

Commensal association of *Corbula gibba* (Bivalvia) and a sub-conical boring

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An examination of fossil and Recent right valves of the infaunal, suspension-feeding *Corbula gibba* (Olivi, 1792) revealed the presence of a slender, sub-conical, unbranched boring. The boring is interpreted as the work of a commensal organism, possible a parasite. Stratigraphic range is from Eocene to Recent.

Key words: Corbulidae, *Trypanites*, *Conchifora*, Cenozoic, commensalism, amensalism.

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In his monograph, Sorgenfrei (1958) described marine gastropods, bivalves and scaphopods collected from the Middle Miocene Amum Formation, Denmark. In shells of *Corbula gibba* (Olivi, 1792) he observed what he termed a “marginal pore”. Sorgenfrei (1958) had no suggestion for the purpose of the “pore”. Except for Sorgenfrei (1958), apparently, the “pore” has not been paid any attention. An interpretation is proposed in the present paper.

Description

The “pore”, which is situated at the posterior margin of the right valve, is located along the boundary between the external and internal shell layers (prismatic and lamellar, respectively, according to Strachimirov 1972). The “pore” has a slender, sub-conical, slightly curved, unbranched shape and a single aperture to the external surface of the shell. The distal end is tapered. The margin is smooth (see Sorgenfrei 1958: 131, Pl. 23: 69a-b, d-f) (Figs 1–2).

Origin

The “pore” has no connection to the internal cavity of the bivalve and consequently there was no connection to its soft parts. The aperture is situated in the external surface of the shell and “pore” cross-cuts the shell layers. Thus, the “pore” is interpreted here as a boring. Müller (1956) argued for the same interpretation

of identical borings. They occur in hard substrates, such as shells (Bromley 1972).

The “pores” in Recent specimens of *C. gibba* may be filled with a gelatinous mass (Sorgenfrei 1958). This mass could represent the decaying tracemaker. According to Müller (1956) and Bromley (1972) various animals, for example annelids, are known to make borings similar to the one in *C. gibba*.

Ichnotaxonomy

The boring in *C. gibba* resembles ichnotaxa of *Trypanites* Mägdefrau, 1932, and partim *Conchifora* Müller, 1968. Bromley & D’Alessandro (1987: 403) diagnosed *Trypanites* as containing “single-entrance, cylindrical or sub-cylindrical, unbranched borings in lithic substrates, having circular cross-section throughout length. The axes of the borings may be straight, curved or irregular”. Following this diagnosis the boring present in *Corbula gibba* cannot be considered a *Trypanites*.

The boring in *C. gibba* resembles *Conchifora zylindrifformis* var. *palisadiformis* Müller, 1968, which was described as “cast of straight to moderately curved, conical, unbranched boring with a single aperture and with blunt-rounded or tapered end in shells of brachiopods” (translated from Müller 1968: 71). Originally the polymorphic *Conchifora* was described as including both unbranched and branched borings (see Müller 1968). A taxonomic revision involving type material is badly needed. According to Bromley & D’Alessandro (1987), *C. zylindrifformis* var. *clavi-*

