

On the Genus Richthofenia, Kays, (*Anomia Lawrenciana*, Koninck,) by WILLIAM WAAGEN, PH.D., F.G.S.

IN one of the later numbers of the "Zeitschrift der Deutschen Geologischen Gesellschaft," M. E. Kayser publishes some notes on the fossils of the carboniferous limestone of Lo-ping in China, collected by Baron Richthofen, which fossils seem to be rather similar in type to those of the *Productus*-limestone of the Salt-range, the description of which is now in progress. He mentions one fossil in particular, the *Anomia Lawrenciana* of deKoninck, for which he proposes the generic denomination of *Richthofenia*.

M. Kayser regards this fossil as belonging to the Brachiopods, very likely somewhere near *Productus*, and this approximately agrees with what I considered it to be. I expressed this opinion in the last remarks appended to the third part of my "Salt-range Fossils" (p. 328); only I was at that time doubtful whether the fossil might not as well be considered a coral.

While preparing the description of the Brachiopods of the Salt-range *Productus*-limestone, I was obliged also to examine the *Anomia Lawrenciana* more in detail; and the result of this examination was so remarkable that I think it worth while to give a preliminary notice of this fossil, together with such figures as will be necessary to understand the description.

The fossil consists, as has been described already by deKoninck, of two valves, one larger and one smaller (Pl. II, *f.* 7, 8, 9). The larger valve is of a conical shape, with the apex fastened to some foreign body (Pl. I, *f.* 9). The smaller valve is flat, a little sunk into the larger one. The two valves articulate by a rather short straight hinge-line. This hinge-line, however, does not show in the outer appearance of the conical valve; it is only marked inside it. On both sides of the hinge-line, the smaller valve is cut out in a semi-circle to receive thickened parts of the shell of the larger valve. The outer side of the larger valve is rugose, provided with many concentric wrinkles, and bears a variable number of hollow, depressed, diverging, tortuous tubes, which, on the one hand, resemble the root-like appendages of some rugose corals, and, on the other, can be compared to the hollow spines of some *Producti*. The resemblance to the latter is chiefly striking because of the silky lustre of the shell-substance of which they are composed. On the whole, the shell of the fossil is dull when quite intact, and of a silky lustre when the outmost layer of the shell is worn off. Then also appears a very close punctation, similar to that occurring in the shell of *Productus*, which is barely visible to the naked eye.

The punctures are not all equal; some larger ones are disseminated irregularly between great numbers of smaller ones (Pl. I, *f.* 3). As has been mentioned above, the punctures appear only when the outermost layers of the shell are removed. The punctured part does not lie immediately below the epidermoidal shell-layer, but succeeds a very thin layer, also already exhibiting a silky lustre, which shows a very close vertical striation, and is composed of numerous very fine excavated lines (Pl. II, *f.* 8 *b*). Sometimes this striation is even visible on

the outermost dull layer of the shell. Both these layers, the dull one as well as the striated one, are entirely lost in the greater number of specimens.

On the smaller (flat) valve the hollow tubes, which are so very characteristic of the larger valve, are altogether absent. When the shell-substance of this valve is perfectly preserved, it is strewn over with very numerous small papillæ which project slightly from the surface of the shell (Pl. II [f. 9]).

On its interior side this smaller valve bears a distinct, but not very high, median septum, which extends from near the margin opposite the hinge-line, to nearly the middle of the valve. Here, in most specimens, it is replaced by two parallel ridges, which in other specimens, however, are combined in one broader septum. On both sides of these ridges large, more or less rounded impressions appear, which are very strongly marked, and distinctly indented on the side nearest the hinge-line; on the side opposite to it they are less strongly marked, but seem to be also indented (Pl. I, f. 1c.; Pl. II, f. 2). On the hinge-line itself there are, vertical to it, two short, thick and prominent parallel ridges, not dissimilar to hinge-teeth, which are, however, about equally high through their whole extent. They are not in connection with the median septum, but are separated from it by a smooth space. They do not protrude much above the hinge-line. On the whole, they might possibly be compared to the very developed cardinal process of the smaller valve of *Productus*, but the similarity is, in fact, only a very distant one. On both sides of these ridges not a trace of dental grooves can be observed. Neither the reniform bodies, which are such prominent features in the smaller valve of *Productus*, nor distinct dental grooves exist on the sides of the short ridges on the hinge-line. Near the outer margin of this smaller valve there are thorny processes, more or less numerous, directed towards the interior of the shell, similar to those seen in some *Producti* (Pl. II, f. 2).

