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EWA OLEMPSKA

ENDOLITHIC MICROORGANISMS IN ORDOVICIAN OSTRACOD VALVES

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The ostracod valves from Middle Ordovician limestones, the profile of Mójcza, Holy Cross Mts., Poland, have been found to contain a new morphologic type of microbial borings. These are phosphate fillings of tunnels (9—13 μm in diameter) parallel to the valve surface, with bottle-like terminal swellings. They occur mainly in big and smooth ostracod valves.

Key words: Endolithic microorganisms, Ostracoda, Ordovician, Holy Cross Mts.

Ewa Olempska, Zakład Paleobiologii, Polska Akademia Nauk, al. Żwirki i Wigury 93, 02-089 Warszawa, Poland. *Received: December 1985.*

INTRODUCTION

The occurrence of organisms boring ostracod valves has been noted by several authors. Hessland (1949), while discussing algal borings in carapaces of Ordovician trilobites, mentioned very rare borings in the valves of ostracods as well. The microborings described by Hessland (1949), by some other authors (Gatrall and Golubic 1970) were proposed to be produced by fungi. Martinsson (1962: fig. 40-AB) described and illustrated traces of boring organisms in Silurian ostracod valves. Circular holes, 100—130 μm in diameter, has been found on the valve surface. Reyment (1963, 1966, 1971) has described borings in Paleocene ostracods from Nigeria, made by gastropods of the families Muricidae and Naticidae. In the opinion of Kornicker and Sohn (1971) multiple-holed specimens illustrated by Reyment (l.c.), attributed to boring gastropods, may have been caused by digestive juice of predators. Numerous microborings of algal and fungal origin in the valves of fossil and recent ostracods have been described and illustrated by Langer (1973, pl. 5: 9—10, pl. 6: 1—9).

Endolithic borings found in trilobite carapaces and molluscs shells are abundant in Lower and Middle Ordovician limestones of the Central Balto-scanian confacies belt. Hessland (1949) has described the mass occurrence of endolithic borings of algal origin in the sediments of the Lower Ordovician, Siljan District, Sweden. Also endolithic borings produced by sponges have been described from the Lower Ordovician of Sweden (Lindström 1979) and the Middle Ordovician of Norway (Pickerill and Harland 1984). Algal, fungal and sponge borings from Lower and Middle Ordovician limestones of Northern Poland have been described by Podhalańska (1984).

The present paper concerns the microborings from the eight metres thick sequence of limestones of Mójcza (Holy Cross Mts.). The Mójcza limestones represent the interval ranging from the Arenigian/Llanvirnian boundary (zone Amorphognathus variabilis) up to the Late Caradocian (zone Amorphognathus superbus) (Dzik 1978 and in press). In the lower part of the sequence the calcareous sandstones of Bukówka formation pass into organodetritic limestones of the Middle Ordovician. The uppermost part of the sequence (Ashgil) contains marly limestones with intercalations of marly shales.

The microboring-bearing ostracods occur in the central part of the profile in organodetritic limestones (the Late Llanvirnian to the Early Caradocian). In the upper and lower parts of the profile the microborings have not been observed.

MATERIAL

One hundred seven rock samples has been examined. Thirty of them contain ostracods valves with microborings. The casts of microborings were prepared from ostracod valves by dissolving the rock samples in acetic acid. This method could be applied thanks to the fact that ostracods were coated on both sides by thin phosphatic lining which remains in residuum after the valve is dissolved. Between the external layer of lining, reflecting the sculpture of the valve external surface, and the internal smooth layer, appears an empty space identical to the dissolved calcitic valve wall. Here, in a few ostracod valves, when one of the walls is damaged, microboring casts can be observed. Tunnels made by endolithic organisms within the ostracod valves have also been cast in phosphate. Thanks to this, their natural casts could be examined by scanning electron microscope (SEM). The microborings can also be examined under the light microscope in the transmitted light when the undamaged phosphatic valve linings are immersed in glicerine. There are about one hundred ostracod valves in which microborings are visible in transmitted light.

