# BORING ALGAE IN BRACHIOPOD SHELLS FROM LOWER CARBONIFEROUS ($D_1$) LIMESTONES IN NORTH DERBYSHIRE, WITH SPECIAL REFERENCE TO THE CONDITIONS OF DEPOSITION

by

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## Summary

Microscopic tubes now infilled with cryptocrystalline calcite were found penetrating the shells of brachiopods, crinoid ossicles and some ooliths, in the Cyrtina septosa Band and associated limestones in the 'Beach Beds' at Castleton, and from the Back-Reef facies of Windy Knoll, all of $D_1$ age.

Brachiopod shells accumulating in quiet waters were found to have algal tubes mainly on their upper surfaces, while both sides of shells accumulating in more turbulent waters possessed these tubes.

The tubes of boring algae were found to be more abundant in limestones of the shelf facies than in the fore-reef facies. In the 'Beach Beds', shells containing algal tubes are thought to have been washed down a submarine channel from the warmer waters of the shelf above.

## Introduction

The presence of penetrative or boring algae in the calcareous tests of molluscs, brachiopods, corals and other algae has been known since the middle of the last century. Boring algae were recognized in 1845 by Carpenter, who described them from modern seas, while tubes of fossil boring algae were first noted in 1855 (Rose).

Nadson (1927) described their presence in many warm and cold seas on a world-wide basis and came to the conclusion that they were very abundant. Ten species were known to him, none of which were found below 50 metres depth. He believed them to be very important in the destruction of coral reefs, where they had been found boring into corals and the alga Lithothamnium.

Johnson (1946) briefly described perforating algae from limestones in Kansas, noting that the fine algal threads had an average diameter of 0.0027 to 0.0036 mm., and that they coated and penetrated fragments of shells, echinoderms, and the larger foraminifera. Where the algal threads were abundant, they appeared to have caused a chemical alteration and disintegration of the fossil fragments.

In a paper by Hessland (1949), details are given of boring algae from the Ordovician of the Siljan area of Sweden. He suggested that their presence indicated shallow, rather stagnant water, such as shallow bays of warm seas in waters not deeper than 20 metres. He thought the action of boring was solution by organic acids. The relationship was probably a symbiotic one, the algae producing oxygen for the animal and using its excretory products in photosynthesis. In the Siljan district, the majority of the algal tubes had a diameter of 5 $\mu$ ; they varied from gently tortuous and fine to straight and thick. Sometimes the tubes were seen to follow the structure of the shell and sometimes they ran irregularly across the shell. The canals could even penetrate right across the shell, cutting it in two. He concluded that penetrative algae belonged to the classes Cyanophyceae, Chlorophyceae and Rhodophyceae.

Wolfenden (private communication) described the presence of boring algae from the standard, reef and fore-reef facies of the Derbyshire massif. He noted an increase towards the centre of the shelf region and a decrease towards the reef and fore-reef. He found remains of boring algae in 30% of his limestone specimens from the standard (shelf) facies and only 6% from the fore-reef and reef facies. He described the tubes left behind by the algae as having diameters of 5-20$\mu$, some of them curved and others branched. The best ones were seen in brachiopod shells, where they ran across the shell structure. Crinoid ossicles, too, were often attacked, but here the tubes were not so distinct. Some corals and molluscs also showed the remains of boring algae.

In 1957, Wanless, Ziebell, Ziemba and Carozzi recorded the presence of tubes of boring algae on shells; this feature was thought to show that there was probably interrupted sedimentation, with exposure on shallow sea bottoms for a time before burial.

Hallam (1963) recorded boring algae in lamellibranch shells from the Lower Jurassic ironstones of Frodingham. The borings consisted of a ramifying network of fine tubes averaging 5 $\mu$ in diameter, which were infilled by cryptocrystalline siderite. He described the tubes as straight or slightly sinuous, occasionally branching and mostly normal to the shell margin, with no relationship to the structure of the shell even when recrystallized.

Swinchatt (1965) described the importance of boring algae in the breakdown of mollusc shells. Extensive boring weakened the outer part of the shell,which became abraded off by current action. This was repeated until the shell was reduced in size. The process only took place in fairly quiet conditions. In very turbulent water abrasion was mechanical.