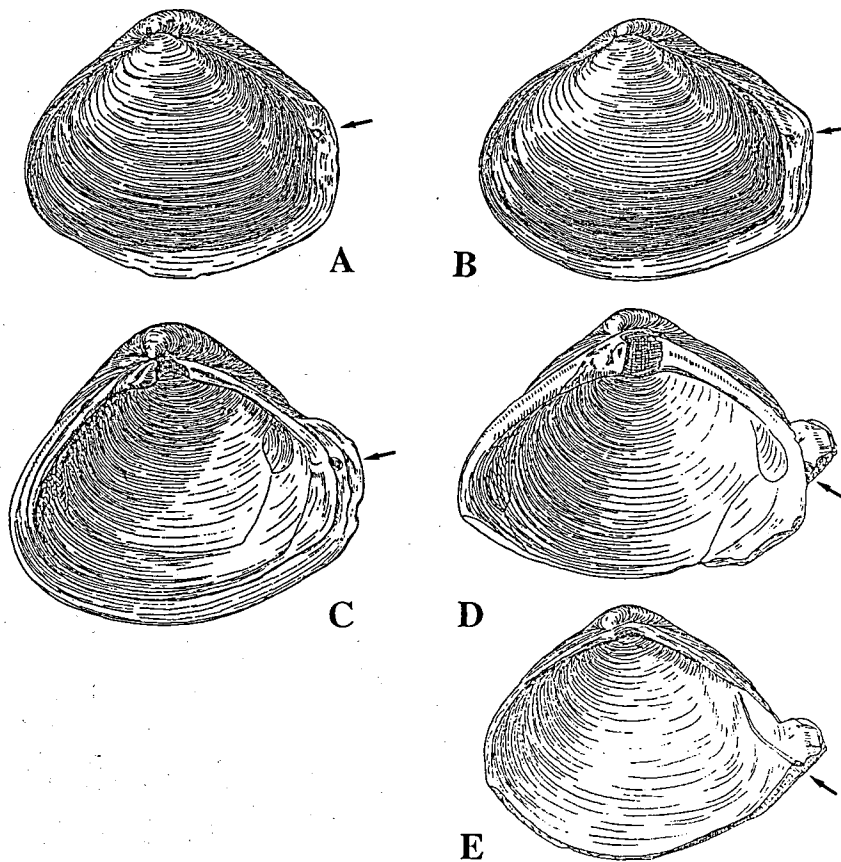


Fig. 1. A, B, articulated valves (length about 4 mm) of *Corbula gibba*. The boring is situated at the posterior margin of the right valve (arrow). C, disarticulated right valve (length 4.27 mm) with a boring. D, a disarticulated right valve (length 4.54 mm) with attached internal shell layer. E, the same valve (length 3.65 mm) with internal shell layer removed. All drawings adopted from Sorgenfrei (1958).

formis Müller, 1968 is a junior synonym for *T. fimbriatus* (Stephenson, 1952). However, C. Plewes (pers. com.) suggests that partim *Conchifora* should be transferred to *Palaeosabella* Clarke, 1921. Based on description and illustrations by Müller (1968), *T. weisei* Mägdefrau, 1932 and *C. zylindriiformis* var. *zylindriiformis* Müller, 1968 seem to be identical. As the latter is holotype for *Conchifora* igen., *Conchifora* may have to be abandoned. Therefore, pending a taxonomic revision of this group of borings, the present structure may remain nameless for the time being.

Stratigraphic range

Sorgenfrei (1958) mentioned that a identical "pore" exists in Eocene (South Carolina to Rio Grande River; Belgium), Miocene (Jamaica) and Recent (Senegal; Shetland Isles, British Isles; Australia) shells belonging to the Corbulidae. I have examined the following samples of *Corbula gibba* housed in the Zoological Museum (ZM), the Geological Institute (GI), and the Geological Museum (GM), University of Copenhagen, Denmark:

Recent (dry samples):

ZM, Nykøbing, Mors, Denmark (Fig. 2). ZM, Skagens Fyrårn: NW 1/2 N, 14 km l., 32 m depth, pure silt, Kattegat, 27-8-1885. Legit: "Hauch" St. 268. Det. C. G. Joh. Petersen. Journ. M.11/8-1887. ZM, Vinduespollen, Bergen, Norway, 17-9-1901. Legit: K. T. A. Jensen. ZM, loc. 3 km l. N to E of Vyl Fyrskib, North Sea, 24 m depth, 29-9-1904. Legit: "Thor" St. 255.

Post-glacial (Holocene):

GM 1970.1525, *Dosinia stratum*, Korsholm, Denmark. GM 1970.1527, southern coast of Øland, Sweden. GM 1970.1528, Kolind Sund, Denmark.

Eemian interglacial (Pleistocene):

GM sample no. 95001, loc. 001, Koleska, Vaga (Sev. Dvina), Russia (collection of S. Funder).

Pleistocene:

GI samples no. 98-565, 98-605, 98-606, Lindos Bay clay, coastal outcrop 600 m SW of Thermes Kalitheas, NE Rhodes, Greece (collection of JKN).