DESCRIPTION

Microborings are in the form of straight or slightly curved tubules, 9—13 μm in diameter, with irregular (pl. 29: 2) or bottle-like terminal swellings, 25—40 μm in diameter (pl. 28: 2). The microboring tunnels stretched parallel to valve surface. No branching of tubules has been observed. It is difficult to assess the original length of tubules. Many of them with terminal swellings at one end and bent in the other one (what suggests contact with the valve surface) have a length of 100—300 μm. It seems, however, that many of them may have been much longer but damaged in the dissolution process. In single cases it has been observed that tubules are associated with faint semicircular structures (pl. 28: 1b), resembling fungal sporangia. It is difficult to decide whether these are morphologic features, or preservational artifacts. The microborings are irregularly distributed in ostracod valves. They are found both in the central parts and near the margins of valves. The number of tubules varies considerably in individual valves. They often occupy a large part of valve surface, especially in smooth, relatively big ostracods (pl. 28: 1a). Due to the presence of phosphatic linings it is difficult to examine how the microorganisms entered the valve surface.

Apart from the described microborings, in the empty spaces between the linings of ostracod valves, perpendicular casts of valve pore canals are often preserved between the external and internal linings. However, these casts are much smaller in diameter than the microborings described, and usually they are almost completely damaged when the linings separate.

No microborings of the type described have been found in fragments of other organisms remaining in residuum, e.g. trilobites, molluscs or echinoderms. However, microborings larger than those described from ostracod valves can be observed in thin sections of trilobite carapaces.

DISCUSSION OF TAXONOMIC AFFINITIES

Boring microorganisms which penetrate carbonate substrate include representatives of blue-green, green and red algae, fungi and sponges. The classification of fossil and recent borings is based mainly on the basis of shape and size of boring casts, mode of branching, general boring pattern and presence or lack of swellings. Fossil forms are identified mainly by comparison with recent ones. In many cases, however, this is very difficult or even impossible. Many authors, however, determine the forms they examine as of algal or fungal origin.

Borings of fungal origin have a diameter ranging from 1 to 4 μm, they are straight or gently curved, branched at regular angles or forked dichotomously with reproductive cells. These features are recognized by most authors as the diagnostic features of these organisms. Microborings of algal origin have a size of over 50 μm. Microborings 5—50 μm in diameter may be both of algal and fungal origin (Bromley 1970, Budd and Perkins 1980, Edwards and Perkins 1974, Perkins and Halsey 1971, Rooney and Perkins 1972, Zeff and Perkins 1979). The algal microborings are also distinguished by a considerable variation in tunnel diameter (Bromley 1970, Perkins and Tsentas 1976). It is often stressed that the various criteria employed to distinguish between fungal and algal borings are unreliable (Bromley 1970, Golubic, Perkins and Lucas 1975).

The microborings from Ordovician ostracod valves are morphologically different from endolithic organisms which have been so far described. They do not show any definite resemblance to recent photosynthetic (algal) endoliths (Le Campion-Alsumard 1979, Budd and Perkins 1980, Edwards and Perkins 1974, Rooney and Perkins 1972, Perkins and Tsentas 1976), or to fungi (Kohlmeyer 1969, Gatrall and Golubic 1970). It seems, however, that the dimensions of tubules, variability of their diameter and lack of branching make these forms closer to those recognised by many authors as microborings produced by photosynthetic algae rather than by heterotrophic fungi. They show a relatively strong resemblance to the microborings of algal origin described by Runnegar (1985) from the shells of Early Cambrian molluscs. The microborings discussed differ from most illustrated endolithic microborings in presence of bottle-like terminal swellings. These swellings seem distantly analogous to terminal heterocysts found in some recent algae. Some of the specimens figured by Runnegar (1985) have also occasional terminal and subterminal swellings interpreted by this author as more analogous to heterocysts than to fungal sporangia. Problematic subterminal swellings found in only a few specimens (pl. 28: 1b) are perhaps preservational artifacts. The microborings described do not resemble borings produced by endolithic sponges either (Lindström 1979, Rooney and Perkins 1972, Budd and Perkins 1980, Pickerill and Harland 1984).