Bathurst (1966) described the presence of micrite envelopes round many skeletal grains from Bimini lagoon, Great Bahama Bank. They were formed by algae boring into the shell wall; the filaments then died and decayed, the tubes infilled with micritic aragonite. Later the shells dissolved away leaving the micrite envelope intact.

## Field Evidence

Algal borings, represented by tubes of approximately 0.008 mm. in diameter, some of which were tortuous and some of which cut straight across the shells, were found in brachiopod fragments and crinoid ossicles at a number of localities in Carboniferous Limestones of $D_1$ age in North Derbyshire. The localities are described below under the headings:- standard (shelf), back-reef, reef and fore-reef facies, and 'Beach Beds', an unusual group of beds in the fore-reef facies west of Castleton (Sadler, 1964a).

### Shelf facies

Ten localities in the standard (shelf) facies were found to contain brachiopod shells and crinoid ossicles attacked by boring algae. Of these ten localities, eight were in the *Cyrtina septosa* Band (described in detail by Sadler, 1964b, and Sadler and Merriam, 1967). This band occurs 25 feet below the Lower Lava flow in the $D_1$ subzone and is found quite widely spread over North Derbyshire. It varies in thickness from about 1 foot to 7 feet and the shells may either be

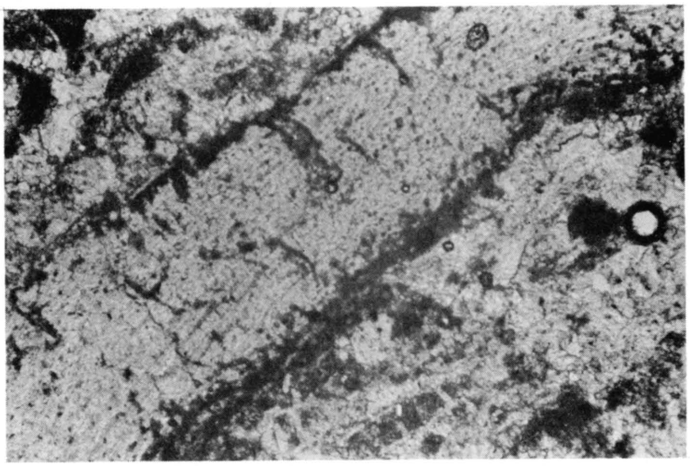


PLATE 22. Photomicrographs of sections of shells showing boring algal tubes.
Fig. 1. Netherlow Farm. Section of brachiopod shell showing tubes of boring algae on both upper and lower surfaces. x100.

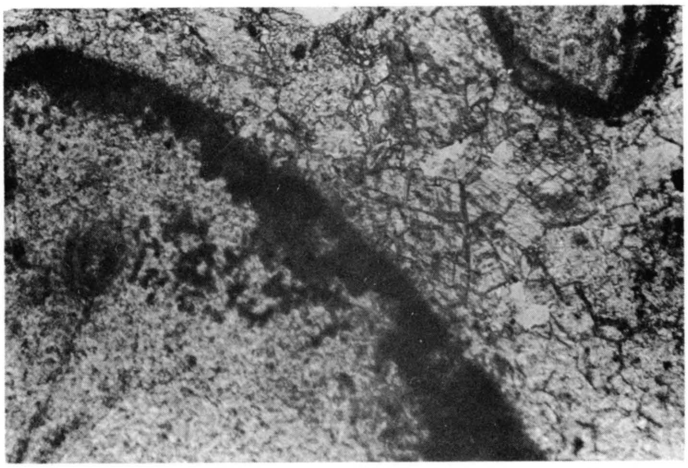


Fig. 2. Section of brachiopod shell showing tubes of boring algae penetrating into it. Shell set in sparite matrix. Windy Knoll. x150.

fairly close together, sometimes forming poorly developed ripple marks, or they may be widely scattered. Numbers of specimens of Davidsonina (Cyrtina) septosa (Phillips) vary from one locality to another, and there is also variation in the orientation, size, distribution and disarticulation of the brachiopods.

The limestones of the Cyrtina septosa Band are fairly massive, light-grey, pinkish grey or yellowish grey, and are classified as medium to coarse calcarenites (Folk, 1959).

