Microscope (SEM) analysis.

This work was supported by the Italian Ministero Università e Ricerca Scientifica.

REFERENCES

BROMLEY R.G., 1970 - Borings as trace fossils and *Entobia cretacea* Portlock, as an example. In T.P. Crimes, J.C. Harper (eds), *Trace fossils*. Geological Journal, Liverpool, [Special Issue], vol. **3**: 49-90.

BROMLEY R.G., D'ALESSANDRO A., 1984 - The ichnogenus *Entobia* from the Miocene, Pliocene and Pleistocene of Southern Italy. *Riv. Ital. Paleontol. Stratigr.,* **90**: 227-296.

CALCINAI B., ARILLO A., CERRANO C., BAVESTRELLO G., 2003 - Taxonomy-related differences in the excavating micro-patterns of boring sponges. *J. Mar. Biol. Ass. UK,* **83**: 37-39.

DESQUEYROUX-FAUNDEZ R., VALENTINE C., 2002 - Family Phloeodictydae Carter, 1882. In J.N.A. Hooper, R.W.M. van Soest (eds), *Systema Porifera. A Guide to the Classification of Sponges*. Kluwer Academic / Plenum Publishers, New York, Vol. **1**: 893-905.

PERRY T.P., BERTLING M., 2000 - Spatial and temporal patterns of macroboring within Mesozoic and Cenozoic coral reef systems. In E. Insalaco, P.W. Skelton, T.J. Palmer (eds), *Carbonate platform systems: components and interactions*. Geological Society, London, [Special Publications], vol. **178**: 33-50.

POMPONI S.A., 1977 - Excavation of calcium carbonate substrates by boring sponges: ultrastructures and cytochemistry. A dissertation. University of Miami. Florida, 133 pp.

RÜTZLER K., 1975 - The role of boring sponges in bioerosion. *Oecologia,* **19**: 203-216.

RÜTZLER K., RIEGER G., 1973 - Sponge burrowing: fine structure of *Cliona lampa* penetrating calcareous substrata. *Mar. Biol.,* **21**: 144-162.

VACELET J., 1999 - Planktonic armoured propagules of the excavating sponge *Alectona* (Porifera: Demospongiae) are larvae: evidence from *Alectona wallichii* and *A. mesatlantica* sp. nov. *Mem. Queensl. Mus.,* **44**: 627-642.