Far more complicated is the structure of the larger valve. It consists of two different parts; the lower, from the apex of the valve up to about the middle of its height, being composed of very numerous narrow water-chambers, divided off by very thin shelly partitions, and the upper forming a large hollow for the reception of the animal. The partitions in the lower part of the shell are very irregular, exactly like the partitions existing in rugose corals. They are, on the whole, convex below, and concave above; not so, however, for their whole extent, as about in their middle they are bent upwards, forming something like a columella, such as exists in many corals. This formation of a columella is caused by the presence of three vertical septa (Pl. I, f. 2, 4, 5), which extend from the apex of the shell, through all the partitions, up to the body chamber. By these septa a vertical triangular space is divided off within the larger valve of this fossil, the base of the triangle being formed by the hinge-line, whilst its apex lies in the middle of the shell, where the three vertical septa, which converge towards this centre from both ends of the hinge-line, unite. The median of the three vertical septa extends from the centre towards the hinge-line, without, however, ever uniting with it. All the space between the vertical septa and the hinge-line is also filled up by shelly partitions.

The animal chamber (Pl. I, f. 1) is tolerably large; the bottom of it is, however,

situated at very different levels. The triangular space marked off by the vertical septa is much more shallow than the remainder of the chamber; but the latter also is not even, as from the centre of the shell a rounded crest extends, forming a shallow saddle, to the wall opposite the hinge-line. On each side of this crest is a deep hollow which occupies the whole lateral parts of the body chamber. The whole bottom is covered by irregular tolerably minute grooving.

The three vertical septa project into the body chamber as three high upright plates, which converge towards the centre of the shell and are highest near this centre. Their upper margins are denticulate. They do not unite, but remain somewhat apart from each other. On the other side, between them and the hinge-line, there is an ascending plane, none of the plates thus reaching the hinge-line. Of these plates or septa, the median one is the highest. The two lateral are limited on their inner side by very deep narrow grooves; from the median one, on the contrary, on both sides start some low secondary septa, which show, on the whole, a pinnate arrangement. They disappear again, however, before reaching the grooves mentioned above.

The hinge-line is quite straight, and shows only in the middle a slight rounded situation for the reception of the two thick terminating branches of the median septum in the smaller valve. Not a trace of any kind of teeth for articulation with the smaller valve is observable.

The inside of the outer walls of the body chamber is provided at very irregular and unequal distances, with tolerably broad and sharp, but not very prominent vertical septa, some of which begin a short distance below the upper border of the chamber, and disappear before reaching the bottom, whilst others begin lower down and then reach down to the bottom of the chamber. The upper termination of each of them bears a round foramen, which forms the entrance to the hollow tubes which can be observed on the outer side of the shell and have been mentioned above (Pl. I, fig. 2). This foramen, however, does not pierce the wall directly, but the tube descends nearly vertically and appears only in the vicinity of the apex at the outer side of the shell.

All round the upper border of the animal-chamber a thickened margin can be observed, which has some similarity to a pallial impression (Pl. I, figs. 1, 8). Of muscular scars nothing can be observed either on the bottom or on the walls of the chamber.

The substance of the shell is of a very singular structure. It is composed in the larger conical valve of three layers. The outer one is very thin, dull and compact outside, and of a silky lustre inside, provided with the characteristic striation and punctation mentioned above. The median layer, the thickest of all, though very irregular in its thickness, is composed of approximately hemispherical cells, such as can be observed in many rugose corals when the radial septa have been obliterated (Pl. I, figs. 2, 7; Pl. II, figs. 1, 5). These cells are arranged in ascending radial rows, and are interrupted at intervals by perfectly straight, radial, very pointedly conical shelly parts (Pl. II, fig. 4) which require further explanation. They begin on the outer shell-layer with a slightly broader base, and extend, in a more or less ascending direction, towards the inner portions of the shell. They are not round but polygonal. All do not

with their sharply pointed ends reach the innermost shell-layers; indeed, most of them stop about half-way. Nor do all of them originate on the outer shell-layer, for some start from the wall of some cell in the median layer of the shell. They seem to be hollow and to form tubes, which apparently communicate with the larger pores, disseminated between the more minute punctation of the shell as described above; but I am not quite certain on these latter points. The hollow tubes which terminate in root-like processes as mentioned above penetrate this median part of the shell in a nearly vertical direction. The innermost layer of the shell is somewhat thicker than the outer one, but otherwise similar to it. The median and the outer layers of the shell fall off easily, and then internal casts of a strange description, which preserve the inner shell-layer, are produced (Pl. I, fig. 8).