The following localities provided specimens which showed good examples of boring algae tubes:-

1 Netherlow Farm (10456973)[see Plate 22 fig. 1.]
2 Wheeldon Trees Farm (10356620)
3 Outcrop above Earlsterndale village (10256671)
4 Monksdale House (13207533)
5 Jericho (08556750)
6 Via Gellia (24115762)
7 Chelmorton Flat (10667130)
8 Waterswallows Quarry (08667511)

For locality map see Sadler (1964b).

Fossil horizons are rare in the $D_1$ Limestones and this accounts for the fact that boring algae are found mostly in the Cyrtina septosa Band.

Algal tubes have also been found attacking shells at two limestone localities situated stratigraphically above the Cyrtina septosa Band. These are:-

1 Twenty two feet below the $D_1/D_2$ boundary in the large Station Quarry at Miller's Dale (13207335).

2 Seventy five feet above the Cyrtina septosa Band on the roadside from Brierlow Bar to Jericho (08256795).

The Miller's Dale locality consists of light-grey, fine-grained, very massive limestone with abundant stylolites. Some specimens of D. septosa were recorded, together with Productid fragments and small crinoid stem fragments. Near Jericho a six-inch band of thin Productid shells and fragments was found in light-grey, fine-grained limestone. One of the shells showed very well defined algal tubes.

Back Reef facies

From a small outcrop of limestone at Windy Knoll, Castleton (12658265) came specimens of oolitic limestone thought to be in the back-reef facies. The beds are light-grey in colour. It was found that the brachiopod shells and crinoid ossicles were attacked by boring algae and the ooliths composed of two or more concentric rims were also attacked (see Plate 22 fig. 2).

Fore-Reef and Reef facies

No examples of boring algae were found in limestones from the fore-reef or reef facies. Wolfenden (private communication) noted only a very small percentage from these facies.

'Beach Beds'

An examination of fifty slides from the Castleton 'Beach Beds' was made, but only five showed tubes of boring algae. Three of these were from limestones found on the fore-reef slope on the west side of the Winnats Pass (13808270), where the 'Beach Beds' extend nearly up to the 1000 foot contour. The other two localities were found much lower (topographically) on the fore-reef slope. The first of these is a limestone behind the Speedwell Mine, on the east side of the Winnats (13988265), and the second is an outcrop of limestone immediately to the west of the Speedwell Vent (14258255). Two of the three localities on the west side of the Winnats Pass contain limestones which are brownish-grey and rubbly, with many brachiopods, some of which are rounded and waterworn. Most of the fragments are broken and crushed shells, nearly all of which are orientated parallel with the bedding. The third locality on the west side of the Winnats contains a very fine-grained, putty coloured limestone which is thinly bedded and consists of abundant broken brachiopod shells; these still retain some of their ornamentation but show no preferred orientation.

Behind the Speedwell Mine are very rubbly beds consisting of many waterworn brachiopod shell fragments, all of which are oriented parallel with the bedding with very little matrix in between them. It was the presence of these beds which led earlier writers (Barnes & Holroyd 1896, Jackson 1943, Parkinson 1947 & 1953) to believe they were laid down on an old sea beach. These very rubbly beds are seen to pass down into black basin limestone, through a narrow band of transitional beds which consist of water worn shells in a black matrix. It is from near the boundary of the transitional beds with the black basin limestone that one waterworn, rounded shell fragment was found which showed good evidence of boring algal tubes.

On the west side of the Speedwell Vent is an outcrop of massive limestones, very fine-grained and containing very small shell fragments and occasional small crinoid stem fragments. Tubes of boring algae are seen attacking many of the crinoid ossicles, but they are not very well defined (see Text-Figure 4).

## General environment of the Derbyshire massif

The conditions of deposition of the Carboniferous Limestone of North Derbyshire were described by Wolfenden (1958) and Sadler (1964a). Wolfenden suggested that the shelf area was one of shallow warm water which was quite often turbulent. The presence of Dasycladacean algae in the limestones, recent forms of which are most abundant at depths of 9 to 15 feet and never below 90 feet (Cloud 1952), and of calcarenites containing grains of a type which at present form in waters less than 30 feet deep, both indicate shallow sun-lit waters over the shelf. The overturning of corals and brachiopod shells to their more stable position of rest (convex side uppermost) and the sorting of shells into ripple marks (Sadler 1964b) indicate that turbulent waters with strong current action must, at times, have been present.

