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DIORYGMA ATRYPOPHILIA N. GEN., N. SP. — A PARASITIC ORGANISM OF *ATRYPA ZONATA* SCHNUR

Abstract. — A boring annelid-like parasite associated with *Atrypa zonata* Schnur from the Givetian shales of the Holy Cross Mountains (Góry Świętokrzyskie, Poland) is described under new generic and specific name — *Diorygma atrypophilia*.

INTRODUCTION

The aim of the present paper is to describe some curious traces of the activity of burrowing animals, which infected the interior of the pedicle valve of *Atrypa zonata*. According to my knowledge, such occurrences have not been previously described in brachiopods.

These peculiar traces have been encountered in Givetian shales from the Holy Cross Mountains. Although in this horizon a very rich brachiopod fauna occurs, the mentioned traces are so far restricted to specimens of one species of atrypids only. They are believed to have been made by some worm-like animals living in shallow marine water.

In dealing with the borings in question I have endeavoured to give as fairly as possible a detailed description of them.

This paper was prepared in the Palaeozoological Laboratory of the Polish Academy of Sciences in Warsaw, being under the guidance of Prof. Roman Kozłowski, to whom I extend my sincere thanks for his interest in the problem. It is a pleasure to record my thanks to Dr D. Atkins from Marine Laboratory at Plymouth for his kind and helpful advice concerning some parasites of invertebrates. To Dr M. House of University of Durham the thanks are due for some suggestions and kind corrections of the English of the present paper.

The photographs are the work of Miss M. Czarnocka, the inking of the drawings of Mrs K. Budzyńska, the thin sections have been prepared by Miss M. Witkowska.

MATERIAL AND METHODS

While studying rich collections of atrypids from the shales of the locality Skały in the Holy Cross Mountains (Biernat, 1959) I observed on the internal surfaces of the pedicle valve of *Atrypa zonata* Schnur some curious structures. These were distinct and very prominent ridges, one or two in number, disposed always on the lateral sides of pedicle muscle area. It seems to be remarkable that when one ridge only is present it is usually placed on the left side of the pedicle muscles, being very rarely recorded on their right side. These excrescences never occur in the brachial valve.

At first the ridges might be interpreted as some internal elements of the atrypid structure, e.g. excessively developed calcareous elevations limiting the pedicle muscles. More detailed studies reveal that they correspond to canals due to the burrowing activity of some animals infesting living brachiopods. Each ridge contains two canals, opening internally by double apertures very similar to burrows of some polychaete annelids. No doubt they have served as convenient habitat of a parasite throughout the life of the brachiopod.

Although hundreds of specimens of different brachiopods washed from numerous marl samples were examined, the ridges in question were found only in *Atrypa zonata*. I have not seen them in any other species, although the Givetian shales contain a great number of brachiopods of different families and genera.

The ridges in question were common and occur on a considerable number of separate valves and closed shells of the brachiopod. Nearly 1/6 of all specimens of *Atrypa zonata* show them (100 specimens with both valves closed and 36 separate pedicle valves).

As it was desirable to know the frequency of occurrences of the ridges in closed shells of *Atrypa zonata,* their umbonal portions were etched from the exterior for a few seconds with dilute hydrochloric acid. As a result of this procedure the valves become transparent and show the presence of the tubes (see pl. IV, fig. 3). The ridges are always well preserved. Sometimes they are broken at the front end and allow the study of their structural characters. Serial cross and longitudinal sections of the shells with developed ridges were prepared in order to show the appearance of the tubes, the arrangement of their limbs and to study their internal structure.

GENERAL CONSIDERATIONS

The nature of Palaeozoic boring animals still remains obscure. Although they occur rather rarely in Palaeozoic sedimentary rocks and especially in the shells of invertebrates a lot of attention has been given to them. As a result many cases are described of infestation of shells by ancient marine parasites, but the knowledge about them is still too fragmentary to allow a safe identification. It seems to be obvious that most of the identifications need revision.