In the flat smaller valve the median shell-layer is absent.

Under the microscope, with a magnifying power of 100 diameters and upwards, the whole shell can be seen to be composed of very thin lamellæ, which disunite for the formation of the cells and join together again in the outer layer of the shell. They are mostly vertical in the inner layer of the shell, bent nearly horizontal but irregularly outward in the median layer, and again vertically upward in the outer one.

Each lamella shows a very distinct striation vertical to its planes, caused apparently by prisms of which it is composed. These prisms are thus placed horizontally in the inner shell-layer from the inside of the shell to the outer, in the median layer vertically, and in the outer layer again horizontally.

Besides this striation fine canals can also be distinctly traced, which originate on the inner side of the shell and pierce the different lamellæ of which the shell is composed, causing thus the fine punctation of the inner shell-layer, similar to that occurring in *Productus*. The canals are, however, not simple, but distinctly and manifoldly ramified, and thus absolutely different from those occurring in *Productus*. They are more similar to the canals which pierce the shell of *Crania*. I do not think that these canals may be the work of boring *Thallophyta*. They seem to exhibit another character than the borings of those organisms. I shall, however, give detailed figures of these canals in my large work on the "Salt-range Fossils."

The fossil is gregarious in its occurrence in nature, and the individuals are often so closely packed together that the root-like appendages of one individual are fastened to the individuals around, but I never found two individuals entirely grown together.

These are the facts I have been able to ascertain relating to the structure of this fossil; it remains now to deduce from them the systematic position the fossil ought to occupy. As I have already formerly indicated, I was from the beginning doubtful whether the fossil ought rather to be considered a coral or a Brachiopod, and the views of palæontologists to whom I showed the specimens were quite equally divided between the two classes. Mons. Barrande, as well as Professor Valérin and Möller, were of opinion that this fossil was rather more related to the corals than to any other class of animals, whilst Professor Zittel and Professor Lindström seemed to be more in favour of the view which

places it among the Brachiopods. The characters exhibited by the fossil are, indeed, of such a conflicting nature that it becomes extremely difficult to assign to it any place in the system.

In favour of the view which inclines to consider the fossil as a Brachiopod, the microscopic structure of the shell can be adduced above all. Its silky lustre is absolutely identical with that of the shell of *Productus*, though this lustre seems not to be effected in both cases by the same means. In the shell of *Productus* it is caused by obliquely ascending prisms, whilst in *Richthofenia* it depends apparently on the fine lamination of the shell as in *Plucuna* or similar genera. Of great importance is the prismatic structure of the single laminæ of which the shell of *Richthofenia* is composed. Such a prismatic structure is, as far as I am aware, chiefly characteristic of molluscs or molluscoids. I certainly have not as yet observed this structure in corals. In *Calceola sandalina*, which seems the most kindred form among the corals, a microscopic section through the larger valve showed beautifully its construction of radial septa, but these septa exhibited all a granular, not a prismatic structure.

The punctuation of the shell is also very similar to that of *Productus*, and so are the hollow root-like tubes which penetrate the shell-substance of the larger valve, and adhere to other bodies.

The smaller valve can also, on the whole, be very well compared to the same valve of *Productus*, though it remains doubtful whether the thick parallel ridges on the hinge-line of this valve in *Richthofenia* can at all be compared to a cardinal process, and whether the impressions on the valve can be taken as muscular impressions. Reniform bodies are most certainly absent.

Nevertheless, among all the Brachiopods the *Productidæ* are the only ones to which the genus *Richthofenia* might stand in any relation; other Brachiopods are certainly considerably less related to the present genus than the *Productidæ*.

But, though all the points indicated may be in favour of the Brachiopod nature of the present fossil, yet it cannot be denied that there exist also certain points of resemblance between *Richthofenia* and rugose corals. Any one who looks only for a moment at Pl. I, fig. 2, will be convinced of this similarity. The irregular partitions in the lower part of the larger valve; the columella-like part which is divided off by three vertical septa; these septa themselves, which can very well be compared with the primary and the two lateral septa of a rugose coral; the cellular structure of the shell; the septa-like ridges on the outer wall of the animal chambers which are in connection with the hollow canals which pierce the substance of the shell; and the tortuous tubes themselves into which the canals are prolonged on the outer side of the larger valve: all these characters remind one strongly of a rugose coral. There can be no doubt that on a first inspection, ignoring the silky lustre of the shell, one would far more likely be led to regard this fossil as a coral than as a Brachiopod.

