

**DESTRUCTION OF TESTS OF THE FORAMINIFER *Sorites orbiculus*
BY ENDOLITHIC MICROORGANISMS IN A LAGOON ON CURAÇAO
(NETHERLANDS ANTILLES)¹**

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ABSTRACT

Kloos, D. P. 1982 Destruction of tests of the foraminifer *Sorites orbiculus* by endolithic microorganisms in a lagoon on Curaçao (Netherlands Antilles) – Geol. Mijnbouw 61: 201-205.

After reproduction or death, the empty shells of the epiphytic foraminifer *Sorites orbiculus*, living in a lagoon on Curaçao, sink to the bottom and are there intensively bored by endolithic algae.

Fragmentation of *S. orbiculus* skeletons due to boring algae contributes to the generation of the silt fraction of the sediment; part of the calcareous tests is dissolved.

The proportion and composition of *Sorites*-derived grains in a sediment sample taken in August differ from one taken in February. There is no trace of micritization in or around the bored soritid grains. This suggests that the demolition of a *S. orbiculus* test by endolithic algae is completed in a few weeks, or at the most in a few months.

INTRODUCTION

Boring microorganisms, comprising representatives of the cyanophytes, chlorophytes, rhodophytes, fungi and possibly bacteria, play an important role in the biogenic disintegration of skeletal grains in carbonate sediments. In addition, they can be instrumental in the development of micrite envelopes around skeletal fragments and in the formation of lime-mud (KLEMENT & TOOMEY, 1967; PERKINS & HALSEY, 1971). Endolithic microorganisms are furthermore assumed to be useful paleoecological indicators (BOEKSCHOTEN, 1966; SWINCHATT, 1969; GOLUBIĆ ET AL., 1975; BUDD & PERKINS, 1980).

Endolithic borings are encountered in various carbonate substrates; in shells of living organisms, in skeletal fragments and in limestone. In general, however, these borings are not easily accessible to investigation because of their small size and their location in hard substrates, impervious to light. Various techniques have been developed to study the organisms and their borings (GOLUBIĆ ET AL., 1975), but these proce-

dures are usually complicated and time consuming, or they forfeit part of the material. The tube pattern of microborers can best be seen in substrates which can be examined under a microscope with transmitted light. The foraminifer *Sorites orbiculus* constructs a relatively thin, imperforate, calcitic shell. The internal structure of these tests becomes visible when they are submerged in a fluid with a high refractive index. A number of bored specimens were SEM-micrographed.

MATERIALS AND METHODS

The samples this study is based on were collected in a small lagoon west of Jan Thiel Bay on the island of Curaçao (Netherlands Antilles). This lagoon is well protected against the northeastern trade-wind and the swell of the open sea. The epiphytic foraminifer *Sorites orbiculus* lives in this very quiet water upon the marine phanerogam *Thalassia* and the codiacean alga *Halimeda* which grows at a depth of approximately 50 cm (see further KLOOS, 1980, 1981). Samples taken in August 1979 and February 1980 were selected as representative for the dry and wet season. The living population *S. orbiculus* was far more prolific in August than in February.

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The underlying sediment, a layer with a thickness of approximately 10 cm, was sampled with a shovel. The sediment samples were sieved through a nylon stocking in order to rinse away the relatively small clay-sized fraction, after which they were stove-dried. This procedure causes the loss of the boring organisms; for this reason our study was limited to the endolithic microborings.

The sediment samples, inspected under a binocular microscope, consist of poorly sorted lime-sand with grains ranging up to approximately 1 cm in diameter. The degree of rounding was low. The bulk of the grains consisted of whole or fragmented *Halimeda* segments. Skeletons and skeletal fragments of other organisms, such as gastropods, ostracods and various foraminifers were also encountered. In a 100 gram sediment from the August sample we found 415 more or less complete *S. orbiculus* shells together with 312 recognizable soritid fragments; the same quantity from the February sample yielded 295 whole shells and 363 recognizable soritid fragments.

Selected specimens were submerged in aniseed oil and examined under the microscope with transmitted light. In 40% of the more or less undamaged *S. orbiculus* shells the roof and floor exhibited delicate borings. The percentage of soritid fragments affected was 80%. These percentages held for both the August and the February sample. This contrasts sharply with the living *S. orbiculus* population where only a few of the thousands examined were found to be infested. A brief inspection of other transparent carbonate grains in the sediment showed comparable borings.

To obtain a three-dimensional picture of the boring patterns, a number of preparations of *S. orbiculus* were subsequently examined with the SEM. It was found that not only the roof and floor, but also septae and septulae are affected by endolithic microorganisms (figs. 1-5).