The tracks of fossil burrowing animals are of many kinds, usually preserved as burrows, tubes or trails. But these fossil records are at present insufficient to allow the exact elucidation of the kind of animal which might have built and inhabited them. It is necessary to increase the knowledge about them by new discoveries. Also informations concerning recent marine annelids, their habits and conditions of life, need to be more complete. No doubt, they will be very useful and important for the students interested with these fossils. Only then will an attempt to establish the systematics of parasitic shell-boring animals be possible.

It has been mentioned that the borings described here are regarded as caused by some marine shallow water worm-like animals of minute size. Judging from the general character and structure the burrows in question seem to bear a very close resemblance to those formed by sedentary polychaete annelids. A somewhat similar structure has been illustrated by Solle (1938, fig. 8) as „Würmspuren" — *Clionolithes* sp., distributed on the external surface of the shell of *Avicula* from Upper Coblenz, Germany. But no description or even explanation has been given by the mentioned author. However, as far as it can be judged, definite comparisons cannot be made. A study of available literature shows that the questioned structures cannot reasonably be identified with any formed by previously described parasitic forms.

The distinctive features considered to be of generic importance are: the appearance of the tubes and their enclosing ridges, their general shape and particularly their symmetrical arrangement in the shell. On the basis of these characters it is concluded that the parasite described below should be distinguished by a special name, that of *Diorygma atrypophilia* n. gen., n. sp.

A few general observations concerning this form are as follows:

1. The described worm-like *Diorygma atrypophilia* might be considered as an example of a parasitic organism associated with a brachiopod.

2. All specimens of *Atrypa zonata* bearing the ridges were also covered with a few tubes of *Spirorbis* and sometimes with numerous traces of burrowing animals, resembling to some extent those made by the annelid described as *Conchotrema* by Teichert (1945), or borings of *Clionolithes* (see Solle, 1938 = *Olkenbachia hirsuta* Solle). But the mentioned traces were observed only on the external surface of the brachiopod.

3. It seems to be certain that the parasites could attack and infect brachiopod shells of young and also mature individuals.

4. The general character of the tubes and surrounding ridges in all

infected shells seems to be the same. The observed variability is insignificant, concerning to some extent the degree of divergence of the limbs, the position of bifurcation of the tube and the distance between the two apertures placed on the free end of the ridges. It might be suggested that all tubes and ridges are of the same origin, bored and built up by a parasite of one species.

5. As has just been mentioned, the limbs of the tube of each ridge run side by side and bifurcate only once. In all probability it is a specific character of this boring parasite. But it might be explained by an increased activity of the pedicle mantle in secreting the shell substance. The mantle of the brachiopod, excited to some extent by the unusual presence of the foreign animal, quickly secreted a great thickness of calcium carbonate to surround the tubes and to restrict the degree of divergence of the limbs. It may be due to this quick covering by shelly deposit that the tubes do not branch more. In recent polychaete annelids, mainly *Lanice* burrowing in sediment, the tubes branch a few times and are very often W-shaped (Seilacher, 1951, p. 274, 276).

6. All infected shells are identical with those of non infected shells of the same species. The general appearance and degree of development of internal structures of both are identical. This seems indicate that the unusual presence of these parasitic forms did not disturbed the normal process of growth of the brachiopod shell.

DESCRIPTION

Diorygma n. gen.

Derivation of name: Gr. *dis* — twofold, *orygma* — tunnel.

Diagnosis. — A boring in the pedicle valve of *Atrypa zonata* Schnur (pl. III, fig. 1 *a*, *b*) consisting of minute, smooth, nearly V-shaped tube, widening slightly anteriorly, burrowed through all the shell substance and all the length of a prominent internal ridge, placed on the lateral sides of the pedicle muscle area. The tubes are opened to the interior of the brachiopod shell by two apertures lying on the anterior, free extremity of the ridge.

Type of genus — *Diorygma atrypophilia* n. sp., described below.

Diorygma atrypophilia n. sp.

(pl. I — IV; text-fig. 1 — 4)

Holotype: pl. I, fig. 6 (Z. Pal. No. P/1).

Derivation of specific name: atrypophilia — loving *Atrypa* (*Atrypa* — generic name, Gr. *philos* — loving).