Pliocene/Pleistocene:

GI sample no. 79-209, at transition from Kritika For-

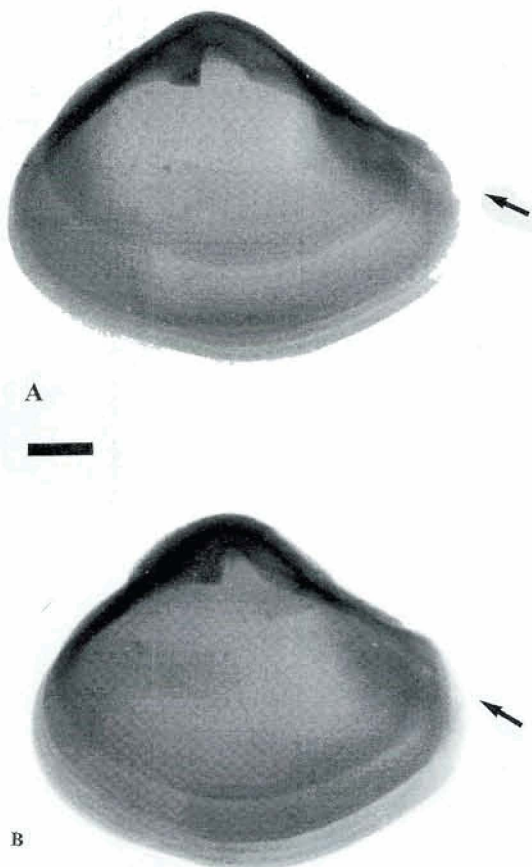


Fig. 2. A, B, x-ray positives of disarticulated right valves of *Corbula gibba* (Recent, Nykøbing, Mors, Denmark). Note the sub-conical shape of the boring in each valve. Scale 1 mm. Photographic work by J. Aagaard (University of Copenhagen).

mation to Rhodes Formation, Monte Smith, N Rhodes, Greece (collection of M. Hallquist and T. Hansen). GI sample no. 106-801, Kritika Formation, Monte Smith, N Rhodes, Greece (collection of M. Hallquist and T. Hansen).

Pliocene:

Facies "grey clays", Olona Valley, Varese province, NW Italy (see Brambilla & Lualdi 1988: Pl. 10: 6b).

Many right valves (length more than 3 mm) in these samples contain a boring aperture. The rest of the boring is covered by the internal shell layer and therefore is not visible. The boring aperture and its position are similar to that described by Sorgenfrei (1958) (Fig. 1A-C).

The sample from near Vyl Fyrskib, North Sea, consists mostly of disarticulated valves of *C. gibba*. There

are 548 disarticulated right valves. The main part, 512 valves, contains a single specimen of the boring. Nineteen valves contain both the boring and *Oichnus paraboloides* Bromley, 1981. The position of the two borings seems not to be related. Four valves contain only *O. paraboloides*. Thirty-two valves do not contain any of these borings.

In summary, the boring seems to have a wide geographic and stratigraphic distribution. Locally the boring may be abundant, indicating some ecological control.

Ethology

Recent specimens of *C. gibba* are suspension feeders and belong to the infauna in marine environments. They are oriented within the substrate with their posterior end upward, having short siphons, a long slender foot and a long byssal thread. The latter indicates a sedentary way of living. If the animal is forcibly disturbed it changes position by burrowing very slowly (Yonge 1946). The bivalve seems not to have had any benefit from the presence of the boring organism, which used the shells for protection. In ethological terms the boring can be classified as a domichnion (see Bromley 1994: Tables 5.1-5.2). The close position of the boring aperture to the posterior end of the bivalve suggests that the occupant was a suspension-feeder which exploited the suspended nutrients transported by water currents created by the bivalve. Thus, the boring probably was made by a commensal organism, possibly a parasite (see Voigt 1965; Müller 1968: 91; Hertweck 1971).

It is remarkable that there is never more than one boring in each right valve of *C. gibba*. This invites an explanation such as amensalism, restriction of nutrients or substrate. The presence of a boring organism primarily requires exposed lithic substrate and current-borne nutrients (e.g., Müller 1968; Hertweck 1971). In the case of *Cardium edule*, large numbers of *Polydora ciliata* (Johnston) may colonize the posterior end of the valves where they are just exposed at the sea floor (Hertweck 1971).

