like the threads of a piece of cloth. The one fiber seems to pass over the other at one place, continuing to do so as far as it or its imprint can be traced on the specimen.

Beyond the three species here described there are fragments of three others from the same locality in the Museum collection, but as they are all so imperfect as not to give any definite indication of their complete form, I shall not describe them at the present time, the last named one, *D. cylindricum*, being used on account of its very distinct and perfectly shown spiculæ. Representatives of the species are in the museum collection.

ART. III.—*Observations on the purposes of the embryonic sheaths of Endoceras, and their bearing on the origin of the siphon in the Orthocerata.* By R. P. WHITFIELD.

The genus ENDOCERAS was proposed in 1847 for a group of fossil Cephalopods, belonging to the ORTHOCERATIDÆ, which presents the anomalous feature of a series of invaginated, conical sheaths, occupying the cavity of the siphon. When the genus was proposed, these sheaths were supposed by its author, to be of the nature of embryonic sheaths designed for the retention and protection of the young shells while they were yet within the body of the parent. The existence of such a feature in an animal, of course, presupposes that animal to be viviparous in character, and the announcement of such a feature existing in a cephalopod was entirely unexpected and novel; and consequently attracted considerable attention among naturalists of the day, especially of those studying Palæontology; and there is perhaps no one feature of the fossil Cephalopoda which has given origin to so much discussion, or about which so much has been written as the supposed purposes of these so called embryonic sheaths of the ENDOCERAS. Most of the Palæontologists of note in Europe, writing within several years of its announcement, expressed their opinions of their nature; and most of them adversely to their embryonic

[*Dec. 23d,*

functions. Notwithstanding these discussions, and their opposition to their embryonic purposes, no one, so far as I have been able to ascertain, has assigned to them any definite functions, or has attempted to show why they were formed. While working over the typical collection of this group of shells originally used by the author of the genus in his studies, and now arranged in the collection of the Am. Mus. of Nat. History, in New York City, the peculiarities of some of these sheaths were studied, and I came to the conclusion that they must have had a purpose in the economy of the animal other than that of the ordinary siphon of the *Orthoceras* and its allied forms; especially as the siphon in these very species is otherwise perfect without them. For the purpose of ascertaining this function I made a critical study of all the forms of this group of shells to which I could get access, and even made a journey to localities where they were common that I might study them in the rocks.

One of the most noticeable characters observed in all species presenting this feature of duplicate sheaths, is their large siphons, commonly one-third as great as the diameter of the shell itself. Another feature is that the duplicate sheaths are seldom found in examples where the outer tube is less than one inch in diameter, and not often in shells of less than one and one-half inches in diameter. Another constant feature is that the young shells of any of these species, even those found within the sheath, and originally supposed to be the offspring of that individual, have very small siphons; even smaller than those of most small specimens of the ordinary *Orthoceras.* These facts alone show conclusively that these duplicate siphons or "embryo sheaths" are a feature consequent on the large siphon; and the question naturally follows, what is there about the large siphon of *Endoceras* that requires these duplicate sheaths; and are they always found, and at regular intervals in those species?

In following out these inquiries, I find them not only all species with large siphons, but that all those having these duplicate sheaths, are forms which increase but very slowly in diameter in proportion to their increase in length, and that most of them occasionally attain a very large size. This as a matter of course implies great length in adult specimens, if entire; and con-

sequently an unwieldly object to be controlled by a comparatively small animal situated entirely at one end of the tube. Another feature is that the shells are usually very thin in substance. Now an animal having a shell of great size and length, and comparatively thin in texture, if an inhabitant of shallow water, would be particularly liable to accident from breakage of the shell by the beating action of the waves; and if an inhabitant of deep seas, to rapid erosion of the shell by the action of carbonic acid in the sea water; so that in either case the shell would be liable to injury to such an extent as to afford free access to water and other extraneous substances to the lower part of the wide siphonal tube, and by it, to the lower part of the body of the animal, or even to the chamber of habitation. In proof of this frequent injury in the case of *Endoceras*, we find them nearly always in a fragmentary condition, the earlier parts having been broken away or otherwise destroyed, even those having a diameter of six or eight inches being seldom more than two to four feet in length, although larger specimens are occasionally found, and the older parts of the shell are even then usually much broken and rotted, and the lower end of the siphon open. So it would appear that for the purpose of protection from these accidents, even if the shell was not in some cases purposely broken, it would be necessary that there should be some provision for closing these avenues, and guarding against these attacks in the rear.