External appearance of the ridges (pl. I, III, IV; text-fig. 1). — On the internal surface of the shell the tubes of the boring parasite are marked by very stout ridges, round in transverse section (pl. III, fig. 2;

pl. IV, fig. 2). One of the most peculiar features is their symmetrical arrangement (pl. I, fig. 1-6). The ridges are elongated running along the pedicle muscle area, diverging and projecting anteriorly. Their free ends raised upwards (pl. III, fig. 3*a*) to the brachial valve always bear two

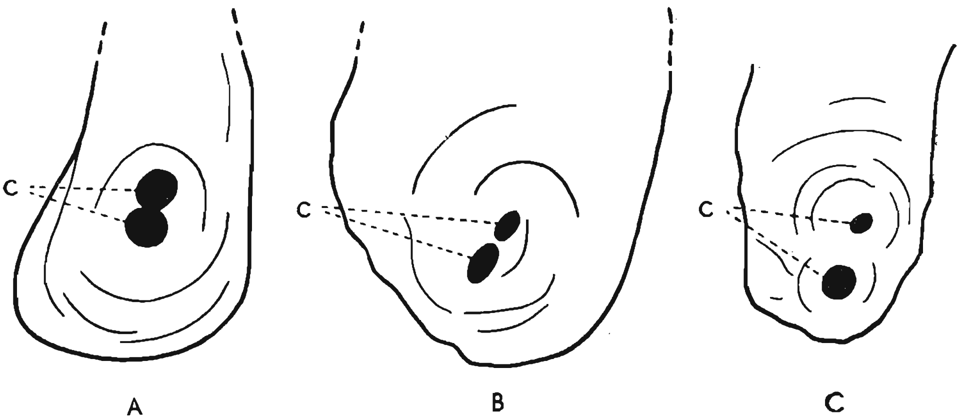

Fig. 1. — *A-C* Three anterior free ends of the ridges illustrating different distance between two apertures of the tube (*c*); approx. × 21.

round or slightly elliptical apertures (pl. I, fig. 6). In the majority of cases one aperture which is usually larger lies some distance in front and beneath of the other (text-fig. 1 *B*, *C*). In some ridges, however, as is shown on text-fig. 1 *A*, two apertures can be in direct contact. As shown by numerous thin sections, the ridges are an integral part of the pedicle valve, secreted by the mantle of the brachiopod (pl. III, fig. 3 *a*, *b*; pl. IV, fig. 1). They are intimately fused with the bottom of the pedicle valve along the length of the muscle area. As a rule, the length of the ridges reaches a half or more of the length of the pedicle valve. Their total length in adult specimens (20 mm long) attains 11.3—12.2 mm and their thickness at the anterior end — 2.5 mm. The ridges arise anterior to the apical cavity, nearly at the level of the teeth and on their inner sides, where they are scarcely elevated. Towards the front they become thicker, as well as more elevated (pl. I, fig. 1-6). In general, the thickness of the ridges is connected with the individual age of the brachiopod. Thin, but always prominent in young, they tend to be thicker in fully grown individuals.

Structure of the ridges (pl. II-IV; text-fig. 2-4). — Longitudinal sections of a ridge show the presence of very narrowly, nearly V-shaped tubes (pl. II, fig. 1). They are single and minute. Exteriorly they appear as continuous linear and slightly flexuous tracks, having a hook-like form, being more or less bent at their posterior part, projecting anteriorly from the pedicle umbo (pl. IV, fig. 3). As shown by serial transverse sections, the tubes arise at the apical part of the pedicle valve as a single canal, which promptly becomes bifurcated. At the place of the bifurcation the tubes in transverse section look like a number 8 (text-fig. 2; pl. II, fig. 3) which usually can lie obliquely. Originally, the tubes are buried within the shell substance and obliquely to it, running across the shell