C. gibba is able to push its foot out through the inhalant siphon to grope on the surrounding substrate (Yonge 1946). This may have prohibited the settlement of a second boring organism, but it does not explain the presence of the first boring organism.

Alternatively, the first boring organism may have prevented the settlement of other boring organisms, e.g., by swallowing them. It would have prevented competition on nutrients carried with currents produced by the bivalve.

Conclusion

Examination of right valves of *C. gibba* revealed that: (1) a slender, sub-conical, unbranched boring may be present, (2) the boring is nameless for the time being, (3) its tracemaker was a commensal organism, possible a parasite, and (4) stratigraphic range of the boring is from Eocene to Recent.

Living specimens of *C. gibba*, with preserved soft parts, exist. It is recommendable that these should be studied to conform the boring and its biogenic origin.

Dansk sammendrag

Corbula gibba (Olivi, 1792) er en infaunal, suspensionsædende musling. I dens højre skal kan der forekomme en slank, sub-konisk, ugrenet boring. Denne er observeret i eocæne til recente skaller. Boringen tolkes som dannet af en kommensal organisme, muligvis en parasit.

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Foraminiferivory revisited: a preliminary investigation of holes in foraminifera

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Planktonic and benthonic foraminiferal tests from modern tropical-subtropical marine environments were investigated with regard to bioerosional traces. The traces found on the foraminiferal tests were grouped into 7 different categories. It is suggested that the different traces may be related to different unknown predators of which at least one is planktonic.

Key words: Foraminiferivory, predation, planktonic foraminifera, borings.

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The term foraminiferivory was introduced by Hickman & Lipps in 1983 to cover the general phenomenon of ingestion of foraminifera. Little is known about the relationship between the predators and the foraminifera in modern communities. The problem is further complicated by the alleged uncertainties as to why foraminifera are eaten (Hickman and Lipps 1983, Walker 1971). Many fish (Daniels & Lipps 1987, Lipps 1988) and macro-invertebrates are known to ingest foraminifera (Arnold et al. 1985, Berger 1971, Boltoskoy & Zapata 1980, Brand & Lipps 1982, Buzas and Carle 1979, Hickman & Lipps 1983, Langer et al. 1995, Lipps et al. 1974, Mageau et al. 1975, Reyment 1966, Sliter 1971, and Walker 1971). All fish and most of the invertebrates do so incidentally. However, a few invertebrates (gastropods, nematodes and scaphopods) seem to prey selectively on benthonic foraminifera (Langer et al. 1995). Few of these animals leave traces on the foraminiferal tests and most tests are probably destroyed in the process of ingestion. In addition, a few reports exist on predaceous and parasitic foraminifera preying on other benthonic foraminifera (Banner 1971, Baumfalk et al. 1982, Cedhagen 1994, Freiwald & Schönfeld 1996, Hallock & Talge 1994, Plewes et al. 1993, Todd 1965, and Vénec-Peyre 1996).

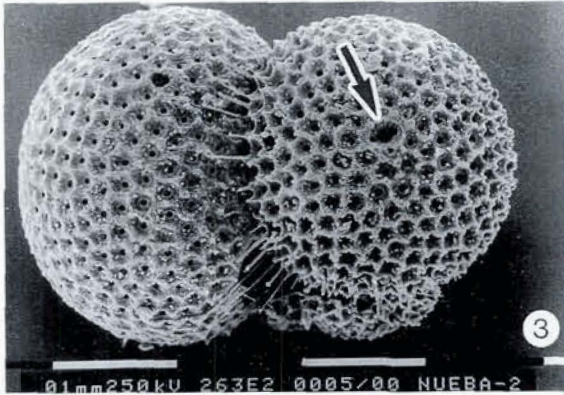
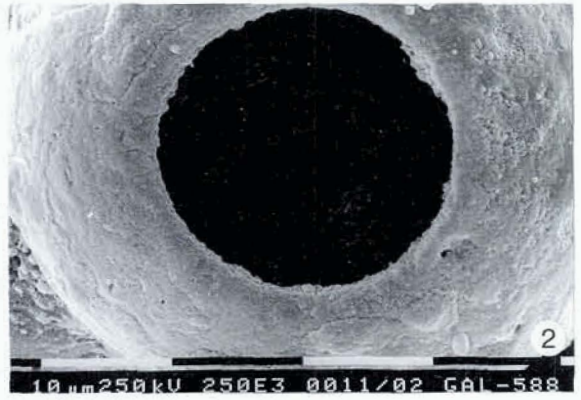
Results