If we examine these conical sheaths or tubes, and ascertain their relations to the siphonal tubes, and to the outer chamber or chamber of habitation, we will find that the passage-way from without through the siphonal tube to the part occupied by the animal above it, is most effectually closed by any one of these sheaths. It is natural, therefore, to infer that they have been constructed for the purposes of self protection. They also show conclusively that the body of the animal extended downward to a considerable distance into the siphonal cavity, and in order to construct one of these sheaths, the part of the mantle of the animal, and that part of the body which lined the upper part of the siphon, which was also the part destined to secrete the shell, would be contracted so as to separate from the siphon and form a long, finger-like projection, hanging loosely in its cavity, (see fig.

1, *d*) ; while the surface of it would soon become coated by the newly secreted shell, having the form of the projection on the surface of which it was moulded ; and when sufficiently thickened would effectually cut off all communication from below and completely repair the damage. After the completion of one of these sheaths at the stage of any particular septum, the growth of the shell and the formation of additional septa go on regularly, and the siphonal space is regularly increased above, leaving it open to the sheath below until occasion requires the formation of another sheath. These sheaths were not only formed in case of accidents already having taken place, but were probably often formed to guard against future troubles; consequently we sometimes find them crowded together so as to leave not more than an inch or so between them, and the intervening space filled with coarsely crystalline calc-spar ; showing that the one below had not been injured so as to admit the access of foreign matter, which is always sure to be the case where injury has occurred to the individual sheath below the cavity so filled.

Fig. 1.

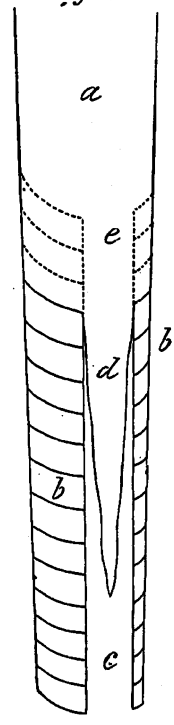


FIG. 1. Ideal section of ENDOCERAS. *a*, outer chamber or chamber of habitation ; *b*, *b*, chamber formed by the ordinary septa ; *c*, siphonal cavity ; *d*, the so called "embryo tube" ; *e*, dotted line, representing the next septa to be formed and the continuation of the siphon walls. The lettering on the other figures correspond to the same parts as on this.

In looking over the observations of M. J. Barrande, of Bohemia, upon this group of shells, in the light of whose writings concerning them those of all others fall entirely into the shade, I find no reference whatever to a probable purpose for which these sheaths were formed, or their connection with the repair of damages to the older parts of the shell. On the contrary he appears to have considered them as a part of the siphon itself, or rather as a second septum intended to divide the siphonal tube into chambers like those of the outer tube, and to have been formed

at somewhat regular intervals; which is by no means the case, at least not in the American species, for I find no regularity whatever in the distances at which they occur even in the same individual. They often occur quite close together, sometimes three or four of them being ensheathed within each other, and others again will have from ten to twenty inches between them; and I have seen examples of the shell from two to four feet long without a trace of a sheath.*

M. Barrande supposes that when formed at irregular and distant intervals, the prolongation of the animal which occupies the sheath has been suddenly elevated or lifted up from its former position and held suspended in the cavity of the shell until a new shell or sheath was secreted on its surface. But he assigns no reasons for such an act. In speaking of this feature in the Bul. Geol. Soc. of France, 1855, p. 173, he says: "in fact, to account for the presence of sundry tubes or sheaths irregularly envaginated in the siphon of the *Endoceras*, it suffices to assume that at certain periods the animal raised itself, more or less at a time, instead of advancing in a slow and continuous fashion."† Now we have no reason for supposing that the animal of *Endoceras* could elevate the siphonal extension of its body to any appreciable extent without also elevating the rest of the body to a nearly equal distance at the same time; in which case we should find the septa of the outer tube placed at irregular distances corresponding to those of the sheaths. But this is never the case; nor do we ever find any more irregularity among the septa of this form than in the ordinary forms of *Orthoceras* where there are never any sheaths formed. There is, however, another group which has been universally confounded with the *Endoceras*, but which is very distinct as far as the origin and formation of the sheaths is