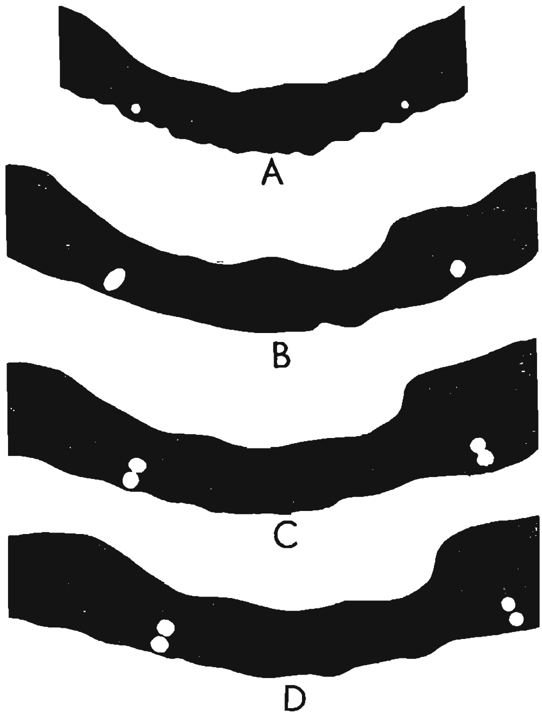

Fig. 2. — *A-D* Four serial transverse sections of the pedicle valve showing successive changes in the outline of the tubes connected with their bifurcation: approx. × 16.

layers, subsequently they lie embedded in the ridge, continuing through all their length (pl. II, fig. 1; pl. III, fig. 3*b*; text-fig. 3). The tubes appear to be thin-walled, covered with clear additional shell deposits of a great thickness. These calcareous shell layers are arranged obliquely to the lateral sides of the limbs and are of similar microstructure as are the internal shell layers of the brachiopod (pl. II, fig. 2; text-fig. 4). The border between the limbs of the V-shaped tube and the enclosed shell substance constituting the ridge is thin but sharp and smooth (no annulation being seen). Unfortunately, the wall is so thin that it is impossible to detect its particular microstructure.

The limbs of the tube are greatly elongated, a little tapering at their posterior end and slightly but gradually broadening anteriorly. They can be straight or insignificantly wavy. Their diameter is small.

At the anterior end the limbs are two or three times larger than at their beginning, attaining 0.3—0.4 mm. In all ridges studied the limbs are nearly of the same diameter and character.

In all cases the limbs run side by side (pl. II, fig. 2, 3; text-fig. 3 *B* and 4). The distance between them is restricted, filled up by calcareous substance identical to that of the teeth or cardinals of brachiopods. The limbs of one tube become converging at a half or more or less of their length and to some extent progressively diverge anteriorly (text-fig. 3 *C*, 4). In some cases, however, they run parallel to each other being in direct contact for all or 4/5 of all their length. In some ridges the limbs tend to be slightly divergent at their anterior end only (text-fig. 3 *B*), in others they do not diverge anteriorly (pl. III, fig. 3 *b*; text-fig. 3 *A*).

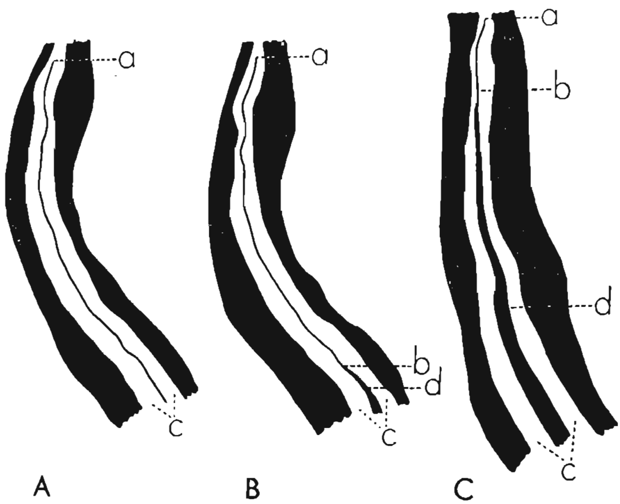

Fig. 3. — *A-C* Longitudinal thin sections of three ridges illustrating some differences in the degree of deviation of the limbs; approx. × 5
a beginning of bifurcation of the tube, *b* beginning of deviation of the limbs, *c* two apertures of the limbs, *d* shell substance, filling up the space between the limbs.