There is, however, yet another character to be pointed out, which is even more conflicting than those hitherto adduced; this is the existence of something like a pallial impression round the upper margin of the larger valve, as figured in Pl. I, figs. 1b and 8a.

This character, as well as the very peculiar appearance of the partial cast as represented in Pl. I, fig. 8, and the longitudinal section, Pl. II, fig. 5, induced me to take yet another group of fossils into consideration for comparison; and these are the *Rudista* in a restricted sense, as defined by Stoliczka in his work on the cretaceous bivalves.

It is a very curious fact that with the *Rudista* the same difficulty prevailed as to their classification as with the present fossil. They had been considered by L. v. Buch as corals, by d'Orbigny as Brachiopods, and recently they are placed by most men of science in the bivalves.

The points of similarity between *Richthofenia* and the *Rudista*, chiefly *Hippurites*, are not very numerous, it is true. It is chiefly the section which may be compared. If we cut open a specimen of *Richthofenia* from the hinge-line to the opposite wall, so as just to touch the median vertical septum (Plate II, fig. 5), we get a figure very similar to that which we obtain when we cut through a *Hippurites* so as to touch the first columellar fold (the hinge-fold and the second columellar fold being left untouched), Plate II, fig. 10. The partitions presented are very similar in both cases. They are bent up in the middle to form a kind of columella, and are separated from the outer walls of the shell by a sharp line in both cases. It is due to this latter circumstance in both cases that the outer walls of the shell fall off easily, and that such strange partial internal casts are formed.

Another point of similarity consists in the direction of the prisms, of which the substance of the shell is composed. The *Rudista* differ from all the other groups of *Pelecypoda* in having the prisms of their outer shell arranged vertically, that is to say, longitudinally to the whole extension of the shell. Just the same is the case in the median shell layer of *Richthofenia*, as has been explained above.

A third point of similarity of great importance exists in the pallial impression, which is common to *Richthofenia* and the *Rudista*; and, finally, it is not quite certain that the sinuations of the large valve of *Richthofenia* on both sides of the hinge-line, which stand in so close a connection to the lateral vertical septa may not be regarded as the beginning of the infoldings of the shell, which are so very characteristic for the *Rudista*.

All these points of similarity between the *Rudista* and *Richthofenia* are important, as they are in connection with the most striking characters of both fossils; and it cannot as yet be positively denied that *Richthofenia* might be a predecessor of the *Rudista*. To say anything positive on this point is at present impossible. The distance in time between *Richthofenia*, which comes probably from the limits between the carboniferous and permian formations, and the *Rudista*, which are for the greater part upper cretaceous, is so enormous, and every connecting link is as yet absent, that a very close affinity between the palæozoic and the cretaceous forms cannot be expected, and thus it will only be possible to prove the connection between the present fossil and the *Rudista*, if further members of such a developmental series should be discovered.

As the case now stands, it will probably be most prudent in accordance with the microscopic structure of the shell to consider the fossil as something like a