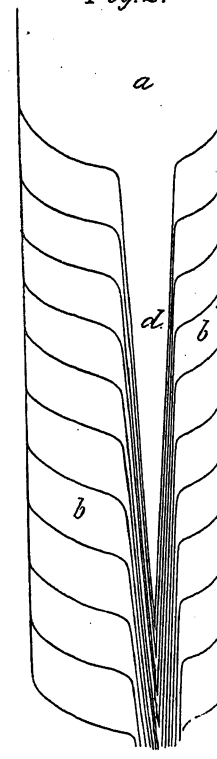
* This mode of repairing injuries is not analogous to that seen in *Orthoceras truncatum* and other forms of Cephalopods, as described by M. Barrande in the Bul. Geol. Soc. France, 1859 and 1860, p. 573; where the entire extremity of the shell is closed over by a deposit of shelly matter, secreted by some appropriate organ from the exterior, but takes place from within entirely, and is performed by the posterior prolongation of the mantle or body of the animal occupying the siphon.

† "En effet, pour se rendre compte de la présence de divers tubes ou gaînes irrégulièrement envaginés dans le siphon des *Endoceras*, il suffit de concevoir qu' á certaines époques l' animal s' élevait rapidement d' une quantité plus on moins grande, au lieu de progresser d' une manière lente et continue."

concerned, and in which the sheaths are regularly formed one within the other, and in close proximity to each other, as stated by Barrande. This is the form which is properly known and characterized as the section *Vaginata* by Barrande and others, and is typified by *Orthoceras duplex* and *O. vaginatum* in Europe and by *Endoceras multitubulatum* in America.

In this form, the true *vaginata*, the siphonal space, for there is no true siphonal tube, is occupied by a succession of invaginated sheaths or tubes, closely formed within each other, so as to be in absolute contact at the upper end, and are usually as numerous as the septa of the outer tube of which they form a part, while the intervening spaces in the lower part are filled up by a peculiar deposit, known as the "*organic deposit*"—("*dépôt organique*") of Barrande. When these sheaths are closely examined, especially in a longitudinal section, each sheath of the siphonal space is traceable to a definite septum, and is seen to be a continuation of it, but from their slight increase in size are in close contact in the upper part where united to the septum. With a glass, however, they are seen to be composed of separate layers, corresponding to the periods of elevation; Just as can be seen in some cases in the tubes of *Endoceras* where the sheaths are near each other.

Fig. 2.



Ideal section of *Endoceras multitubulatum*.—HALL.

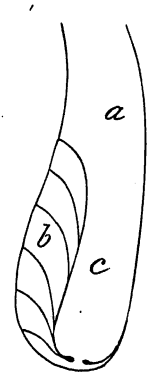
These sheaths in the true *Vaginata* actually divide the siphonal space into separate chambers, while the coalescence of their upper ends appear to form a continuous tube resembling the siphonal tube of the *Endoceras*, though the spaces below are invariably filled up solid by the "*organic deposit.*" So far as I have been able to determine from the specimens I have examined, many of which have been in the field, and not capable of separation from the matrix

except in fragments, the sheaths are not perforated at the lower end, and do not allow of any kind of communication between the chambers of the siphonal space, any more than do the septa of the outer tube of an *Orthoceras* between the several chambers where the siphon is continuous. From this it would appear that the entire shell of the true *Vaginate Orthoceras* is actually divided into separate and distinct transverse sections, without any means of intercommunication between them; while in the *Endoceras* there is a true siphonal tube which is continuous, but which may be partitioned off at irregular intervals at the will of the animal, by a conical tube similar to those in the true *Vaginata*.

If this view is correct, and the facts seen are properly interpreted, *Endoceras* would seem to have made a distinct step in advance in the development of the siphon, beyond such forms as the true *Vaginata*, where the siphonal space is divided into distinct chambers, toward the open siphon of the normal *Orthoceras*.