The limbs may be filled with mud, nearly identical with the enclosed sediment on which the brachiopod lived, with calcium carbonate, or partly with mud and calcium. In some cases they seem to be partly empty and can look as if they were chambered.

Process of boring (pl. III, fig. 2). — No doubt the parasites infested the brachiopod interior from without. This may be explained by the anchored mode of life of specimens of *Atrypa zonata*. Their shells in life were raised some distance above the muddy see bottom by a protruding pedicle. Owing to this, the umbonal portions of the mentioned brachiopods were directed downwards to the bottom of the sea and could be especially subject to attacks of the annelids which crawled on the surface of the mud. The parasites started their borings on the external surface of the brachiopod invariably on one or both umbonal slopes of the pedicle valve and bored at first one or two minute holes. These appear very distinctly on the exterior surface after etching the umbones of pedicle valves of infected shells with dilute hydrochloric acid. The holes are round or elliptical and usually scarcely definable because of their small size. At all events they might be considered as the entrance of the parasitic annelid. They have a connection with the interior of *Atrypa zonata* by a system of single tubes.

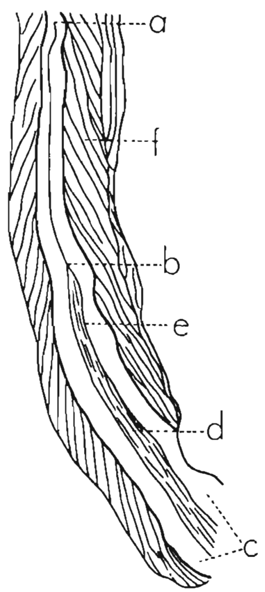

Fig. 4. — Longitudinal thin section of the ridge showing its microstructure and appearance of the limbs of the tube; approx. × 10

a beginning of bifurcation of the tube, *b* beginning of deviation of the limbs, *c* two apertures of the limbs, *d* shell substance filling up the space between the limbs, *e* wall of the limbs, *f* shell layers of the ridge.

The annelid on making an entrance to the brachiopod interior then bored one tiny and short canal through the shell layers, directed usually a little towards the apex of the pedicle valve. This canal runs for a short distance (0.5—1.0 mm) and then it turns in a semicircle or in an acute angle running forwards and as a rule soon becomes bifurcated (see p. 22). The unusual presence of a foreign animal provoked the formation of a projected ridge on the internal surface, lateral to the muscle area of the brachiopod and placed in the interior of the conical spire of the brachidium (pl. III, fig. 2). In consequence, the annelid which lived in the tubes could find very favourable conditions for its parasitic life, and convenient protection for it.

Two apertures of the tube, in all probability inhalant and exhalant, being completely internal were opened to the brachiopod cavity. The cavity currents of sea water created by the brachidium would have passed also into the apertures of the tube of the parasite. Owing to this the animal placed so conveniently could at all times obtain easily a good deal of oxygen and the nourishment necessary for life.

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GERTRUDA BIERNAT

DIORYGMA ATRYPOPHILIA N. GEN., N. SP. — PASOŻYT U *ATRYPA ZONATA* SCHNUR

Streszczenie

Praca dotyczy śladów po organizmach drążących w postaci kanałów w muszlach brachiopodów. Ślady te zostały dotychczas zaobserwowane wyłącznie w skorupkach wentralnych *Atrypa zonata* Schnur, pochodzących z łupków żyweckich z miejscowości Skały w Górach Świętokrzyskich. Na podstawie dokładnych badań oraz dostępnej literatury została stwierdzona ich odrębność w porównaniu z dotychczas opisanymi śladami form pasożytniczych. Pasożyty *Atrypa zonata* Schnur musiały być zwierzętami małych rozmiarów, należącymi prawdopodobnie do grupy Polychaeta (Annelida). Dla tego problematycznego organizmu proponowana jest nazwa: *Diorygma atrypophilia* n. gen., n. sp.