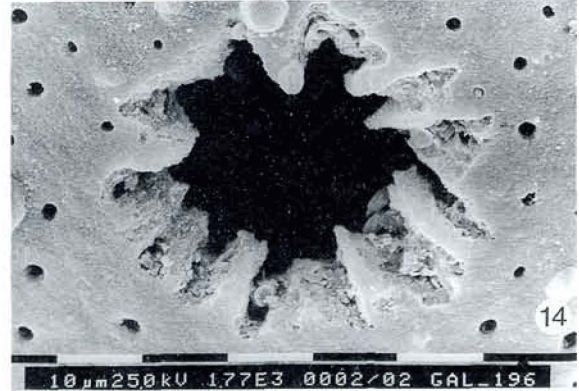
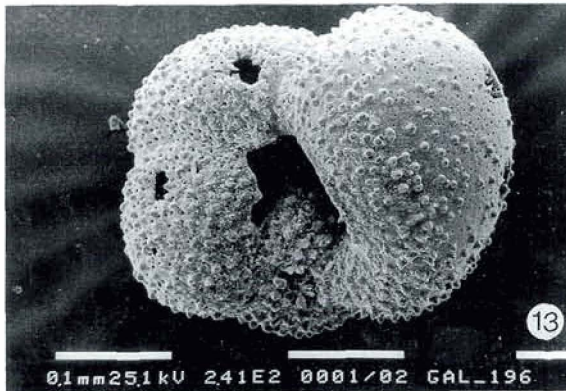
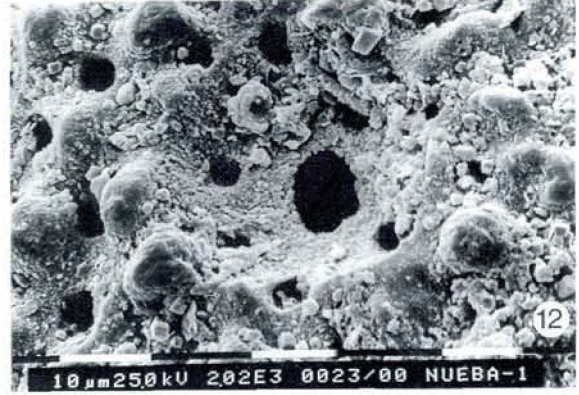
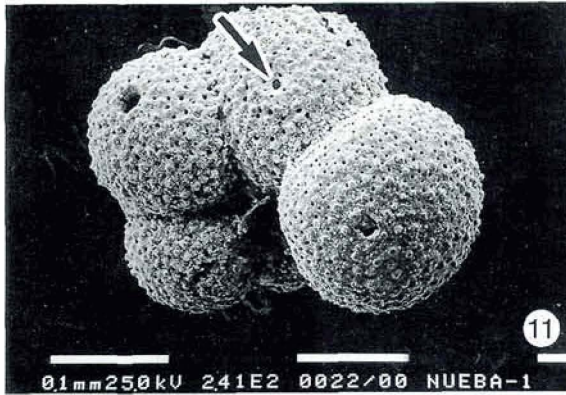
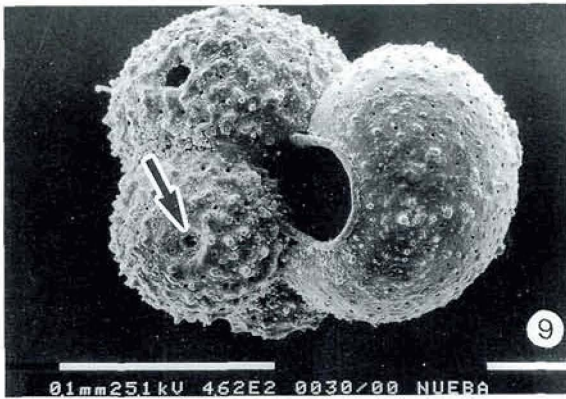
Holes in foraminiferal tests found in five samples from the Danish deep-sea expedition Galathea (1950–52) and two samples from the Gulf of Aqaba are here interpreted as predation of foraminifera through boring.