M. Barrande has stated in his observation in the Bull. loc. cit. that *Ascoceras* was probably the prototype of the entire *Nautilidæ;* that it contains all the elements of the true Nautilus but in a simple and more undeveloped form. This genus, which has a sack-like form, with imperfect septa extending only partially across the cavity of the tube, leaving a vacant space on one side the entire length of the tube, which he considered as equivalent to the siphon of the ordinary *Orthoceras*, is unquestionably of an extremely simple type. It seems to me however that it is more properly an aberrant or imperfectly developed branch or offshoot of the ordinary *Orthoceras* than a prototype; and consequently appears at a period in geological history in which the greatest diversity among these simple chambered forms of Cephalopods had been attained. Its author even questions the correctness of a reference of the genus by Prof. F. Rœmer to a lower horizon than that in which he has obtained its great specific development. In the true *Vaginata* it seems to me we have a much nearer approach to the probable original form of the chambered

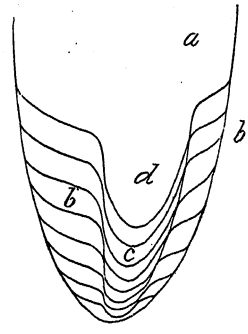
Fig. 3.



Ideal section of ASCOCERAS.

shell; that in which there was only a simple partition across the tube, no siphon and no communication between the several chambers.

Fig. 4.



Ideal section of PILOCERAS.

In the genus *Piloceras* of Salter we probably have the nearest approach to this simple form yet known. It consists of a broad conical shell, with a broad conical siphonal tube, divided into chambers by a series of inverted, envaginated cones, which are simple continuations of the ordinary septa; but which are just deep enough to have their necks connect so as to present the appearance of the siphon being continuous, but without means of communication between the several chambers into which they divide the siphonal space. In other words it may be described as a broadly conical shell with the simple septa pressed downward on one side of the centre so as to cause the depression of one septum to enter that of the one below. In this way the siphonal space seems to be limited by a continuous wall and presents the same appearance that do shells of the true vaginate *Orthoceras*, as *O. duplex*, &c.; and differ in reality only in the shell and siphonal depression being wide and spreading, instead of narrow and cylindrical as are those of that group.

These forms having wide spreading shells with similarly formed siphonal tubes, are found only in the lower geological formations, and as we ascend into the higher formations the siphonal tubes become gradually narrowed until in the Upper Silurian and Devonian they reach nearly a minimum size. These facts alone would seem to indicate that the development of the siphon had resulted in this direction, and the most likely course would be from a simple septum (not yet found) through the broad open depression existing in *Piloceras* and *Cyrtocerina* to the narrower envaginated siphonal tubes of *Orthoceras duplex* and its congeners without communication between their chambers through the tube, to the open siphon of *Endoceras* with its occasional conical partitions used only in case of accident to the somewhat narrower but similarly formed tubes of *Cameroceras*, where the conical