Badane ślady przedstawiają się jak następuje:

1. Wewnętrzne delikatne kanały, rozwidlone w kształcie przypominającym na przekroju podłużnym literę V, których ramiona są położone blisko siebie, często oddzielone tylko cienką ścianką kanalika. Kanały te przebijają ukośnie całą grubość skorupki wentralnej brachiopoda w kierunku jej wnętrza. Obecność kanalików może być też obserwowana na zewnętrznej powierzchni skorupki wentralnej, po zaatakowaniu jej bardzo rozcieńczonym kwasem solnym.

2. Grube wałeczki wydzielane przez płaszcz brachiopoda na wewnętrznej stronie skorupki wentralnej, umieszczone zawsze symetrycznie z jednej lub obu stron pola mięśniowego skorupki, całkowicie z nią zrośnięte. Przednie końce wałeczków są wzniesione ku górze w kierunku skorupki dorsalnej. W wałeczkach tych kontynuują się kanaliki, otwierające się dwoma ujściami na ich końcach.

Wygląd zarówno kanalików, jak i wałeczków we wszystkich obserwowanych przypadkach jest jednakowy; ewentualne różnice są znikome. Należy więc przypuszczać, że były one drążone przez organizmy jednego tylko gatunku.

Obecność obcego organizmu nie zakłócała normalnego wzrostu muszli brachiopoda. Okazy *Atrypa zonata* ze śladami kanalików nie wykazują żadnych różnic ani w wyglądzie zewnętrznym, ani w stopniu wykształcenia strukturalnych elementów wewnętrznych w porównaniu z tymi, w których pasożyty się nie osiedliły. Pasożyt zamieszkujący wydrążone przez siebie kanaliki stwarzał sobie w ten sposób sprzyjające warunki życia oraz odpowiednie zabezpieczenie przed ewentualnymi wrogami.

OBJAŚNIENIA DO ILUSTRACJI

Fig. 1 (p. 21)

A-C Różnice w odległości ujść kanalików, otwierających się na przednich końcach wałeczków; ca × 21.

Fig. 2 (p. 22)

A-D Cztery poprzeczne przekroje skorupki wentralnej, uwydatniające kolejne zmiany w zarysie kanałów; ca × 16.

Fig. 3 (p. 23)

A-C Wałeczki na przekroju podłużnym, ilustrujące różnice w stopniu rozgałęzienia kanalików: *a* podział na 2 kanaliki, *b* rozchodzące się kanaliki, *c* ujścia kanalików, *d* substancja skorupkowa wypełniająca przestrzeń między dwoma kanalikami; ca × 5.

Fig. 4 (p. 23)

Mikrostruktura wałeczka na przekroju podłużnym: *a-d* vide fig. 3, *e* ściana kanalika, *f* warstwy skorupkowe tworzące wałeczek; ca × 10.

Diorygma atrypophilia n. gen., n. sp.

Pl. I

Fig. 1-5. Pięć skorupek brzusznych różnych osobników *Atrypa zonata* Schnur, od wewnątrz, z wykształconymi wałeczkami; ca × 2.

Fig. 6. Wnętrze skorupki wentralnej starego osobnika; widoczne wyraźne ujścia na przednich końcach wałeczków; ca × 4.

Pl. II

Fig. 1. Mikrostruktura wałeczka na przekroju podłużnym; ca × 14.

Fig. 2. Zarys ramion kanalika na przekroju poprzecznym; ca × 65.

Fig. 3. Przekrój poprzeczny *Atrypa zonata* Schnur, widoczne kanaliki; ca × 13.

Pl. III

Fig. 1. Dorosły osobnik *Atrypa zonata* Schnur: *a* od strony skorupki dorsalnej, *b* od strony skorupki wentralnej; nieco powiększ.

Fig. 2. Przekrój poprzeczny muszli, ilustrujący wałeczki z kanalikami we wnętrzu brachidium; ca × 4.

Fig. 3. Dwa podłużne przekroje *Atrypa zonata* Schnur ilustrujące: *a* wykształcony wałeczek, *b* położenie obu ramion kanalika względem siebie; ca × 8.

Pl. IV

Fig. 1. Wałeczek i ramiona kanalika na przekroju poprzecznym; ca × 5.5.

Fig. 2. Przekrój poprzeczny *Atrypa zonata* Schnur, ramiona i wałeczek kanalika bardzo wyraźne; ca × 4.