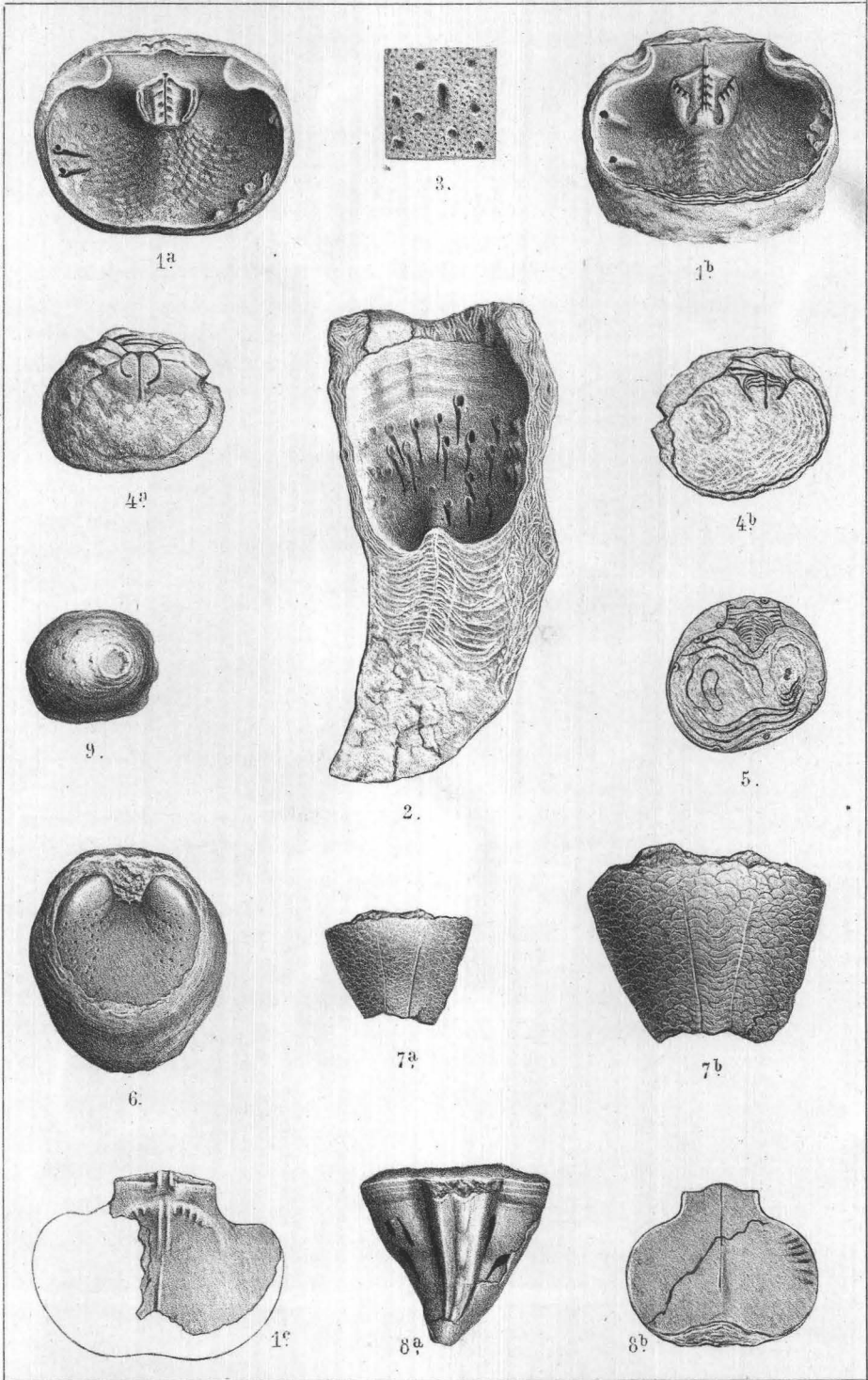
Brachiopod. As far as my opinion goes, I am convinced that *Richthofenia* is a member of a series, which, branching off somewhere from the rugose corals, has reached in *Richthofenia* a Brachiopod-like stage, and is going to terminate its career as a Pelecypod, as one of the *Rudista*. But opinion is nothing in science, and proofs are everything. I hope that these lines will give an impulse to the elucidation of the very obscure relations of the fossil which has been the object of this paper.

PLATES.

EXPLANATION OF PLATE I.

RICHTHOFFENIA LAWRENCIANA, Kon. sp.

- Fig. 1. Silicified specimen from the upper region of the Middle Productus-limestone of Musa Kheyl. *1a*, view of the body chamber straight from above; *1b*, the same slightly oblique from the front; *1c*, interior side of the smaller valve of the same specimen: all natural size.
- „ 2. Natural section through a specimen from the coral beds of the Middle Productus-limestone of Virgal; the section being parallel to the hinge-line and just touching the termination of the three vertical septa. The cells in the walls of the animal chamber are not quite correctly represented.
- „ 3. Portion of the shell surface enlarged 4 to 5 times to show the punctation, in a specimen from the upper region of the Middle Productus-limestone of Musa Kheyl.
- „ 4. Fragmentary specimen from the Middle Productus-limestone of the Chittawán; *4a*, natural section through the lower part of the animal chamber, showing the section of the three upright blades; *4b*, artificial section, very oblique, lower down through the partitioned part of the shell, showing the vertical septa and the space that is limited off by them.
- „ 5. Artificial transverse section through a specimen from the Lower Productus-limestone of Amb. The two lateral vertical septa unite in the middle.
- „ 6. One of the partitions of the larger valve seen from below on a broken specimen from the Middle Productus-limestone of the Chittawán.
- „ 7. Fragmentary specimen, showing the cellular structure of the median shell-layer, the outer layers having been removed by weathering; from the Middle Productus-limestone near Khura.
- „ 8. Partial internal cast of a specimen from Musa Kheyl; *8a*, view from the hinge-line; *8b*, view from the smaller valve.
- „ 9. Small specimen from the lowest beds of the Middle Productus-limestone of Katta from below, showing the point by which it has been fastened to the bottom of the sea.