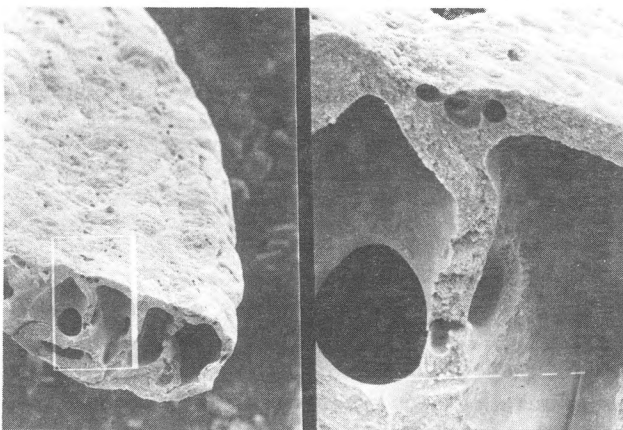


Fig. 1
Part of a *Sorites orbiculus* shell at the onset of endolithic boring. The cross section cuts four chambers; borings are seen in the fractured shell elements. (130x)

Fig. 1A
Detail of Fig. 1. Three neighbouring borings are visible in the roof of the test and one in a septum. (645x)

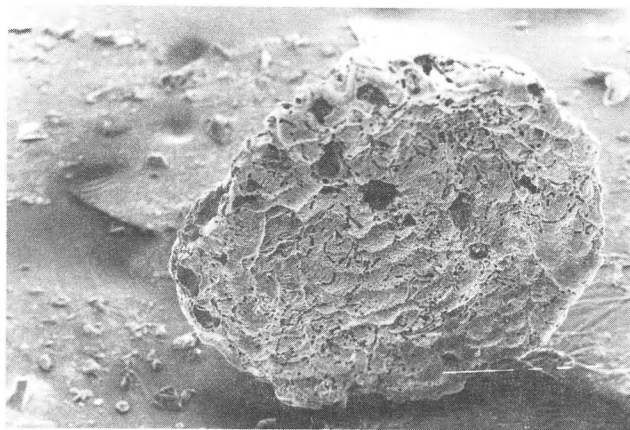


Fig. 2
A strongly infested *S. orbiculus* test. A number of perforations through which algae have penetrated the host are visible. many collapsed tunnels are also seen. (85x)

DESCRIPTION OF THE BORING

The borings usually begin with a perforation in the roof or floor of the test, through which the microborer enters the host. In the SEM micrographs, the outside of the test accordingly shows a number of perforations whilst the further course of the tubes is not visible (Fig. 1). Often, however, the corridors collapse permitting their course to be seen from the outside (Figs 2 and 3). The borings often continue into the septae or septulae, but they are always confined to the skeleton, never opening into a chamberlet (Figs 4 and 5), a phenomenon also recorded by ALEXANDERSSON (1972-a) from the foraminifer *Archaias sp.*

The borings are extremely variable in shape and length. They may consist of a number of short tubes extending from one central point in different directions; this is frequently found in the centre of the test (Fig. 6). Often, however, the borings begin with a single tunnel which later branches out to varying degrees; this type is usually longer (Figs 7 and 8). Borings may be more or less straight, but they can also be tortuous (Figs 2, 7 and 8).

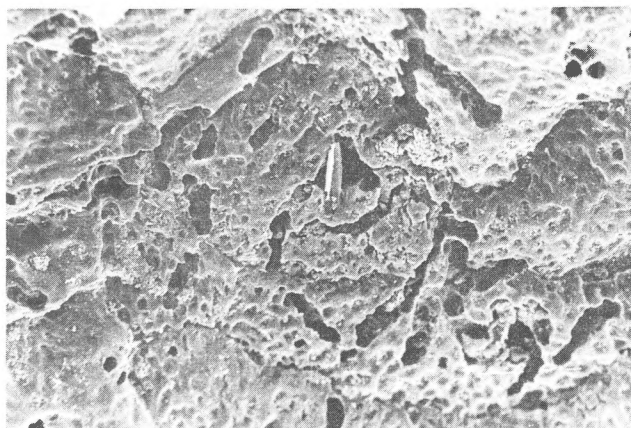


Fig. 3
Detail from Fig. 2. (525x)

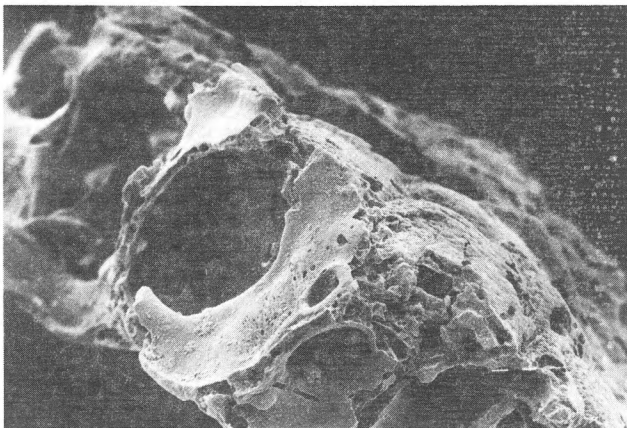


Fig. 4
Intensively infested *S. orbiculus* fragment. The fracture mainly runs along borings and the skeleton has already partially crumbled. (225x)