Fig. 3. Ślad kanalika widoczny na zewnętrznej powierzchni skorupki wentralnej brachiopoda; ca × 6.

ГЕРТРУДА БЕРНАТ

DIORYGMA ATRYPOPHILIA N. GEN., N. SP. — ПАРАЗИТ У *ATRYPA ZONATA* SCHNUR

Резюме

Настоящая статья касается следов сверлящих организмов, которые представляются в виде каналов в раковинах брахиопод. Следы эти, как до сих пор, обнаружено исключительно в вентральных створках *Atrypa zonata* Schnur, происходящих из живетских сланцев местности Скалы в Свентокржиских Горах. На основании обстоятельных исследований и доступной литературы, установлено их отличие по сравнению с описанными до сих пор следами паразитных форм. Паразиты *Atrypa zonata* Schnur были, как можно предполагать, животными мелких размеров, относящимися по всей вероятности к группе Polychaeta (Annelida). Для этого проблематического организма предложено название: *Diorygma atrypophilia* n. gen., n. sp.

Изученные следы представляются в виде:

1) внутренних тонких канальцев, разветвленных в продольном сечении в форме буквы V, с ветвями лежащими близко себя, часто разделенными только тонкой стенкой канальца. Канальцы, направленные наискось к внутри, пробивают всю толщину вентральной створки брахиопода. Наличие канальцев можно тоже наблюдать на наружной поверхности вентральной створки, после действия на нее сильно разбавленной соляной кислотой;

2) толстых валиков, отложенных мантией брахиопода на внутренней стороне вентральной створки, расположенных симметрично по одной или обеим сторонам мускульного поля створки, полностью сросшихся с ней. Передние концы валиков подымаются кверху по направлению к брахиальной створке. В этих валиках продолжаются канальцы, открывающиеся двуми устьями на их концах.

Вид канальцев, равно как и валиков, во всех наблюдаемых случаях одинаков. Если имеются отличия, то минимальные. Следует поэтому полагать, что они были просверлены организмами одного и того же вида.

Присутствие чуждого организма не нарушало нормального роста раковины брахиопод. Образцы *Atrypa zonata* со следами канальцев не проявляют никаких отличий ни во внешнем виде, ни в степени развития внутренних структуральных элементов по сравнении с теми, в которых не населились паразиты. Паразит, занимающий просверленные им каналы, создавал для себя благоприятные условия жизни и обеспечение перед возможными врагами.

EXPLANATIONS OF PLATES

Diorygma atrypophilia n. gen., n. sp.

Pl. I

Fig. 1-5. Internal view of five different pedicle valves of *Atrypa zonata* Schnur with the ridges; × 2.

Fig. 6. Interior of old pedicle valve with distinct apertures on the free ends of the ridges; approx. × 4.

Pl. II

Fig. 1. Longitudinal thin section of the ridge showing its microstructure and appearance of the tube; approx. × 14.

Fig. 2. Thin transverse section of the tube of one ridge showing the outline of the limbs; approx. × 65.

Fig. 3. Thin transverse section of the shell of *Atrypa zonata* Schnur with tubes in the interior of the pedicle valve; approx. × 13.

Pl. III

Fig. 1. Mature specimen of infected *Atrypa zonata* Schnur: *a* brachial view, *b* pedicle view; slightly enlarged.

Fig. 2. Transverse section showing tubes in the interior of the brachiopod's brachidium; approx. × 4.

Fig. 3. Two longitudinal sections of the same shell of *Atrypa zonata* Schnur: *a* appearance of the ridge, *b* arrangement of the limbs of the tube embedded in the ridge; approx. × 8.

Pl. IV

Fig. 1. Transverse section of the pedicle valve with the limbs and enclosed them ridge; approx. × 5.5.

Fig. 2. Transverse section of the shell of *Atrypa zonata* Schnur, the limbs and the ridge very distinct; approx. × 4.

Fig. 3. Hook-like trace of the burrow from exterior; approx. × 6.