The reef and back-reef limestones were probably formed also in shallow wave-agitated waters. The fossils in these two facies are often fairly well-preserved.

In several areas (e.g. the Winnats), horizontal limestones of the shelf facies are seen resting on steeply dipping fore-reef beds, showing that the dip is depositional and that the fore-reef beds probably dipped down into deeper water, forming a submarine slope of at least 400 feet.

The 'Beach Beds', which are found near the foot of the fore-reef slope and in one place extending up it, are thought to have been laid down at the foot of a submarine channel cutting through the reef complex, the site of which is now the Winnats (Sadler 1964a).

On the lower slopes of the fore-reef the waters would probably have been too cold and dark for algae to live and photosynthesise, and therefore any shells attacked by algae found low on this slope, such as those in the 'Beach Beds', must have been brought down the submarine channel from the shallow, warmer waters of the shelf above.

Evidence from thin sections

Thin sections were studied in detail from localities where boring algae tubes were found. From two localities of the Cyrtine septosa Band (Monksdale House [ see Text-Fig. 1 ] and Netherlow Farm), where field evidence indicates fairly quiet water conditions, several large brachiopod (Productid) shells show very well-developed tubes of boring algae on their upper surface only. This probably indicates that the shells rested in one position for a considerable length of time and were not turned over and over by currents. It is unlikely that boring algae would accumulate on the under surfaces of shells which were not exposed to sunlight. At the second locality, occasional shells do show algal tubes on both upper and lower surfaces (see Plate 22 fig. 1).

Where water conditions were more turbulent, it is found that tubes of boring algae are present on both sides of the shells and all round the crinoid ossicles, indicating that the fragments were turned over and rolled about by water movement. Specimens of such fragments can be seen from the Via Gellia, above Earlsterndale, at Jericho (see Text-Fig. 3), Wheeldon Trees Farm and Chelmorton Flat.

At Waterswallows Quarry, a specimen containing a section of D. septosa shows very well defined algal tubes on the outside and upper surface only, while the lower surface and inside remain unattacked (see Text-Fig. 5).

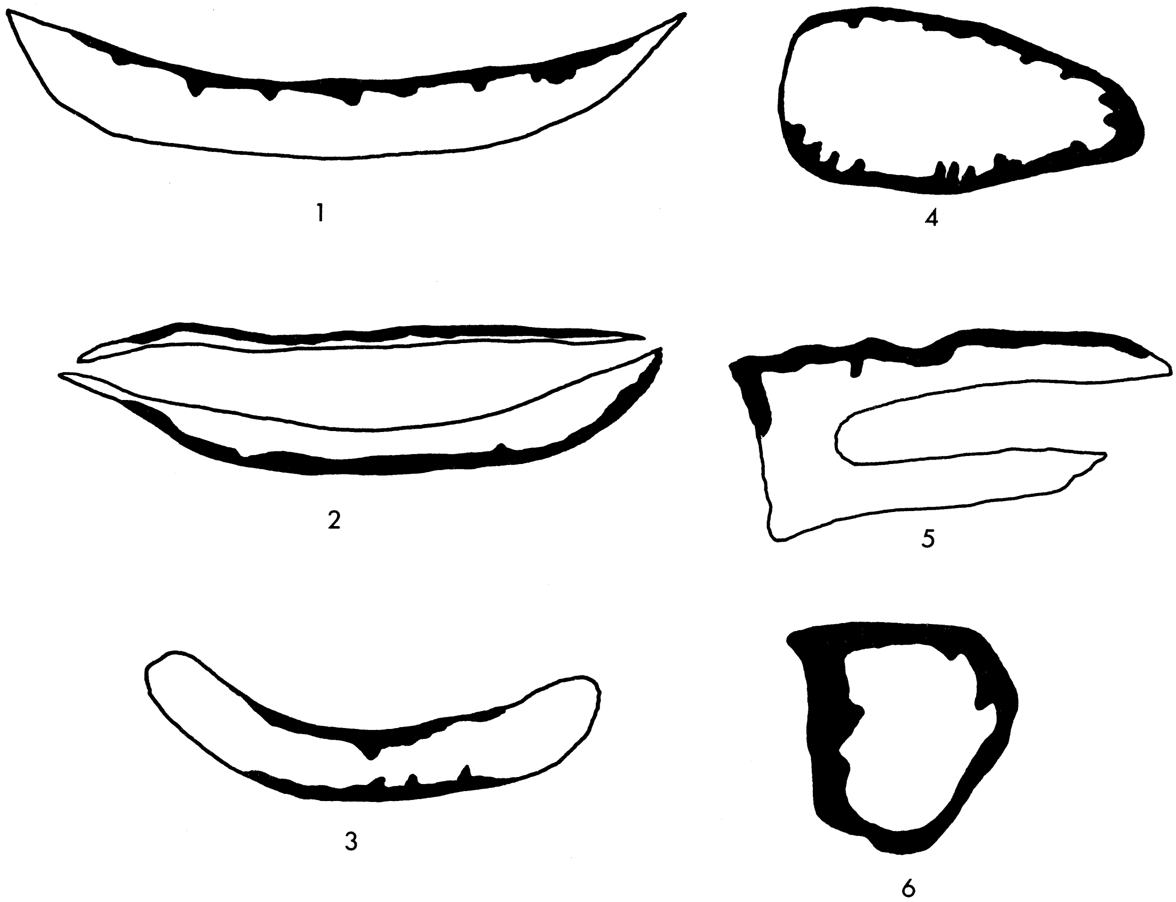
In the Station Quarry, Miller's Dale (22 feet below the $D_1/D_2$ boundary), and on the road-side near Jericho (75 feet above the Cyrtina septosa Band), all evidence shows that water conditions were fairly quiet. Disarticulated Productid shells containing tubes of boring algae on their upper concave surfaces only are present, indicating that they have not been turned over by turbulent water. Very well preserved tubes are seen in shells from Jericho.