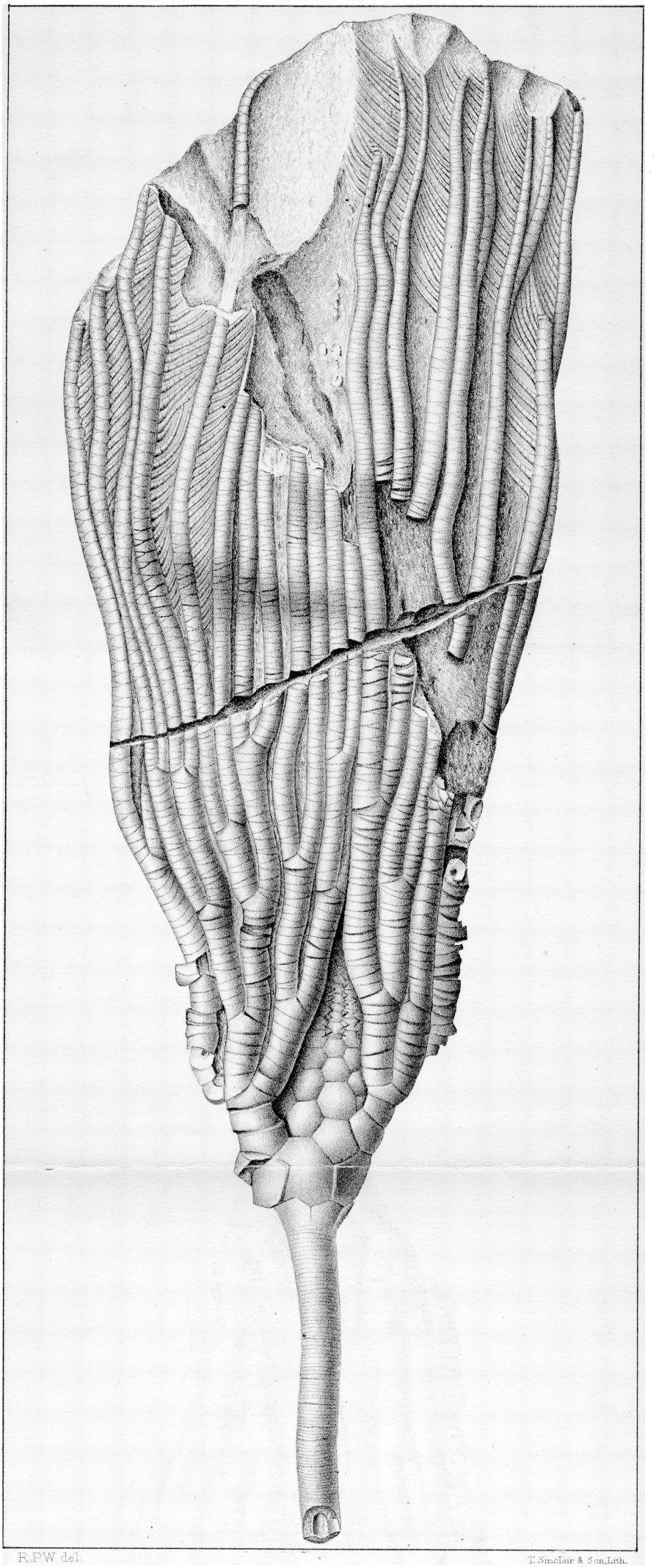
tubes are never formed, on to the narrow unobstructed siphons of the ordinary *Orthoceras*, where it is so narrow as to leave no appreciably open avenue for the entrance of extraneous substances in case of accident. While during the progress toward the narrow plain siphons, there have been developed all the numerous forms of obstructed siphons so abundant and various in the Trenton and Niagara formations.

[*Dec. 23d*, 1881.]

EXPLANATION OF PLATE 1.

POTERIOCRINUS JESUPI. Page 7.

View of the anal side of a specimen, showing the anal series of plates and base of proboscis.



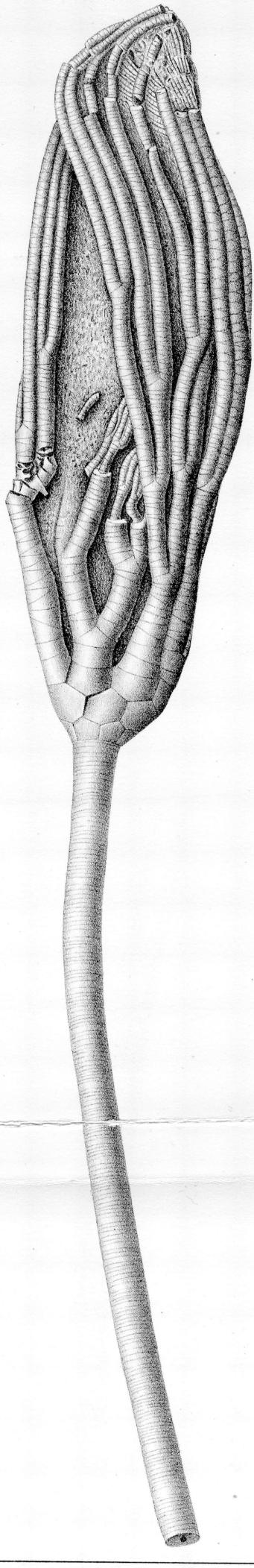
R.P.W. del. T. Sinclair & Son, Lith.

EXPLANATION OF PLATE 2.

POTERIOCRINUS JESUPI. Page 7.

View of the anterior side of a specimen, on which the arms of the left antero-lateral ray have been broken and partially restored.