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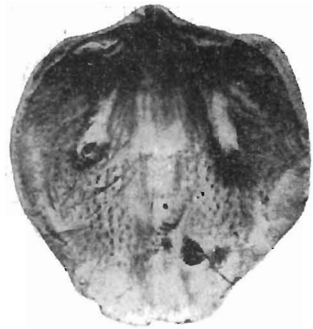
3



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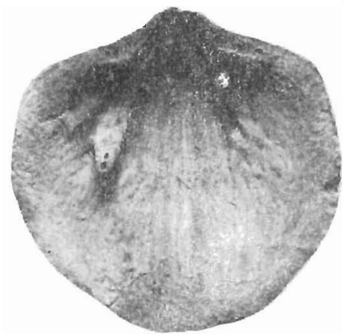

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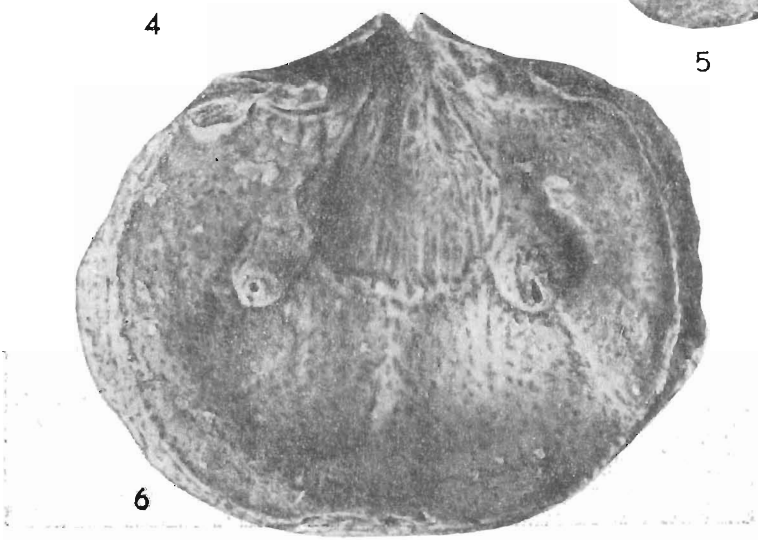

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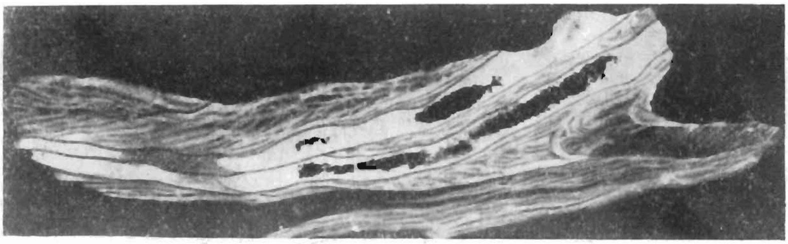

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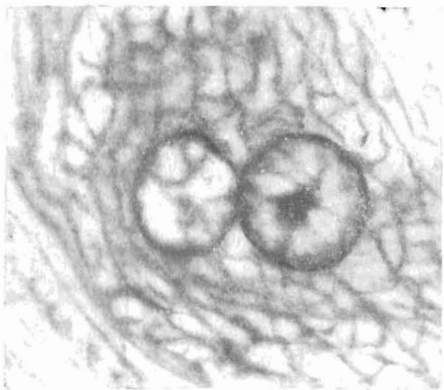

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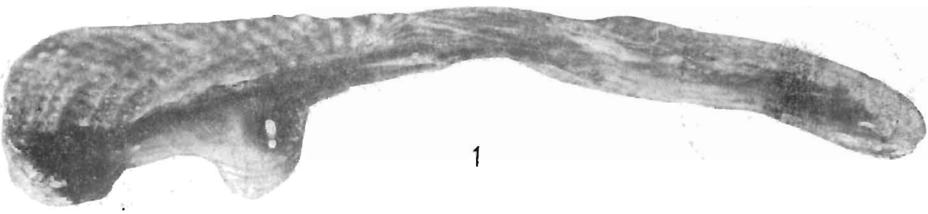
1a

1b

2

3a

3b



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