The diameter is usually uniform for an individual boring, but may differ from 2 to 10 μm for different tunnel systems, with an average of 5 μm . Fig. 8 shows two boring patterns which differ strongly in diameter, each of them having a uniform diameter. The length of the tubes may be up to several hundred μm . The boring organisms do not often have much leeway, as the thickness of the soritid test is in the order of 5-10 μm . In a section of a thicker part of the skeleton, one may often observe corridors which cross each other or run parallel without touching (Fig. 5). Little by little the microborers hollow out the skeletons, thus weakening them considerably. From the SEM micrographs it is evident that most fracture-planes are situated where testwalls were weakened by borer tubes (Figs 4 and 5). Traces of secondary precipitation of carbonate have not been discovered in the borings or elsewhere on the calcareous soritid shells.

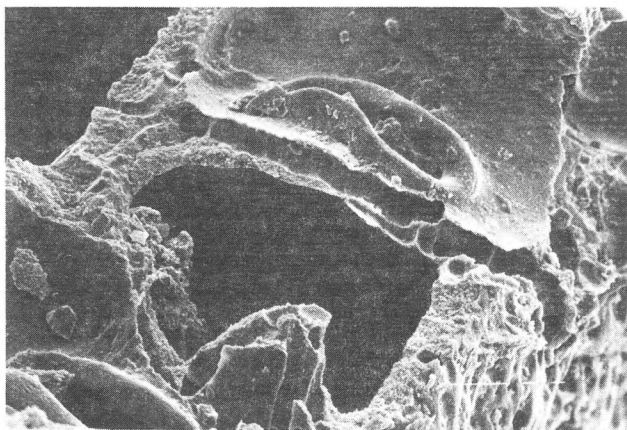


Fig. 5
The centre of this SEM micrograph shows a bored septulum the thickness of which is scarcely larger than the bore-diameter. At the centre-bottom of the picture, in contrast, several tubes can be seen side by side in a chamber-wall which is considerably thicker than the diameter of the borings. (730x)

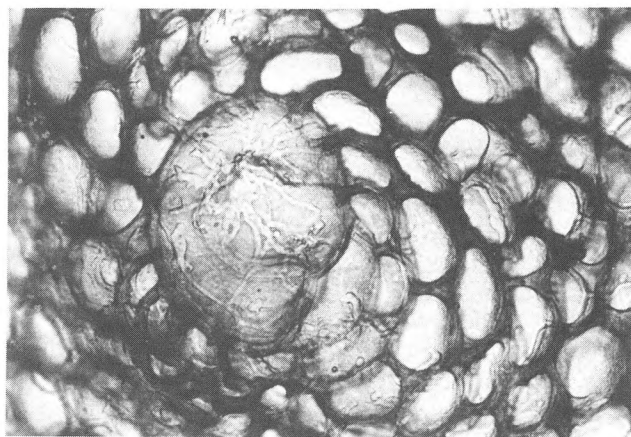


Fig. 6
Boring pattern, in the roof of the embryonal part of a soritid, with a number of short tubes extending in different directions from a central point. (140x)

CONCLUSIONS AND DISCUSSION

The borings in *S. orbiculus* conform to BROMLEY'S (1970)-characterization of algal borings and show a strong resemblance to algal borings described and illustrated in other papers (e.g. BATHURST, 1966; ALEXANDERSSON, 1972-a; GOLUBIĆ ET AL., 1975; PERKINS & TSENTAS, 1976; BUDD & PERKINS, 1980). Such algae are found predominantly in environments with low hydraulic energy (SWINCHATT, 1965; ALEXANDERSSON, 1972-a). In places where the sediment is subjected to strong movements and abrasion, the algae cannot easily attach themselves. Bio-erosion by endolithic algae is thus inversely proportional to mechanical abrasion. Endolithic algae are generally considered to operate exclusively in the photic zone on account of their dependence on light for photosynthesis (SWINCHATT, 1969; PERKINS & TSENTAS, 1976). The presence of endolithic algal borings can therefore serve as an ecological indicator.