Almost all hitherto described examples of foraminiferivory involve either ingestion of or borings in benthonic foraminiferal tests. Based on the morphology of the holes found in the planktonic foraminifera it is possible to establish seven different categories. *Group A:* Circular to sub-circular holes (Figs 1, 2), *Group B:* Oval to sub-oval holes (Figs 3, 4), *Group C:* Pits (Figs 5, 6), *Group D:* Bite traces (Figs 7, 8), *Group E:* Circular to oval holes that end in a floor with a minute perforation (Figs 9, 10), *Group F:* Cup-shaped holes (Figs 11, 12), *Group G:* Star-shaped holes (Figs 13, 14). None of the bored tests exceeds 350 µm in size and in tests containing more than one boring the additional borings occur in separate chambers. All hole categories, except for group G, were also found in benthonic foraminifera.

Discussion

It is assumed that most of the borings are the result of predation. Since the unknown predators seem to be size-selective relative to planktonic foraminifera, it is likely that the primary target for these predators is the cytoplasm in the foraminiferal test. The position of additional borings in separate chambers seems to support this suggestion. Bé & Spero (1981) described repair processes in planktonic foraminifera when subjected to experimental damage of the test. No such structure has been observed in association with the borings and it is assumed that the foraminifera died from the attack. Since planktonic and benthonic foraminifera inhabit different environments it is most





Figs 1–14. General and close-up views (see arrows). 1, 2: Group A. 3, 4: Group B. 5, 6: Group C. 7, 8: Group D. 9, 10: Group E. 11, 12: Group F. 13, 14: Group G. All figures except 5 and 6 are planktonic foraminifera. Scale at bottom of figures.

likely that at least two different predators are involved of which one is planktonic.

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investigation and for helpful suggestions; Richard G. Bromley and Eckart Håkansson (Copenhagen), for their critical review of the manuscript and Jan Ågaard for helping with the pictures.

Dansk sammendrag

Betegnelsen foraminiferivory blev i 1983 introduceret af Hickman & Lipps for at dække det generelle fænomen, at nogle marine dyregrupper og fugle fortærer foraminiferer. Tidligere undersøgelser synes at indikere, at foraminiferer ikke har været et primært fødeemne for de fleste af disse dyregrupper. Analyser af maveindholdet fra nogle arter af rovsnegle og søtænder viser dog, at kalkskallede bentoniske foraminiferer udgør en betragtelig del af disse makroinvertebraters diæt.

For størstedelen af de foraminiferer, som bliver spist, gælder det formodentlig, at deres kalkskaller enten bliver knust af dyrets munddele, bliver opløst under fordøjelsesprocessen eller passerer igennem dyrenes fordøjelsessystem uden at der efterlades spor på skallen, der vidner om, at foraminiferen er blevet fortæret.

Prøver fra den danske Galatheaekspedition (1950-1952) og fra Aqaba bugten blev undersøgt med henblik på at påvise spor på kalkskallerne efter prædation på nulevende arter af planktoniske foraminiferer. De fundne spor kan morfologisk inddeles i 7 kategorier (A-G). Sporene er her tolket som værende af biologisk oprindelse og menes dannet ved prædationsadfærd af et eller flere planktoniske rovdyr.

Hypotesen synes understøttet af den omstændighed, at de ukendte spordannere udvælger planktoniske foraminiferer af en størrelse, der er mindre end 350 µm, og at hvis der forekommer mere end et spor i skallen, er disse placeret i forbindelse med nye skalkamre.

Da alle kategorier af spor undtagen gruppe G også er påvist på kalkskaller af bentoniske foraminiferer er det muligt, at der er mere end to forskellige spordannere og at en af dem er et planktonisk rovdyr.

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