EXPLANATION OF PLATE II.

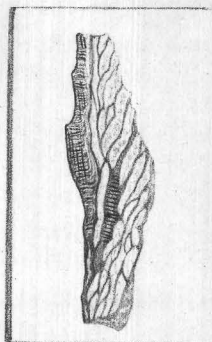
Figs. 1—9. *RICHTHOFENIA LAWRENCIANA*, Kon. sp.

Fig. 10. *HIPPURITES*, sp.

- Fig. 1. Section through the shell of a specimen from the Lower Productus-limestone of Amb enlarged four times. To the right the outer, to the left the inner, side of the shell, at the lower extremity one of the shelly cones which traverse the shell substance; prisms slightly indicated.
- „ 2. Internal cast of the smaller valve of a specimen from the Middle Productus-limestone of Musa Kheyl. The spines on the inside of the valve appear as deep grooves.
- „ 3. Fragmentary specimen from the Middle Productus-limestone of the Chittawán, viewed from below, to show the irregularity of the partitions, the one figured being made up of five pieces.
- „ 4. Fragment of the shell of a specimen from the Upper Productus-limestone (Cephalopoda bed) of Jabi, very obliquely weathered and enlarged about four times, to show the cells and the, in this case exceptionally numerous, shelly cones which are between them.
- „ 5. Artificial section through a specimen from the Lower Productus-limestone of Amb. The section is vertical to the hinge-line, just missing the median vertical septum, but yet hitting at the upper end of the columella the secondary septa which are joined to the median one. Mineral matter partly intercalated between the partitions, as in all sections (Pl. I, fig. 2; and Pl. II, fig. 6).
- „ 6. Artificial section through a specimen from the Lower Productus-limestone of Amb, the section being parallel to the hinge-line, missing the three vertical septa altogether.
- „ 7. External view of a fragmentary but tolerably large specimen from the Middle Productus-limestone of the Chittawán.
- „ 8. Specimen with exceptionally well preserved external surface of the larger valve, showing the longitudinal striation from the Lower Productus-limestone of Amb. 8a, lateral view, obliquely to the hinge-line; 8b, portion of the surface enlarged.
- „ 9. Specimen from the Lower Productus-limestone of Amb; view from above to show the smaller valve and the fine granulations by which this as well as the bent over parts of the larger valve is covered.
- „ 10. Section through *Hippurites* sp. from the Gosau formation of the Neue Welt near Vienna, figured for comparison with fig. 5. (Property of the K. K. Geologische Reichsanstalt in Vienna.)



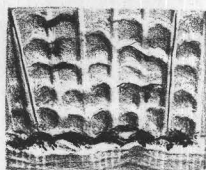
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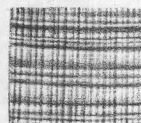
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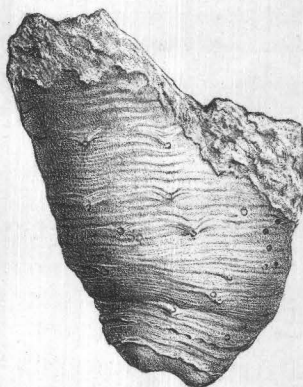
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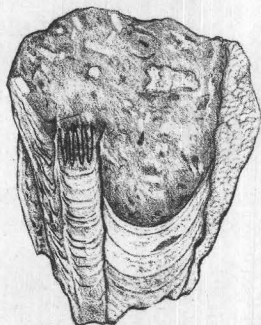
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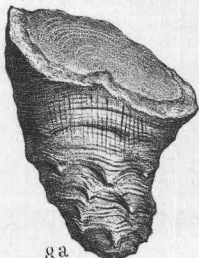
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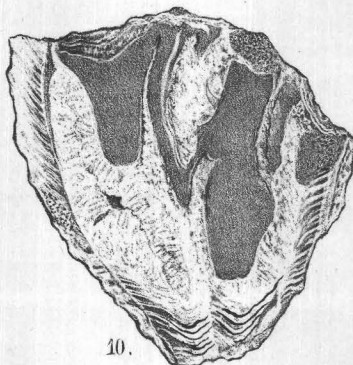
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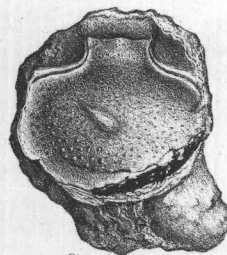
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9.