The abundance of bored shells found in the quiet, shallow, clear lagoon next to Jan Thiel Bay supports the above-men-

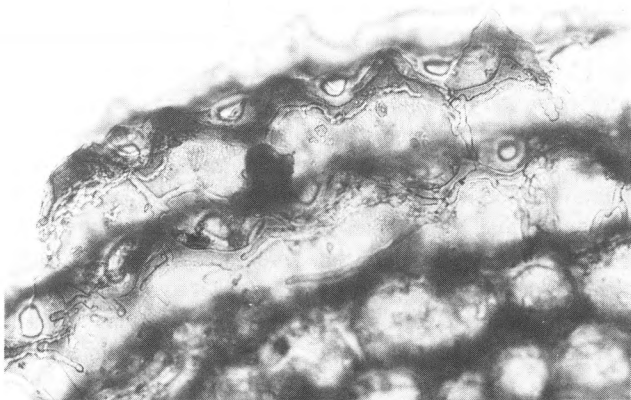


Fig. 7
Outer chambers of a *S. orbiculus*. The borings are located inside the roof or floor and partly follow the sutures of the test. (140x)



Fig. 8
Two bore patterns of different diameter possibly caused by different species; the borings of each pattern itself are of uniform diameter (2 μm and 5 μm). (350x)

tioned criteria. Borings are seldom found in the shells of living *S. orbiculus* indicating that empty shells that have settled on the lagoon bottom are more suitable for boring by algae (KLOOS, 1980).

The endolithic algae are very active at the sediment surface as shown by the high percentage of infested soritids. As these form 40% of the whole specimens and 80% of the fragments in both samples, it follows that fragmentation is mainly due to boring activity. This fragmentation continues until the resulting particles become too small for further infestation. Whole soritid shells have thus been in the sediment for a shorter time than fragments and larger fragments for a shorter time than smaller ones. The algae thus fulfill an important role in the generation of the fine fraction in the sediment (cf. SWINCHATT, 1965; PERKINS & HALSEY, 1971) which does not result from mechanical activity. The intensive boring activity also results in the dissolution of a considerable portion of the soritid skeletons (carbonate recycling).

It is noteworthy that the August sample contained more whole soritid tests than fragments (415 to 312), whereas in the February sample the reverse held true (295 to 393). This difference is statistically significant and not to be ascribed to variations in boring activity of the algae as the percentages of infested whole tests (40%) and of infested fragments (80%) are the same in the August and the February samples. As the rate of infestation is equal, this difference may be due to the greater productivity of the living population in August than in February, which contributes a greater number of empty tests to the sediment per unit of time. From this it follows that the rate of fragmentation may be rapid in order to account for the preponderance of whole shells in the summer sediments: such a seasonal difference would not be seen in the sediment if it were slow. The rate of fragmentation is therefore thought to be in the order of a few months or less. Carbonate substrates of shells and organic calcite placed in the sea by PERKINS & TSENTAS (1976; St. Croix, Virgin Islands) were colonized up to

10% by endolithic microorganisms in nine days; after four months 95% were severely infested. Evidently microborers can rapidly desintegrate bioclats.

The absence of micritization may also indicate that *S. orbiculus* tests, once settled on the sediment, can disintegrate in a very short time. BATHURST (1966) describes the micritization process in calcareous skeletons taking place in three stages: 1) algae bore into the shell wall, 2) the algal filaments die and decay, 3) secondary precipitation of micritic aragonite fills the tubes. This secondary precipitation frequently occurs in highly carbonate saturated seawater such as the warm tropical waters of the West Indies and the Mediterranean (ALEXANDERSSON, 1972 a, b). The absence of micritization in *S. orbiculus* from Curaçao is therefore contrary to expectation. It could mean that the rate of formation of borings and fragmentation is too rapid for the formation of micrite. KOBLUK & RISK (1977) explain the micritization process in terms of calcification of exposed dead filaments of endolithic algae and they state that these algal filaments can completely calcify in 65 to 95 days. If so, the fragmentation process of the fragile shells of *S. orbiculus* with their thin walls could occur within weeks. However, the absence of micritization may also be due to lack of turbulence in the lagoon or to lowering of the carbonate saturation level because of respiration-photosynthesis influences of fauna and flora on the CO_2 partial pressure (ALEXANDERSSON, 1972-b).

The following points may be made in summary. Fragmentation of *S. orbiculus* tests down to silt size is brought about by the activity of boring algae. The proportion of recognizable skeletal debris of *S. orbiculus* in the sediment will be strongly reduced by this activity. It is conceivable that all the skeletons are disintegrated soon after the death of a population of *S. orbiculus*, leaving no recognizable traces in the sediment. Differences in the proportion of *S. orbiculus* skeletal grains and the ratio of whole skeletons of skeletal fragments, may be the result of seasonal fluctuations in the living population. Further research is needed to decide if there is any seasonal cyclicity in a vertical profile.

In Jan Thiel Bay one process, the bio-erosion of boring algae, leads to results which are generally thought to be produced by mechanical fragmentation and sorting.

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