PALEOECOLOGIC IMPLICATIONS

Boring microorganisms occur in all marine habitats from intertidal and supratidal zones (Budd and Perkins 1980) to abyssal depth (Golubic *et al.* 1984). Each has its own bathymetric range, and thus may be useful for environmental and paleobathymetric reconstructions of local benthic conditions (Swinhatt 1969, Rooney and Perkins 1972, Golubic, Perkins and Lucas 1975, Zeff and Perkins 1979, Budd and Perkins 1980, Golubic *et al.* 1984). The depth at which photosynthetic endoliths live is limited to shallow photic zone (Gatrall and Golubic 1970, Perkins and Halsey 1971, Rooney and Perkins 1972, Golubic, Perkins and Lucas 1975, Le Campion-Alsumard 1979, Budd and Perkins 1980). Depth distribution of heterotrophic endoliths is much wider, from the shallow photic zone down to the abyss, though some taxons are limited to certain depths (Golubic *et al.* 1984). Budd and Perkins (1980) have observed differences in directions of penetration between upper photic zone (to the depth of 20 m), where microborings are orientated perpendicular to the surface and penetrate deeply into the shell, and lower photic zone, where the dominant orientation of microborings is parallel to the substrate surface and penetration is less deep. Golubic *et al.* (1984) have proved that endolithic organisms have a benthic nature and that valves of planktic origin are exposed to boring following after their deposition on the ocean floor. The shells taken for study from the water column showed no evidence of boring.

In Ordovician ostracods, microboring casts occur most often in relatively big (about 1 mm and more) and smooth valves of various species of podocopids. In more richly ornamented valves they are rarely found. They do not occur in ostracod valves having less than 1 mm in length. Reyment (1963, 1966, 1971) made similar observations while studying Paleocene ostracods from Nigeria drilled by gastropods. Reyment (1963, 1971) has observed that some ostracod species have no traces of drillholes while others are drilled very often. According to Reyment (*l.c.*) species with small diameters in adult stage, rare species, and perhaps species with active burrowing mode of life or plant dwellers are not subject to drilling. On the other hand, ostracods with smooth or poorly ornamented valves are drilled most often.

In Mójcza profile microborings are found in valves from organodetritic limestones of the middle part of the profile (Late Llanvirnian to Early Caradocian) but they are absent in the lower part of the profile, in calcareous sandstones (Arenigian) as well as in the upper part (Ashgilian) where ostracods occur in shales and marly limestones. The absence of microborings in the lower part of the sequence may be the result of unfavourable environmental conditions, but such factors as *post mortem* changes prior to fossilization, or later diagenetic changes, may also play their part. The absence of microborings may also be caused by nature of ostracod assemblage from basal sandy part of Mójcza section. Generally these are species with small, richly ornamented valves. This part of profile contains no big, smooth forms in which microborings occur most often in the upper part of the profile (Llanvirnian, Llandeilo).

Studies by Swinhatt (1965) have shown that currents and wave action mechanically affect sedimentary particles and interfere with colonization by the microorganisms, so that the more intensive boring is found in protected environments. In the upper part of the profile (Ashgilian) ostracod valves are very poorly preserved and therefore, it is very difficult to say whether microborings are present or not. Ostracod valves are penetrated often by so numerous microborings that it must have influenced their rapid damage: Similarly rapid damage of recent foraminiferal tests by endolithic algae in span of a few weeks to a few months maximum, has been described by Kloos (1982).

It is impossible to determine what percentage of drilled valves each

Mójcza sample contains, due to different preservation states of the valves. Moreover, their internal sides are often covered by sediment and cannot be examined in the transmitted light. Ostracods are also quite often preserved as internal moulds. No preference of endolithic borings for one ostracod species or another has been observed.

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EWA OLEMPSKA

ENDOLITYCZNE ORGANIZMY W SKORUPKACH ORDOWICKICH MAŁŻORACZKÓW

Streszczenie

W skorupkach małżoraczków ordowickich z profilu Mójczy w Górach Świętokrzyskich stwierdzono obecność długich, cienkich rurek, będących fosforanowymi wyściółkami tuneli wykonanych przez mikroorganizmy borujące. Są to cienkie rurki o średnicy 9—13 μm, równoległe do powierzchni skorupek małżoraczków, zakończone nieregularnymi lub buteleczkowatymi rozszerzeniami o średnicy 25—40 μm.

Z uwagi na średnicę rurek, jej pewną zmienność w poszczególnych rurkach, brak rozgałęzień, wydaje się, że formy te bardziej zbliżone są do form uważanych przez większość badaczy za powstałe w wyniku działalności borujących alg niż grzybów. Od większości ilustrowanych endolitycznych mikro-drążeń opisane formy różni obecność buteleczkowatych rozszerzeń na końcach rurek.