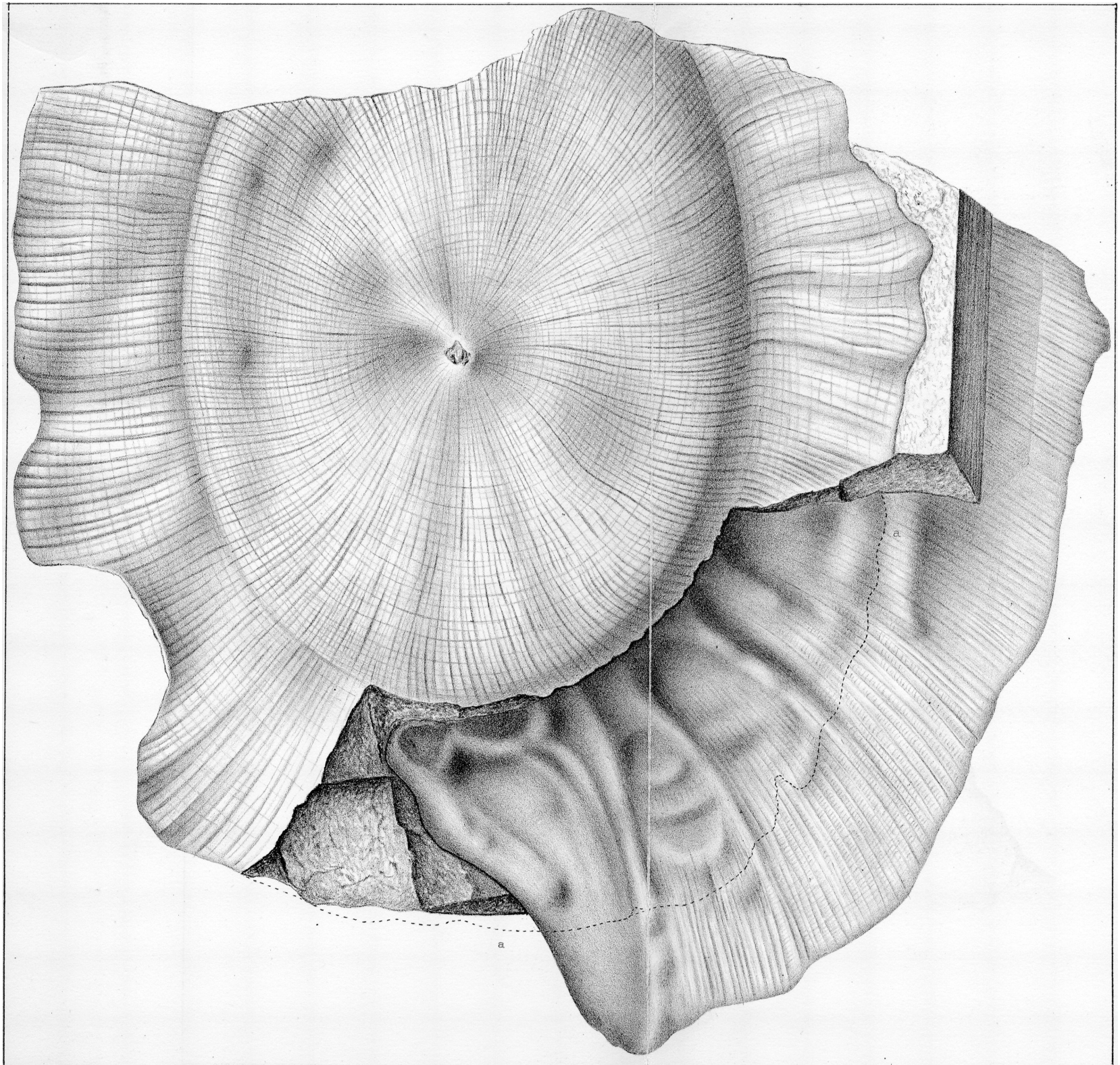
POTERIOCRINUS JESUPI.



EXPLANATION OF PLATE 3.

DICTYOPHYTON CATILLIFORME. Page 18.

View of the top of a specimen, natural size. The marginal frill has been removed purposely, as represented by the dotted line *a*, *a*, to show the obliquely compressed cylindrical body below.



R.P.W. del.

T. Sinclair & Son, Lith.

EXPLANATION OF PLATE 4.

UPHANTÆNIA DAWSONI. Page 16.