In the back-reef facies, oolitic limestones from Windy Knoll are evidence of water movement; the ooliths were accumulated and rolled about in shallow turbulent water. Many of the shell fragments and crinoid ossicles are also rounded. The outer oolitic rims show tubes left by boring algae. One ribbed shell exhibits an interesting feature, in that the boring algae have attacked it on both sides in the depressions between the ribs rather than on the ribs themselves, suggesting that the ribs received more intense erosion than the depressions, the latter being quieter areas more favourable to the accumulation of boring algae. Boring algae tubes are not common in the 'Beach Beds' (see Plate 23); of nearly 50 slides studied, only 5 showed evidence of algal attack. It seems probable that water in this environment was too swift-flowing, cold and deep, for the algae to have lived there. The shells which do contain remains of boring algae are thought therefore to have been brought down the submarine channel by strong currents of water which crushed and abraded them.

Wolfenden noted some boring algae on the upper fore-reef slopes, but on the lower slopes and in the deeper waters of the basin it was again probably too cold and dark for algae to live.

Conclusions

Tubes left behind by boring algae are seen in greatest numbers in the shallow water shelf limestones, particularly in the Cyrtina septosa Band, the deposition of which may mark a considerable period of time to allow fragments to be rolled about and accumulate algae. Evidence of boring algae also comes from the back-reef where the shallow warm turbulent waters were ideal for the algae. Any evidence of boring algae in the 'Beach Beds' is accounted for by the




TEXT-FIGS. 1-6. Photomicrographs of sections of brachiopod shells and crinoid ossicles, showing evidence of boring algae.

1. Ventral valve of Productid (x3), showing tubes of boring algae on upper surface of shell only. Monksdale House.
2. Articulated Productid (x3.75), showing evidence of boring algae on upper surface of dorsal valve and lower surface of ventral valve. Netherlow Farm.
3. Slightly abraded brachiopod valve (x18), with boring algae on upper and lower surfaces. Jericho.
4. Crinoid ossicle (x 27) attacked by boring algae. Adjacent to the Speedwell Vent.
5. Fragment of *Davidsonina (Cyrtina) septosa* (x 4.5), showing boring algae on upper surface only. Waterswallows Quarry.
6. Crinoid ossicle (x 33) attacked by boring algae. Chelmorton Flat.