W skorupkach ordowickich małżoraczków mikro-drążenia występują najczęściej w skorupkach różnych gatunków podokopidów o dość dużych, około 1 mm i większych, gładkich skorupkach. W skorupkach o bogatszej rzeźbie powierzchni spotyka się je rzadko, sporadycznie występują w małych skorupkach o długości poniżej 1 mm.

Praca została wykonana w ramach problemu MR II 6.

EXPLANATION OF PLATES 28 AND 29

Plate 28

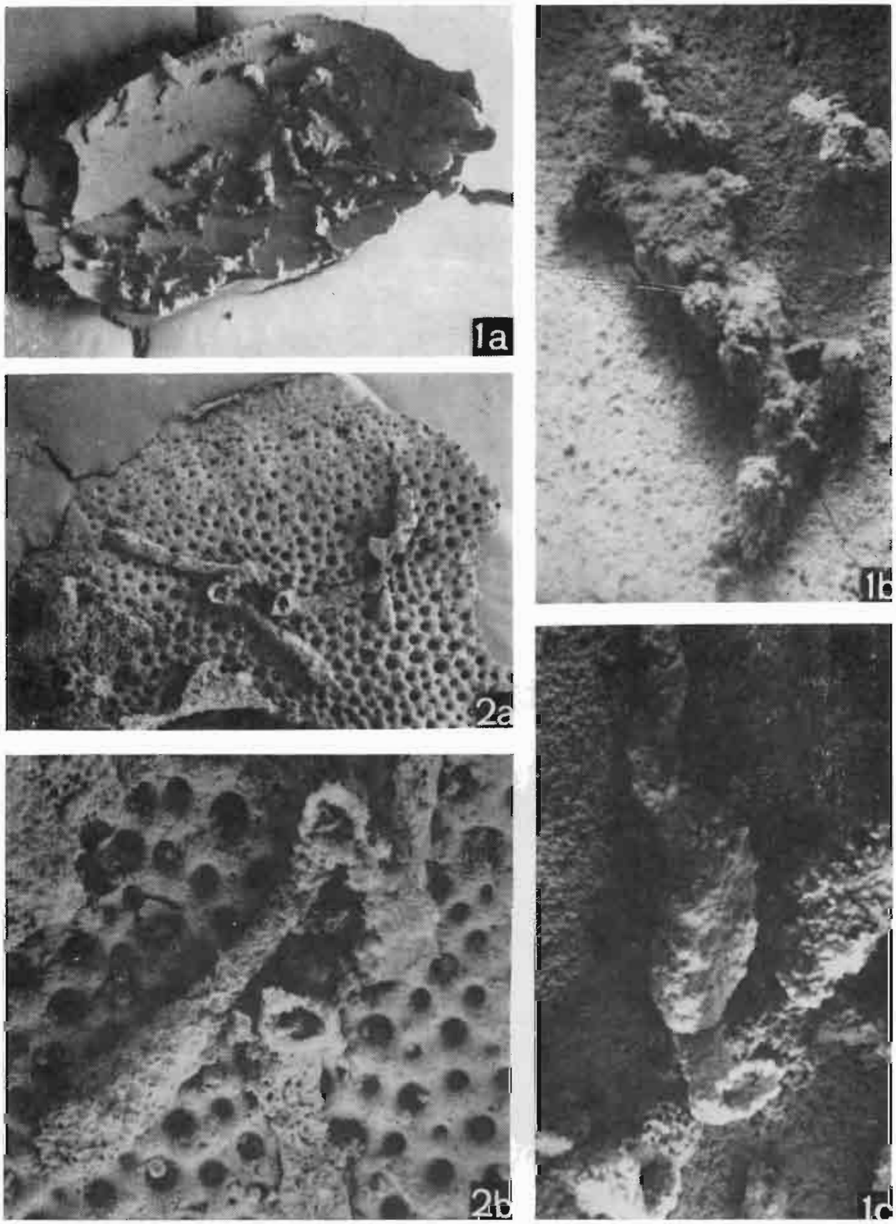
Microbial endoliths in Middle Ordovician ostracod valves

1. *a* Phosphate lining of podocopid ostracod valve showing phosphatic casts of the microborings, × 80, *b* endolith cast with faint semicircular swellings, × 480, *c* fragments of tubules, × 800. Llanvirnian.
2. Fragment of phosphate lining of *Piretella* sp. Microborings with bottle-like terminal swellings *a* × 60, *b* × 240. Caradocian. Mójcza, Holy Cross Mts.