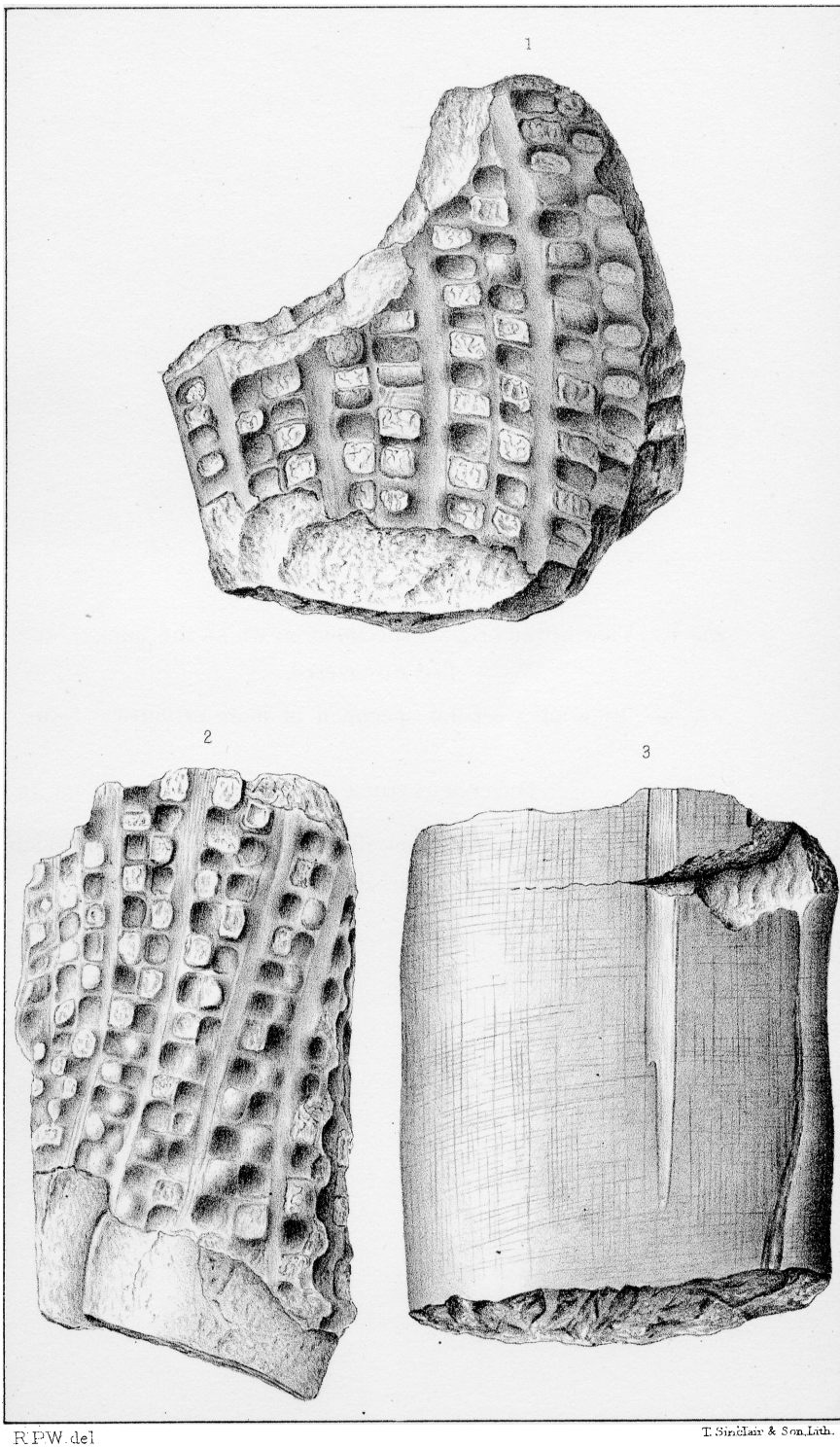
Fig 1. View of the original specimen on which the spiculæ were first discovered.

Fig. 2. View of a second specimen of more cylindrical form.

DICTYOPHYTON CYLINDRICUM. Page 19.

Fig. 3. View of the fragment described, the spiculæ on which are remarkably distinct.

FOSSIL SPONGES.



R.P.W. del

T. Sinclair & Son, Lith.