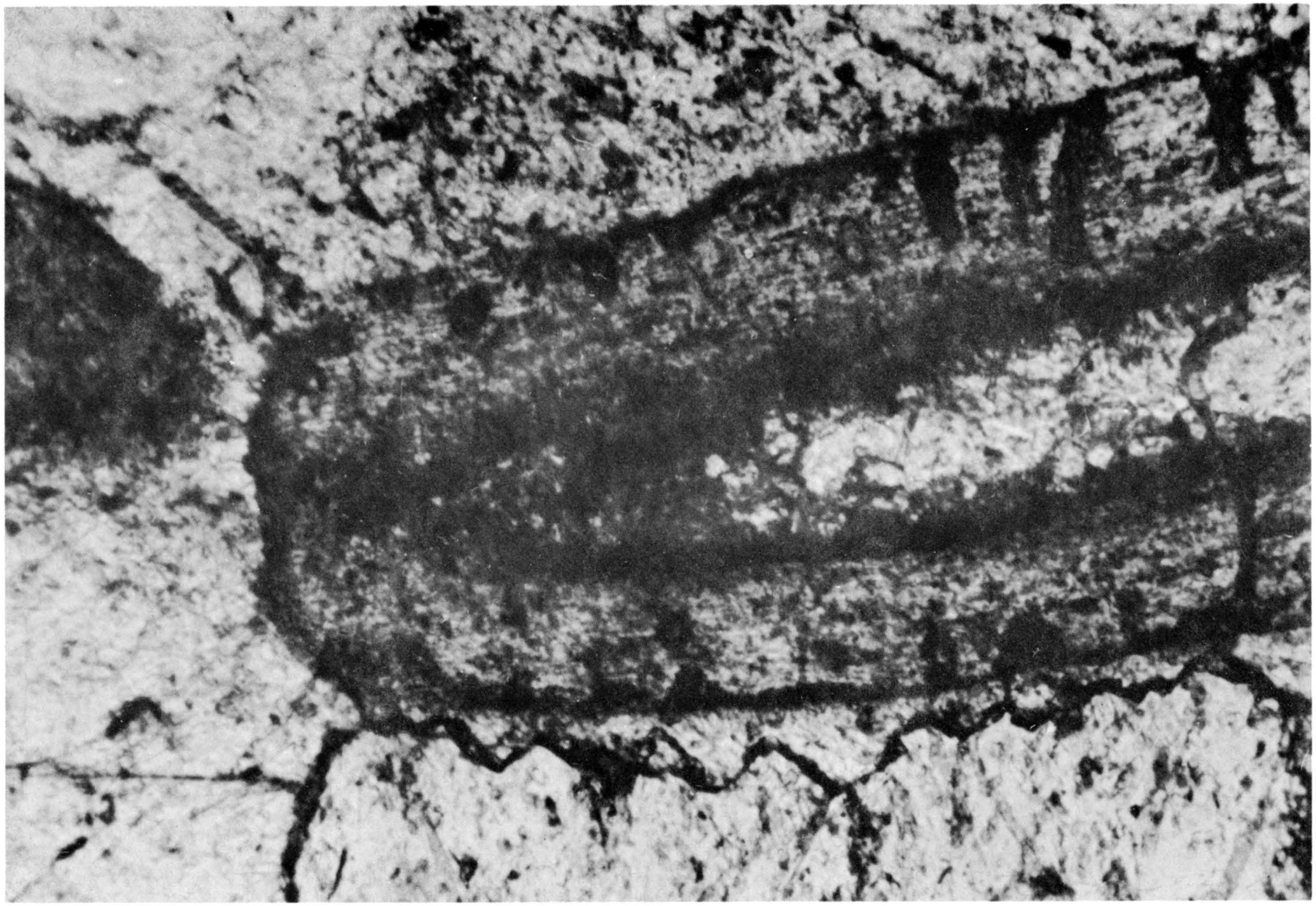


PLATE 23. Photomicrograph of section of brachiopod spine showing boring algal tubes. The tubes are wider than was normally found, being about 0.02 mm. in diameter. They are found on the outer surface of the spine section only. Above the Speedwell Cavern. x250.

fact that the fossils which have been attacked lived in the shallow shelf seas and were washed down to their present position through the submarine channel. Boring algae are not found elsewhere on the lower fore-reef slopes or in the basin facies.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