Plate 29

Microbial endoliths in Middle Ordovician ostracod valves

1. 3. Fragments of podocopid valves with endolithic microboring casts; *1* Llandeilo, × 300; *3* Caradocian, × 250.
2. Microboring tubules with irregular terminal swellings, × 450. Llandeilo. Mójcza, Holy Cross Mts.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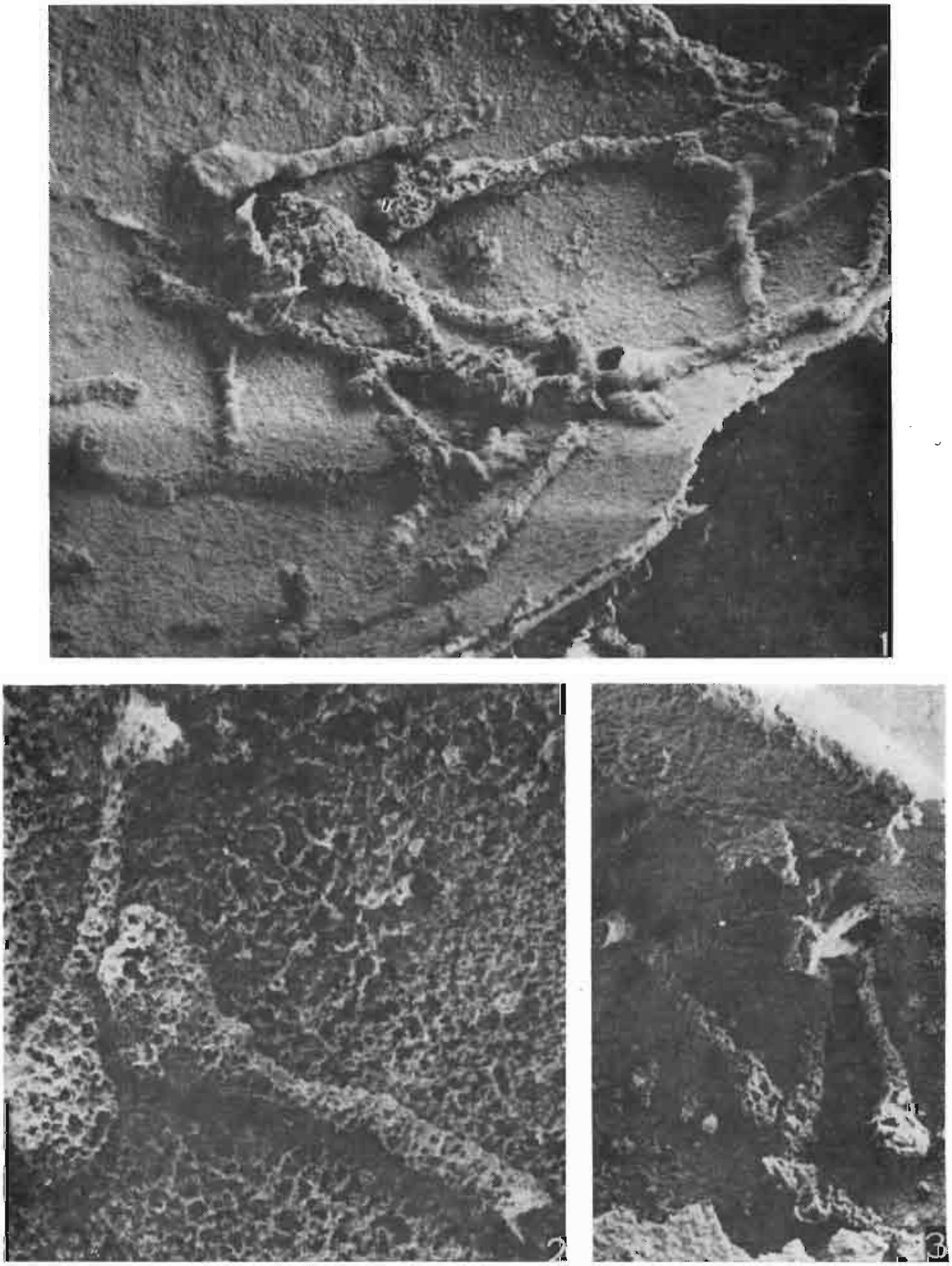
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